APPENDIX 1. RDM STUDY FOR THE ROOIELS ESTUARY

1.1 Introduction

This RDM report forms part of a larger study to undertake the Classification of and determine the Resource Quality Objectives for significant water resources within the Breede-Gouritz Water Management Area (i.e. the Water Resources Classification System (WRCS) as prescribed by Regulation 810 in terms of section 12(1) of the National Water Act (1998)). The WRCS is a step-wise process whereby water resources are categorized according to specific classes that represent a management vision of a particular catchment by taking into account the current state of the water resource and defining the ecological, social and economic aspects that are dependent on the resource. The resulting WRC are then used to set specific Resource Quality Objectives (RQOs) which are numerical and/or narrative descriptive statements of conditions which should be met in the receiving water resources in order to ensure that the water resource is protected. A detailed understanding of the links between the quantity and quality of freshwater that an estuary receives is required to establish the RQOs for that particular system. A system for determining the ecological water requirements for estuaries (and hence links between the quantity and quality of freshwater that an estuary receives) has been developed, termed the "Methods for the Determination of the Ecological Reserve for Estuaries" the most recent version of which was published in 2012 (DWA 2012). This process includes determining the Present Ecological Status (current health state) of the system, the Recommended Ecological Category (REC, a desired future health state that will allow for protection and management of the resource), and the quantity and quality of freshwater inflows and other conditions required to maintain the system in the REC, and implications of a range of alternative flow scenarios.

Reserve determination (or RDM) studies have been completed for all of the significant estuaries within the BGWMA apart from Onrus and Rooiels estuaries. This study was thus undertaken by a team of experts to determine the Ecological Reserve for the Rooiels Estuary as a necessary input to the Classification process (Table 0.1).

Table 0.1. Project team

Specialist	Affiliation	Area of responsibility
Dr Barry Clark	Anchor Environmental Consultants (Pty) Ltd	Study leader
Gerald Howard	Aurecon South Africa (Pty) Ltd	Hydrology
Andre Görgens	Aurecon South Africa (Pty) Ltd	Hydrology
Ms Lara van Niekerk	CSIR	Physical processes, hydrodynamics
Dr Susan Taljaard	CSIR	Water quality
Prof Janine Adams	Nelson Mandela Metropolitan University	Microalgae and macrophytes
Dr Bruce Mostert	Anchor Environmental Consultants (Pty) Ltd	Invertebrates
Dr Ken Hutchings	Anchor Environmental Consultants (Pty) Ltd	Fish
Dr Stephen Lamberth	Independent	Fish
Dr Jane Turpie	Anchor Environmental Consultants	Birds & overall method & editing

1.2 Delineation

Delineation of the Rooiels Estuary was based on the National Estuary Layer. The area of "estuary functional zone" below the 5 m contour and the open water area were estimated to be 16 ha and 1.9

ha, respectively, making the Rooiels one of the smallest estuaries in the Brede-Gouritz WMA (Figure 0.1). The geographical boundaries for the study were defined as follows:

Downstream boundary:	Estuary mouth 18^0 49'15.76"; 34^0 17'44.79"
Upstream boundary:	18°49'28.61"; 34°18'08.71"
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 0.1. Extent of the Rooiels Estuary.

1.3 Overall context and pressures

The Rooiels is a very small estuary with a relatively small floodplain and covers in total approximately 16 ha. The Rooiels catchment (Figure 0.2) lies within the Overstrand Local Municipality (OLM, part of the Overberg District Municipality, ODM) in the Western Cape Province and is included in the Breede-

Gouritz Catchment Management Area. The Rooiels River rises in the Hottentots Holland Mountains and flows for about 9 km before reaching the estuary, which is situated on the east side of False Bay, adjacent to a small settlement of the same name. The catchment falls within the Fynbos Biome, and is located entirely within the Kogelberg Biosphere Reserve and is almost entirely naturally vegetated. The catchment is located within the winter rainfall region, although orographic rain originating from the mountain ranges close to the coast result in local concentrations of rainfall (Heinecken & Damstra 1983).

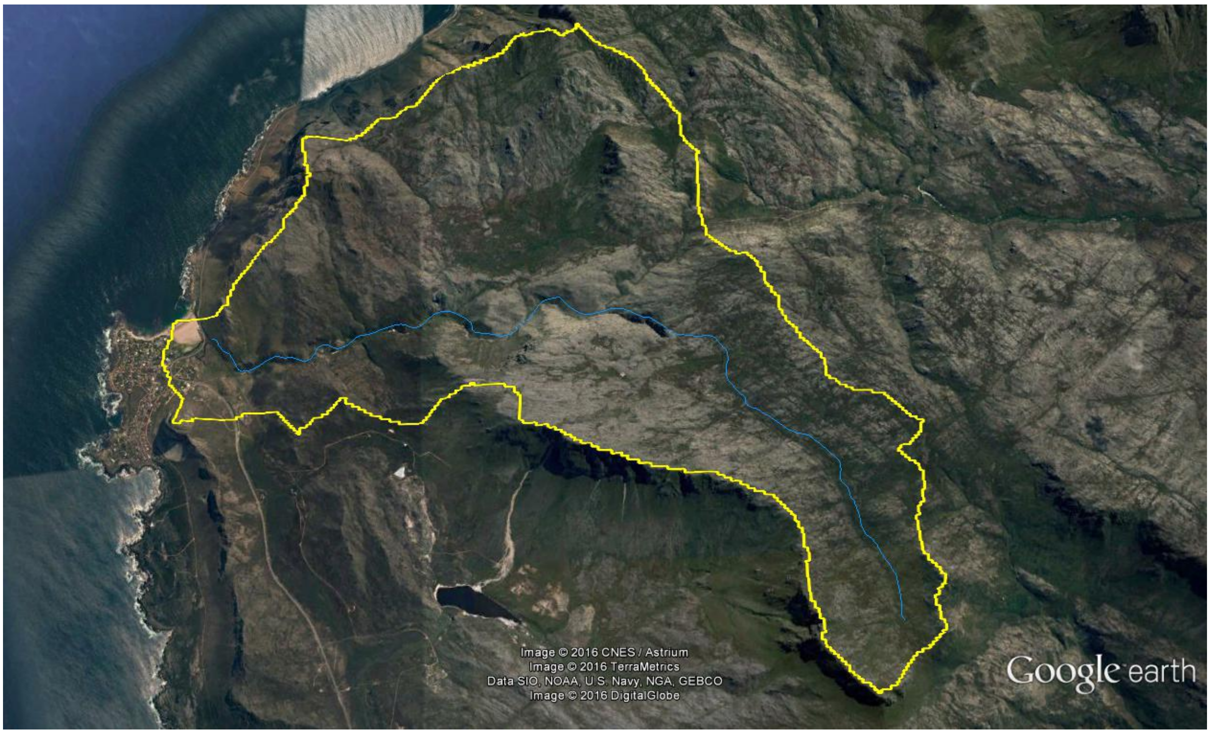

Figure 0.2. Rooiels Estuary catchment.

1.4 Hydrology

1.4.1 Present and Reference State

Natural and present day simulated freshwater flow sequences for the Rooiels Estuary were generated using the Water Resources Simulation Model 2000 (WRSM 2000) (Pitman) rainfall-runoff model. Monthly flow sequences are presented at the end of this appendix while summary flow data are presented in

Table 0.2 (Reference conditions) and Table 0.3 (Present day). There has been little change in mean annual runoff (MAR) between Reference (9.571 Mm^3/a) and Present (9.439 Mm^3/a) (1.4% reduction in MAR) which is not unexpected given the lack of any dams or significant use of water in the catchment.

Table 0.2. Simulated monthly flows (in 106 m³) under REFERENCE CONDITIONS.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.731	1.170	0.591	0.448	0.369	0.441	1.685	3.555	4.034	5.060	4.875	3.174
90%ile	1.400	0.832	0.410	0.167	0.104	0.135	0.470	1.513	3.202	3.089	2.977	2.047
80%ile	1.199	0.666	0.278	0.125	0.089	0.080	0.253	1.017	2.299	2.619	2.463	1.814
70%ile	1.034	0.587	0.238	0.105	0.073	0.070	0.175	0.668	1.769	2.103	2.081	1.627
60%ile	0.979	0.525	0.212	0.089	0.060	0.056	0.136	0.526	1.450	1.805	1.890	1.478
50%ile	0.923	0.482	0.202	0.086	0.050	0.046	0.112	0.443	1.156	1.606	1.705	1.366
40%ile	0.834	0.467	0.188	0.080	0.039	0.038	0.087	0.378	0.886	1.436	1.549	1.311
30%ile	0.797	0.437	0.180	0.072	0.037	0.030	0.074	0.287	0.741	1.248	1.443	1.214
20%ile	0.722	0.402	0.158	0.061	0.032	0.022	0.050	0.242	0.603	1.010	1.232	1.136
10%ile	0.629	0.329	0.146	0.054	0.024	0.020	0.024	0.166	0.447	0.813	1.051	0.957
1%ile	0.467	0.238	0.116	0.050	0.020	0.007	0.014	0.043	0.209	0.424	0.788	0.769

Table 0.3. Simulated monthly flows (in 106 m³) under PRESENT CONDITIONS.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.717	1.156	0.584	0.437	0.362	0.433	1.659	3.510	3.997	5.003	4.831	3.132
90%ile	1.383	0.820	0.403	0.165	0.102	0.133	0.463	1.489	3.159	3.048	2.946	2.015
80%ile	1.186	0.660	0.278	0.121	0.087	0.077	0.248	1.000	2.265	2.583	2.426	1.785
70%ile	1.026	0.580	0.234	0.103	0.070	0.068	0.169	0.654	1.746	2.071	2.052	1.602
60%ile	0.968	0.520	0.209	0.089	0.059	0.054	0.134	0.516	1.426	1.777	1.866	1.458
50%ile	0.913	0.477	0.197	0.084	0.049	0.045	0.109	0.435	1.137	1.580	1.682	1.351
40%ile	0.827	0.461	0.184	0.078	0.039	0.037	0.087	0.371	0.871	1.417	1.528	1.292
30%ile	0.789	0.430	0.178	0.068	0.037	0.030	0.072	0.281	0.726	1.226	1.424	1.197
20%ile	0.718	0.399	0.156	0.060	0.030	0.022	0.049	0.236	0.590	0.992	1.215	1.126
10%ile	0.619	0.325	0.143	0.054	0.024	0.020	0.024	0.164	0.436	0.798	1.033	0.944
1%ile	0.462	0.235	0.115	0.047	0.020	0.007	0.014	0.043	0.207	0.415	0.774	0.753

1.4.2 EWR Scenarios

Although there are no firm plans for increased (or decreased) utilisation of water in the Rooiels River catchment, a number of hypothetical scenarios were constructed to examine likely impacts of a reduction in flow on the health of the Rooiels Estuary. The following scenarios were considered:

- **Scenario 1:** Steady state reduction in baseflow of 0.0015 m³/s (equivalent to reduction in MAR of ~5.6% from Present and 6.9% from Reference)
- **Scenario 2:** Steady state reduction in baseflow of 0.0025 m³/s (equivalent to reduction in MAR of ~8.8% from Present and 10.1% from Reference)
- **Scenario 3:** Steady state reduction in baseflow of 0.0035 m³/s (equivalent to reduction in MAR of ~11.8% from Present and 13.0% from Reference)

Summary data of MAR for the Reference, Present Day and EWR scenarios is presented in Table 0.4, while monthly flow distributions for the EWR scenarios 1-3 are presented in

Table 2.5, Table 0.5 - Table 0.7, and simulated monthly flow data are included at the end of this appendix. All of the EWR Scenarios were designed to investigate the impact of reduction in runoff to the estuary resulting from, for example runoff river abstraction.

Table 0.4. Summary of the scenarios evaluated in this study

Scenario name	Description	MAR (x 106 m^3)	Percentage remaining
Natural	Reference condition	9.57	100%
Present	Present day	9.44	99%
Scenario 1	- 5.6% of Present	8.91	93%
Scenario 2	- 10.1% of Present	8.61	90%
Scenario 3	- 11.8% of Present	8.33	87%

Table 0.5. Simulated monthly flows (in 106 m3) under SCENARIO 1.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.670	1.108	0.536	0.390	0.315	0.386	1.612	3.463	3.949	4.956	4.784	3.085
90%ile	1.335	0.772	0.356	0.118	0.055	0.086	0.415	1.442	3.112	3.000	2.898	1.968
80%ile	1.139	0.612	0.230	0.074	0.040	0.029	0.201	0.952	2.217	2.536	2.379	1.738
70%ile	0.979	0.532	0.186	0.055	0.024	0.023	0.122	0.607	1.699	2.024	2.004	1.555
60%ile	0.921	0.472	0.161	0.042	0.020	0.022	0.087	0.468	1.379	1.730	1.818	1.411
50%ile	0.865	0.429	0.150	0.036	0.019	0.018	0.061	0.387	1.089	1.533	1.634	1.304
40%ile	0.780	0.414	0.137	0.031	0.017	0.015	0.040	0.324	0.824	1.370	1.481	1.244
30%ile	0.742	0.383	0.130	0.023	0.014	0.012	0.025	0.233	0.678	1.179	1.377	1.150
20%ile	0.670	0.351	0.108	0.017	0.012	0.010	0.014	0.189	0.543	0.944	1.168	1.079
10%ile	0.572	0.277	0.095	0.007	0.010	0.007	0.011	0.116	0.389	0.751	0.986	0.897
1%ile	0.415	0.187	0.068	0.004	0.003	0.003	0.004	0.019	0.160	0.368	0.727	0.706

Table 0.6. Simulated monthly flows (in 106 m3) under SCENARIO 2.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.638	1.077	0.505	0.358	0.283	0.354	1.580	3.431	3.918	4.925	4.752	3.053
90%ile	1.304	0.741	0.325	0.086	0.025	0.054	0.384	1.410	3.080	2.969	2.867	1.936
80%ile	1.108	0.581	0.199	0.042	0.022	0.024	0.169	0.921	2.186	2.505	2.347	1.706
70%ile	0.947	0.501	0.155	0.025	0.019	0.020	0.090	0.575	1.667	1.992	1.973	1.524
60%ile	0.890	0.441	0.130	0.023	0.016	0.017	0.055	0.437	1.347	1.699	1.787	1.379
50%ile	0.834	0.398	0.118	0.020	0.013	0.014	0.030	0.356	1.058	1.501	1.603	1.272
40%ile	0.748	0.383	0.105	0.018	0.012	0.011	0.024	0.292	0.792	1.338	1.449	1.213
30%ile	0.710	0.351	0.099	0.017	0.011	0.009	0.018	0.202	0.647	1.148	1.345	1.118
20%ile	0.639	0.320	0.077	0.010	0.009	0.007	0.014	0.157	0.511	0.913	1.136	1.048
10%ile	0.540	0.246	0.064	0.005	0.007	0.005	0.008	0.085	0.358	0.719	0.955	0.865
1%ile	0.383	0.156	0.036	0.001	0.001	0.001	0.001	0.003	0.128	0.336	0.695	0.674

Table 0.7. Simulated monthly flows (in 106 m3) under SCENARIO 3.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.607	1.045	0.473	0.327	0.252	0.323	1.549	3.399	3.886	4.893	4.721	3.022
90%ile	1.272	0.709	0.293	0.055	0.026	0.028	0.352	1.379	3.049	2.937	2.835	1.905
80%ile	1.076	0.549	0.167	0.026	0.022	0.019	0.138	0.889	2.154	2.473	2.316	1.675

70%ile	0.916	0.469	0.123	0.023	0.017	0.017	0.059	0.544	1.636	1.961	1.941	1.492
60%ile	0.858	0.409	0.098	0.022	0.015	0.014	0.026	0.405	1.316	1.667	1.755	1.348
50%ile	0.802	0.366	0.087	0.021	0.012	0.011	0.024	0.324	1.026	1.470	1.571	1.241
40%ile	0.717	0.351	0.074	0.018	0.010	0.009	0.019	0.261	0.761	1.307	1.418	1.181
30%ile	0.679	0.320	0.067	0.016	0.009	0.008	0.015	0.170	0.615	1.116	1.314	1.087
20%ile	0.607	0.288	0.045	0.014	0.008	0.006	0.011	0.126	0.480	0.881	1.105	1.016
10%ile	0.509	0.214	0.032	0.013	0.006	0.005	0.006	0.053	0.326	0.688	0.923	0.834
1%ile	0.352	0.124	0.007	0.008	0.005	0.002	0.002	0.010	0.097	0.305	0.664	0.643

1.4.3 Hydrology health score for present day & EWR scenarios

Reduction in MAR for the Rooiels Estuary for the Present day and EWR Scenarios 1-3 is estimated to be 7, 10, and 13%, respectively. The reduction in the size of the 1:10, 1:20 and 1:50 year floods for the Present day and Scenarios 1, 2 and 3 are negligible, and are estimated at 1.0, 2.1, 2.8, and 3.5%, respectively.

Hydrological health for Present day and the EWR scenarios was assessed on the basis of the overall change in MAR and in flood frequency. Results are presented in Table 0.8. Confidence in this assessment was rated as low as simulated flows have not been properly calibrated against gauged data.

Table 0.8. Similarity scores for hydrology for Present and EWR scenarios relative to the Reference condition.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. % similarity in MAR	99	93	90	87	M
b. Change in flood frequency	99	98	97	97	M
Score (min + average(a : b)/2)	**99**	**94**	**92**	**89**	M
Score min (a to b)	**99**	**93**	**90**	**87**	**M**

1.5 Hydrodynamics

The Rooiels Estuary is classified as a temporarily open/closed system (Figure 0.3, Van Niekerk & Turpie 2012). Very little information is available on the hydrodynamics. Personal observation (L van Niekerk and P Huizinga) indicates that the mouth is at times in a closed state due to a sandbar that forms across the mouth. However this tends to be the exception; due to its small size the estuary is most often in a semi-open state as it meanders through an outflow channel to the sea.

Total open water area is estimated at less than 2 ha up to the head of tidal effect about 1 km from the mouth. The estuary, which is flanked by steep slopes of the Kogelberg Mountains, has a multi-channel configuration through its floodplain (Heinecken 1982). The main water body above the road is roughly H-shaped. A broad flat beach extends from the road to the sea which acts as a sandbar for the estuary. During high tide very little water flows out of the estuary and seawater enters the system over the beach.

Figure 0.3 The Rooiels Estuary Mouth in a near closed state (Source: Google Earth)

The estuary is generally less than 1 m deep; however the main channel above the bridge has a depth of 3 m. When the mouth is open this part of the estuary is subjected to tidal effects. Heinecken (1982) estimated the tide to be 8 cm during the survey in 1979. However, during high spring tides the entire beach area is flooded indicating a significant tidal push.

During floods the river can cut directly to the sea across the centre of the beach (Heinecken 1982). Once the flood dissipates under the influence of waves and longshore drift, the mouth moves across the beach to a position against the rocky shoreline on the southern side of the bay.

The 1938 historical aerial photographs show that at that time the river formed an extensive meander across the lower end of its floodplain. It is evident that with the construction of the bridge and embankment for the coastal road in the early 1950s the main flow channel was relocated towards the northern side of the floodplain under the present configuration with a meander on the seaward side of the road embankment (Heinecken, 1982). Wooden pylons of the old road bridge can still be seen in the southern arm of the estuary above the road. The diversion of the channel most likely involved the construction of an artificial channel to connect the upper and lower estuary after construction of the bridge.

Two abiotic states (***Closed*** and ***Open***) were identified for the Rooiels Estuary based on personal observation and photographs (Figure 0.3,

Table 0.9). However it is not impossible to estimate the occurrence/duration of these abiotic states with a high degree of certainty.

Table 0.9 below represents a best estimate based on available resources.

Table 0.9. Characteristic abiotic states in the Rooiels Estuary

Abiotic State	Water level (m) associated with abiotic state	State duration	Estimated occurrence from water level data	Salinity
Closed (no connectivity)	> 1.6	Weeks to months	10%	<5
Open (with tidal exchange)	< 0.7m	Months	90%	25-30

The estimated occurrence of the abiotic states were superimposed on the simulated runoff time series for the Present State and the associated flow ranges used to calculate the relative occurrence of the Abiotic States under the Reference Condition, Present State and Future Scenarios. There has been a less than 1% increase in the occurrence of absolute mouth closure from Reference to Present, with a concomitant decrease in the semi-closed state (Table 0.10). Overall the estuary has experienced little loss of connectivity to the sea. However, this changes significantly under the future scenarios with a 9%, 16% and 26% increase in closed conditions under scenarios 1 to 3.

Table 0.10. The occurrence of the abiotic states under the Reference Condition, Present State and alternative scenarios 1 – 3.

Abiotic State	Flow range (m^3/s)	% Occurrence				
		Reference	Present	Sc 1	Sc 2	Sc 3
Closed	<0.0015	10.3	10.7	19.6	26.0	35.9
Semi-closed	0.01-0.0015	31.6	31.2	23.8	18.8	14.1
Open	> 0.01	58.1	58.1	56.6	55.2	50.0

The shifts in the hydrodynamics are largely unrelated to changes in the flow regime of the system. The construction of the bridge is the main reason for change in the dynamics of the system. Table 2.12 provides the hydrodynamics similarity EHI scores for the Rooiels Estuary.

Table 0.11. Similarity scores for hydrodynamics under the various operation scenarios relative to the Reference Condition.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Mouth condition	96	53	40	29	M
b. Abiotic states	100	91	84	74	M
Score (min + average(a : b))/2	**97**	**63**	**51**	**40**	**M**
Score min (a to b)	**96**	**53**	**40**	**29**	**M**

1.6 Water quality

For the purpose of this study, the open water area of the Rooiels Estuary was sub-divided into two zones; below the road bridge and above the road bridge (see Figure 0.1). Heinecken (1982) reported variations in surface salinity of 24-28 PSU in the southern arm of the system. Bollmohr *et al.* (2011) reported average surface salinity values of 0-10 PSU, and average bottom salinity values of 10-30 PSU. This is expected as the system is relatively deep in the upper reaches (~ 3 m), and therefore retains saltwater effectively under low flow conditions. The salinity in the system is very similar to reference with potentially slightly more retention in the upper reaches above the bridge due to the bridge bisecting the system.

No measured data on the reference water quality (i.e. prior to anthropogenic influences) could be obtained for this estuary. However, considering the catchment of this clear, black water system, it can be assumed that, on average, its open water areas were clear (suspended solids < 2 mg/ℓ), well-oxygenated (dissolved oxygen ~8 mg/ℓ) and oligotrophic (DIN <30 mg/ℓ and DIP < 10 mg/ℓ).

Considering the undisturbed catchment and available information (e.g. Heinecken 1982) pollution in this system is largely limited to litter in picnic areas. Bollmohr *et al.* (2011) did, surprisingly detect some signs of pesticide contamination which they attributed to atmospheric deposition. Based on very limited data and expert opinion, the average water quality conditions under each of the abiotic states, for reference, present and future scenarios are shown in Table 0.12. Water quality scores for the present and future scenarios are presented in Table 0.13 and a summary of changes in water quality for the present and EWR scenarios is presented in Table 0.14.

Table 0.12. Estimated average water quality conditions under various scenarios

Salinity (PSU)	Reference	Present	Scenario 1	Scenario 2	Scenario 3
Above road bridge	20	20	20	18	15
Below road bridge	25	25	25	22	20
DIN (µg/ℓ)	Reference	Present	Scenario 1	Scenario 2	
Above road bridge	20	20	20	20	20
Below road bridge	50	60	60	60	60
DIP (µg/ℓ)	Reference	Present	Scenario 1	Scenario 2	
Above road bridge	10	10	10	10	10
Below road bridge	10	12	12	12	12
DO (mg/ℓ)	Reference	Present	Scenario 1	Scenario 2	
Above road bridge	8	8	8	8	8
Below road bridge	8	8	8	8	8
TSS (mg/ℓ)	Reference	Present	Scenario 1	Scenario 2	
Above road bridge	2	2	2	2	2
Below road bridge	2	2	2	2	2

Table 0.13 Summary of changes and calculation of the water quality health score

Variable		Present	Sc 1	Sc 2	Sc 3	Confidence
1	Salinity	99	98	96	92	M
2	General water quality					
	a) Nutrient concentrations (DIN/DIP)	95	95	95	95	L
	b) Dissolved oxygen	100	100	99	98	L
	c) Total suspended solids	100	99	99	98	L
	d) Toxic substances	90	90	90	90	L
Water quality score*		94	94	94	92	L

**Score = (0.6 x S + 0.4 x min (a to d))*

Table 0.14 Summary of changes water quality for the Present EWR scenarios

Parameter	Summary Of Changes
Salinity	No marked change
Inorganic nutrients (DIN/DIP) in estuary	No marked change
Dissolved oxygen in estuary	No marked change
Suspended solids in estuary	No marked change
Toxic substances in estuary	⇧ study indicated limited contamination from pesticides (atmospheric deposition)

1.7 Physical habitats

Heinecken (1982) reported that there was no evidence of catchment-derived siltation in this system. The survey conducted in December 1979 showed a thin layer of decayed organic matter and fine black mud in the upper reaches of the southern arm above the road, but no signs of catchment erosion (Heinecken 1982).

However, there has been some loss of subtidal and intertidal area from Reference to Present due to infilling around the bridge embankments. The road bridge has also caused stabilisation and loss of variability in the meandering section of the lower estuary. As the system is relatively sediment starved from a catchment perspective it is assumed that the subtidal areas (and related estuary volume) in the upper reaches will remain relatively unmodified under the future scenarios. However, of concern is marine siltation processes in the lower reaches (i.e. filling in of intertidal and subtidal areas) which is likely to escalate as a result of loss of floods. The sediment structure is not likely to change much due to the system at present having a strong marine sediment signal. Table 0.15 below provides a summary of the EHI scores for the physical habitat of the Rooiels Estuary.

Table 0.15. Similarity scores for physical habitats under different scenarios.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Supratidal area and sediments	90	85	80	75	M
b. Intertidal areas and sediments	95	90	85	80	M
c. Subtidal area and sediments	95	92	90	85	M
d. Estuary bathymetry/water volume	95	92	90	85	M
Score (min + average(a : d))/2	**92**	**90**	**85**	**80**	**M**
Score min (a to d)	**90**	**85**	**80**	**75**	**M**

1.8 Microalgae

There is little information available on the microalgae of the Rooiels Estuary. Heinecken (1982) described a number of pennate diatoms and chlorococales associated with filamentous algae in the estuary. Grindley (1978 unpublished, cited in Heinecken 1982) recorded a prolific filamentous green algae in the upper part of the estuary in April 1978. *Ulva* sp., *Chaetomorpha* sp., *Cladophoropsis* sp. and threads of the diatom *Melosira* sp. were recorded in the ECRU surveys. Bollmohr *et al*. (2011) measured water column and benthic microalgal chlorophyll in an overall comparative study of the Lourens and Rooiels estuaries. The absolute values cannot be used as the analysis methods were incorrect, however, an interesting finding was that chlorophyll-a (microalgal-biomass) in the Lourens (disturbed) was higher than that in the Rooiels (undisturbed) system.

Due to little change in the abiotic environment the present state of the microalgae is likely close to natural. Small reductions in flow for the future scenarios would increase retention time and therefore biomass. There are no signs of nutrient enrichment and therefore the microalgal species richness and community composition is also largely unchanged. In terms of anthropogenic impacts the bridge may have increased retention time in the upper reaches of the estuary resulting in a small deviation from natural conditions.

Table 0.16. Similarity scores under the different scenarios

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Species richness	100	95	93	91	M
b Abundance	95	90	88	86	M
c. Community composition	100	95	93	91	M
Score (min + average(a : c))/2	**97**	**92**	**90**	**88**	**M**
Score min (a to c)	**95**	**90**	**88**	**86**	**M**

1.9 Macrophytes

1.9.1 Macrophyte groups

The main habitats and macrophyte groups present in the Rooiels Estuary are described in Table 0.17.

Table 0.17. Macrophyte habitats and functional groups recorded in the estuary (spp. examples in italics).

Habitat type	Defining features, typical/dominant species	Area (ha)
Open surface water area	Serves as a possible habitat for phytoplankton. Below the bridge large fluctuations in surface area temporally.	2.8
Intertidal sand and mudflats (beach)	Provide a possible area for microphytobenthos to inhabit.	1.2
Macroalgae	The estuary was visited in July 2016 after a heavy rainfall event and no macroalgae were collected possibly due to flushing.	-
Submerged macrophytes	Pondweed *Potamogeton pectinatus* was identified amongst reeds standing in the open water but this area is too small to map.	-
Reeds and sedges	*Juncus acutus* wetland was dominant and situated mainly on an ‘island’ above the road embankment. Common reed *Phragmites australis* fringed the open water in some areas.	2.2 rushes + 0.6 reeds =2.8
Salt marsh	A small patch of salt marsh habitat represented by *Bassia diffusa* and *Sarcocornia littorea* was present near the mouth of the estuary.	-
Saline grasses	Heinecken (1982) recorded *Paspalum vaginatum*, brakgrass *Sporobolus virginicus* and the daisy *Dimorphotheca fruticosum* (previously *Osteospermum)* in this area.	1.9
Riparian vegetation	The steeper banks of the estuary were vegetated with Kogelberg Sandstone Forest and Overberg Dune Strandveld (Mucina *et al*. 2014). The invasive red eye wattle *Acacia cyclops* was present amongst the coastal habitat in the lower reaches, mostly on the seaward side of the road bridge. Approximately 1.2 ha of the floodplain is disturbed.	2.8 (of this 1.2 ha disturbed)
Development	Roads and embankment	0.7

1.9.2 Baseline description

The present day area of the different macrophyte habitats and their distribution within the 5m contour around the estuary is shown in Figure 0.4. Rooiels is a temporarily open/closed estuary (see Figure 0.5a) and therefore intertidal salt marsh is not expected. On 25 July 2016 the mouth was open with salinity ranging from 0.3-1.1 PSU. A large island of *Juncus acutus* situated above the road bridge was the dominant macrophyte habitat (see Figure 0.5b). Grassy banks in the upper reaches of the estuary cover the second largest area; these could not be accessed during the 2016 field survey. Common reed *Phragmites australis* fringes the banks of the estuary in some areas. The submerged macrophyte pondweed *Potamogeton pectinatus*, although not mapped, was identified during a field survey in July 2016 (see Figure 0.5e). The reeds occurred mostly in the upper reaches of the estuary although a narrow fringe of reeds (not mapped) was present along the seaward side of the road bridge. Young individuals of an unidentified sedge were abundant in the undergrowth of the reeds in the upper reaches as well as fringing the banks of the estuary above the road bridge (see Figure 0.5c). These plants had germinated due to a drop in water level following the opening of the mouth.

A few salt marsh species were present below the houses near the mouth of the estuary. There were individuals of *Sarcocornia littorea* and *Bassia diffusa* (previously *Chenolea*) growing amongst rocks and *Sporobolus virginicus* in this sandy area, which was elevated compared to the beach (see Figure 0.5d). A small area of the submerged macrophyte *Potamogeton pectinatus* was present in the upper reaches adjacent to the reed habitat. The steeper banks of the estuary were vegetated with Kogelberg Sandstone Forest and Overberg Dune Strandveld (Mucina *et al.* 2014). Species present included *Plantago crassifolium, Metalasia muricata, Nidorella foetida* and *Searsia glauca*. The invasive red eye wattle *Acacia cyclops* was present amongst the coastal habitat in the lower reaches, mostly on the seaward side of the road bridge. Some evidence of invasive clearing was present in this area (see Figure 0.5f).

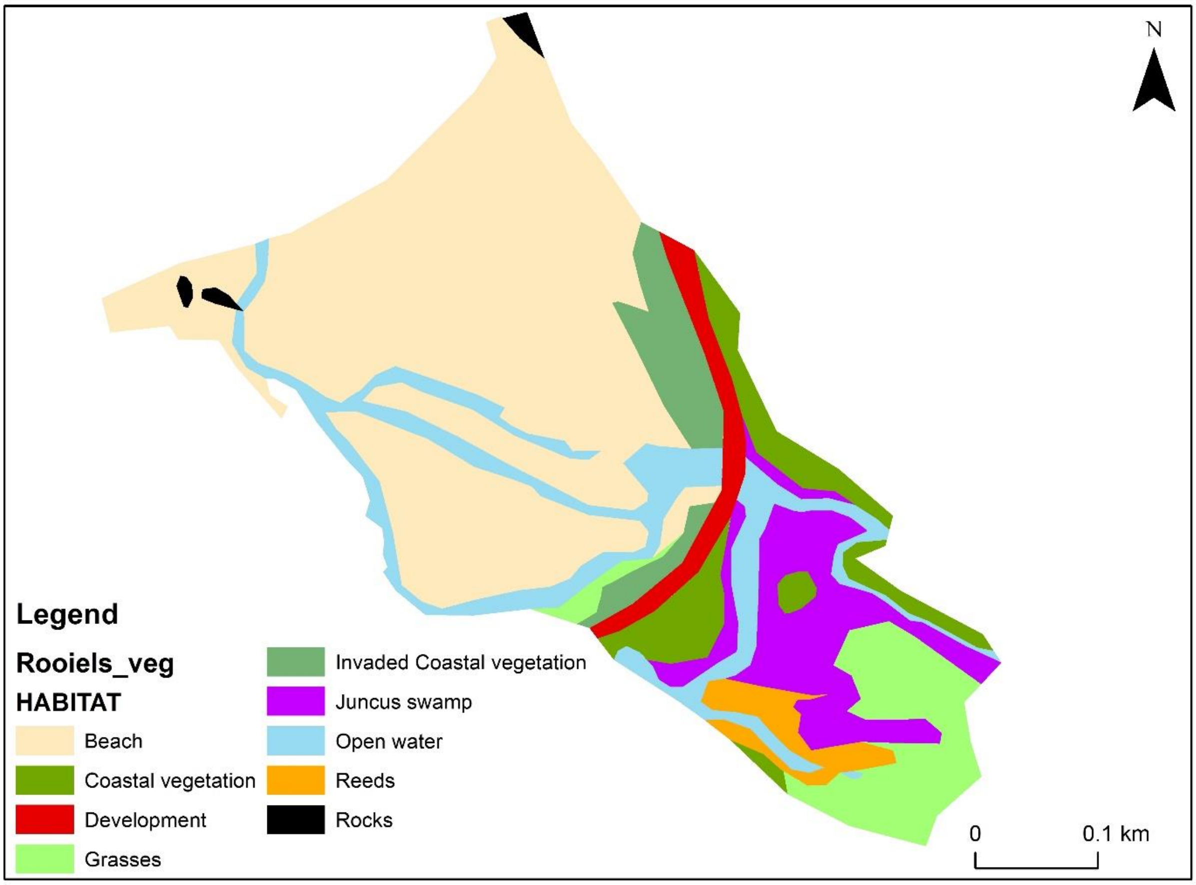

Figure 0.4. Distribution of macrophyte habitats at Rooiels Estuary in 2016 based on a field survey and 2014 aerial photography.

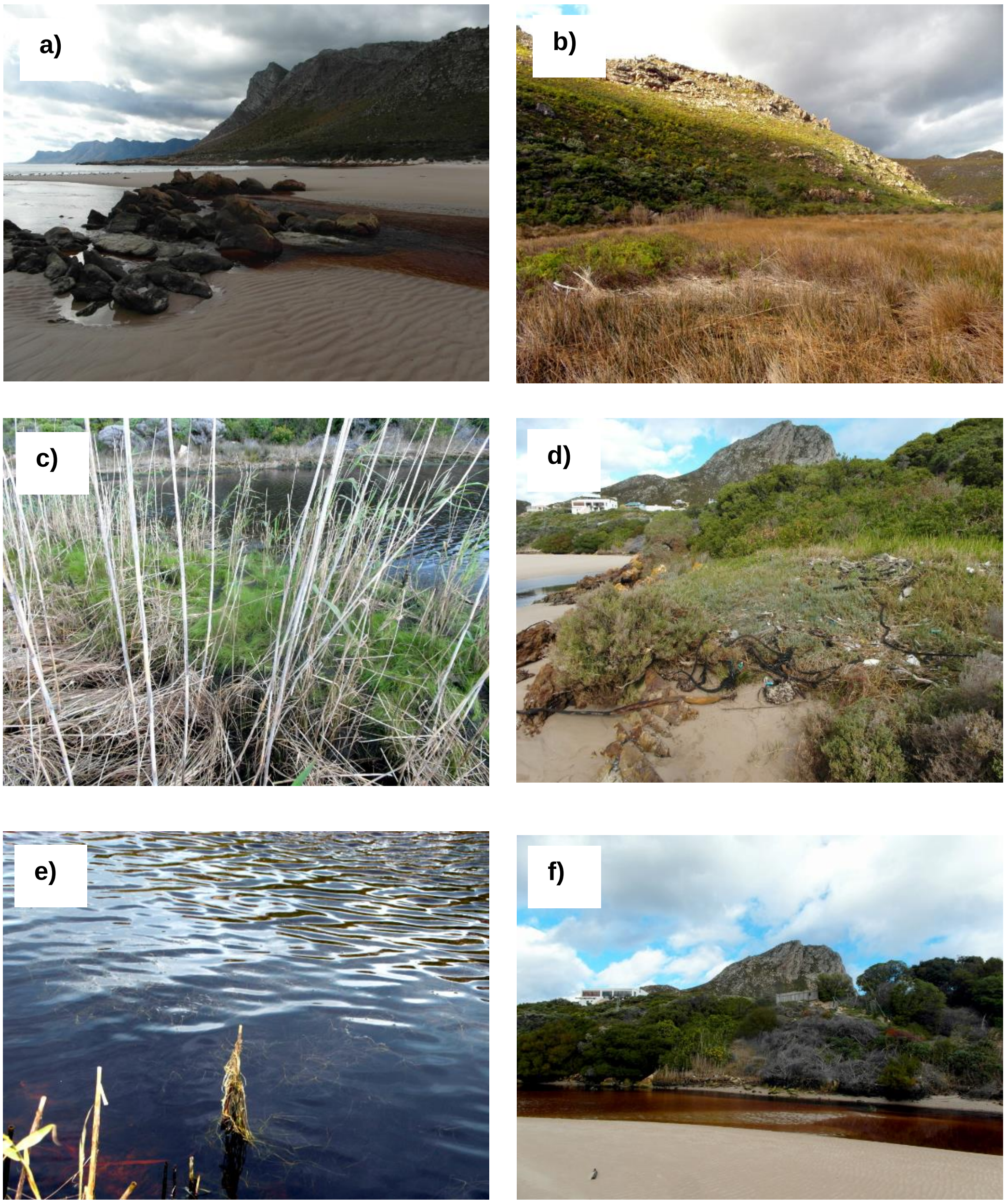

Figure 0.5. (a) Mouth of the Rooiels Estuary, July 2016 (b) Large *Juncus acutus* beds present on an island above the road bridge (c) Young sedges growing amongst the dead reeds in the upper reaches of the estuary (d) *Bassia diffusa* growing amongst *Sporobolus virginicus* on the bank below houses at the mouth of the estuary (e) Submerged *Potamogeton pectinatus* growing in the black water at Rooiels Estuary (f) Vegetation growing on the bank below the road bridge on the seaward side, note the dead brush with invasive *Acacia cyclops* trees.

1.9.3 Reference condition

The R44 road bridge and embankment constructed in the early 1950s resulted in the relocation of the main flow channel towards the northern side of the floodplain under the bridge with a meander hugging the embankment and then flowing out to sea at its original location (rocky area on the western extremity of the bay, Heinecken 1982). The main water body above the road bridge is ‘h’ shaped and it is suspected that the channel connecting the northern and southern arm was artificially created following the construction of the bridge. Approximately 0.7 ha of the habitat is now occupied by road and 1.2 ha of the floodplain is disturbed.

The estuary is located in the Hottentots Holland Nature Reserve and thus the catchment is fairly natural and undisturbed. Grindley (1978, unpublished report cited in Heinecken 1982) recorded *Ruppia* in the estuary above the bridge. Pondweed was present as a submerged macrophyte in July 2016. Field notes from 1958 illustrated dense *Phragmites australis* at the upper end of the southern channel above the road embankment. In 1979 reeds also occurred on the seaward side of the road. The same distribution was apparent in 2016 with sparse reeds on the seaward side.

1.9.4 Macrophyte health

The health of the macrophytes was assessed in terms of species richness, abundance and community composition. Change in species richness was measured as the loss in the average species richness expected during a sampling event, excluding species thought to not have occurred under Reference conditions (Table 0.18). Abundance was measured as the change in area cover of macrophyte habitats. (% similarity = 100*present area cover/ reference area cover; 100*10.1/12.2 = 83% similar). Change in community composition was assessed using a similarity index which is based on estimates of the area cover of each macrophyte habitat in the reference and present state. (Czekanowski’s similarity index: ∑ (min (ref,pres) / (∑ref + ∑pres)/2)). The macrophytes are 83% similar to what they were under reference conditions.

Table 0.18. Summary of how the macrophytes in the Present condition have changed relative to the Reference condition.

Estuary habitat	Reference Area (ha)	Present Area in 2016	Minimum
Open water	2.8	2.8	2.8
Sand/mud banks	1.2	1.2	1.2
Reeds & sedges	3.5	2.8	2.8
Salt marsh	0.8	0	0
Saline grasses	2.3	1.9	1.9
Riparian vegetation intact	1.6	1.6	1.6
Riparian vegetation disturbed	0	1.2	0
Development	0	0.7	0
TOTAL	**12.2**	**12.2**	**10.1**
Community Composition	**10.1/12.2= 83% similarity**		

Table 0.19. Similarity scores of macrophytes in the Present condition relative to the Reference condition.

Variable	Change from natural	Score	Confidence
1. Species richness	Invasive species displace natural vegetation and decrease species richness.	95	M
2. Abundance	The construction of the road and bridge embankments removed some macrophyte habitat and redirected the main channel (0.7 ha). Invasion by *Acacia cyclops* has transformed 1.4 ha of floodplain habitat.	83	M
3. Community composition	Salt marsh may have been removed from the mouth area due to the redirection of the mouth and residential developments above the beach.	83	M
Macrophyte health score		**83%**	M
% of impact non-flow related		**100**	

1.9.5 Summary of change in macrophytes under different scenarios

The decrease in flow for each Scenario will result in small increases in the abundance of reeds and submerged macrophytes. Little change in species richness is expected (Table 0.20).

Table 0.20. Similarity scores under the different scenarios.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Species richness	95	90	90	90	M
b Abundance	83	80	79	78	M
c. Community composition	83	80	79	78	M
Score (min + average(a : c))/2	**85**	**82**	**81**	**80**	**M**
Score min (a to c)	**83**	**80**	**79**	**78**	**M**

1.10 Invertebrates

1.10.1 Baseline condition

Estuarine invertebrates can be divided into a number of sub-groups based on where they reside in the estuary. Zooplankton live mostly in the water column, benthic organisms live in the sediments on the bottom and sides of the estuary channel, and hyperbenthic organisms live just above the sediment surface. Benthic organisms are frequently further subdivided into intertidal (those living between the high and low water marks on the banks of the estuary) and sub-tidal groups (those living below the low water mark).

There is no available information on zooplankton, insects, nor invertebrates residing in the vegetation in the Rooiels Estuary (Heineken 1982). There was, however, limited information on benthic and hyperbenthic invertebrates (Heineken 1982, Knox 2003). The invertebrate data contained in the report compiled by Heineken (1982) was sourced from Grindley (1978, unpublished). Grindley (1978) sampled six sites below the road bridge and a further two sites above the road bridge and identified 10 benthic and hyperbenthic invertebrate species from three taxonomic classes (Heineken 1982). Subsequently Knox (2003) identified six species from two taxonomic classes. However, this study was restricted to only two sampling sites; one below and one above the road bridge. Differences in numbers of species, taxa and abundances between the two surveys is likely due to the different number of sites sampled, time of year (April for Heineken 1982 and September - October for Knox 2003), sampling effort and technique at each of the sites.

Sandprawn *Callichirus kraussi* and mudprawn *Upogebia africana* were both present and relatively abundant in the lower reaches (Heineken 1982, Knox 2003) and there was evidence of prawn holes from a visit to the system during November 2016 (pers. obs.). The isopods *Cirolana longicornis* and *Excirolana latipes* were fairly abundant in the lower reaches as were amphipods *Melita zeylanica* and species from the *Taliridae* family (Heineken 1982). The gastropod, *Assiminea ponsonbyi* and the Nemertean *Cerebratulus fuscus* were also found below the road bridge (Heineken 1982). Above the road bridge, the isopod *Cyathura carinata* was collected as was the shrimp *Palaemon pacificus.* The Crown crab *Hymenosoma orbiculare* was found above the road bridge (Heineken 1982) and was again noted in seine net hauls below the road bridge during in 2016 (pers. obs.).

1.10.2 Reference condition

Under the reference condition invertebrate richness, abundances and composition would have been similar to those noted in the baseline description due to the overall negligible change in water quality and hydrodynamics of this system. The available invertebrate habitat (macrophytes and benthic sediment composition) has changed very little over time indicating that the present habitat is similar to the reference habitat available. Regular overtopping events along with relatively stable water flow rates have ensured the predominately open status of the estuary, allowing the influx of saline water and persistence of marine and estuarine taxa within the system. However, abundances of invertebrates were likely to be greater under reference conditions (especially prawns) as bait collection for fishing during the baseline condition would have negatively affected overall numbers.

1.10.3 Summary of change in invertebrates under different scenarios

A summary of the changes in invertebrates under different scenarios is provided in Table 0.21. Estimated health scores are provided inTable 0.22.

Table 0.21. Summary of change to invertebrates

Scenario	Summary of changes
1	The decreased flow with the increase of closed mouth conditions will decrease salinities due to less seawater input thus affecting both marine and estuarine taxa present within the system. As changes will be minimal, decreased salinities will cause a slight decrease in abundance of marine taxa with a slight increase in estuarine and freshwater taxa within the system with these species moving closer to the mouth of the estuary. There will be a small change in richness and species composition.
2	Similar to Scenario 1 but slightly more severe response due reduced water flows and increase of closed estuary incidences.
3	As flow rates will decrease substantially under this scenario, and closed estuary incidences occur more frequently, this could possibly negatively impact marine invertebrates decreasing abundances, possibly eliminating some taxa, especially those already under anthropogenic induced pressure (sand prawns). However, even with reduced flow, regular overtopping events will maintain the input of sea water ensuring the persistence of estuarine taxa. Freshwater taxa will likely become more prolific under this scenario and change their distribution slightly, moving closer to the estuary mouth. Overall this scenario would negatively affect invertebrate abundances and possibly species richness and composition.

Table 0.22. Similarity scores under the different scenarios.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Species richness	100	98	95	90	M
b Abundance	95	93	90	85	L
c. Community composition	100	95	90	87	M
Score (min + average(a : c))/2	**97**	**94**	**91**	**86**	**M**
Score min (a to c)	**95**	**93**	**90**	**85**	**M**

1.11 Fish

1.11.1 Baseline description

Studies of the icthyofauna of the Rooiels Estuary include two surveys conducted in 1968 and 1978 and those done during the 1979 and 1981 ECRU surveys (Heineken 1981). These data are qualitative, presence/absence data and few or no details are provided on the methods used or sampling intensity ("netting"). These surveys recorded six species including estuarine resident and estuary-dependent marine species (Table 0.23). Harrison (1999) sampled the estuary in 1994, recording four species with the southern mullet dominating these samples. Three experimental seine net (30m x 2m x 12mm stretch mesh) hauls were undertaken in the Rooiels Estuary on the 3 November 2016. During this survey the mouth was open, the estuary was stratified in the deeper sections in the vicinity of the road bridge, salinity varied from 8-24 PSU and water temperature was 18-20°C. A total of nine species were caught in the 2016 survey, bringing the total number of species recorded for the estuary to date to ten (Table 0.23). These include three estuarine resident species; estuarine round herring *Gilchristella aestuaria* (Whitfield 1999 estuarine dependence category IA), Knysna sand goby *Psammagobius knysnaensis* and silverside *Atherina breviceps* that breed in estuaries (the latter two also have marine breeding populations, category IB). Juvenile flathead mullet *Mugil cephalus*, white steenbras *Lithognathus lithognathus* and leervis *Lichia amia* are dependent on estuaries as nursery areas (Category IIA). Juvenile, groovy mullet *L. dumerilli* and Cape sole *Heteromycteris capensis* occur mainly in estuaries (Category IIB). Juvenile southern mullet *Liza richardsonii* and white stumpnose *Rhabdosargus globiceps* occur in estuaries but are generally more common at sea (Category IIC). No freshwater species were recorded in any of the surveys but this may reflect the relatively high salinities in the areas that were sampled. Sampling further upstream may reveal the presence of some indigenous or alien freshwater fish.

Table 0.23. Relative abundance (average number per haul) of fish species sampled in the Rooiels Estuary during surveys conducted prior to 1981 (Heinecken 1981), 1994 (Harrison 1999) and 2016 (this study). EDC: Estuarine Dependence Category (Whitfield 1999).

Species	Common name	EDC	1980	1994	2006
Gilchristella aestuaria	Estuarine roundherring	IA		2	13
Psammogobius knysnaensis	Speckled sandgoby	IB	x	1	28
Atherina breviceps	silverside	IB	x		133
Lithognathus lithognathus	White steenbras	IIA	x		14
Lichia amia	Leervis	IIA			1
Mugil cephalus	Flathead mullet	IIA	x		1
Heteromycteris capensis	Cape sole	IIB	x	1	
Liza dumerilli	Groovy mullet	IIB			1
Liza richardsonii	Southern mullet	IIC	x	205	2
Rhabdosargus globiceps	White stumpnose	IIC			0.3

During the 2016 survey, fish abundance was dominated by Category I estuarine breeding species *A. breviceps*, *P kysnaensis* and *G. aestuaria* (Figure 0.6). Larger Category IIA estuarine dependent marine species, white steenbras and leervis, however, dominated the samples by mass. Most white steenbras in the sample ranged from 13-17 cm total length (TL) and represent fish that recruited to the estuary the previous summer. Five white Steenbras between 25-30 mm TL were also netted and represent a successful recruitment that occurred within the preceding few weeks. It is interesting that such small white steenbras were recruiting to the Rooiels Estuary as this endangered sparid is known to undertake spawning migrations to the Eastern Cape, which is thought to be the only spawning area.

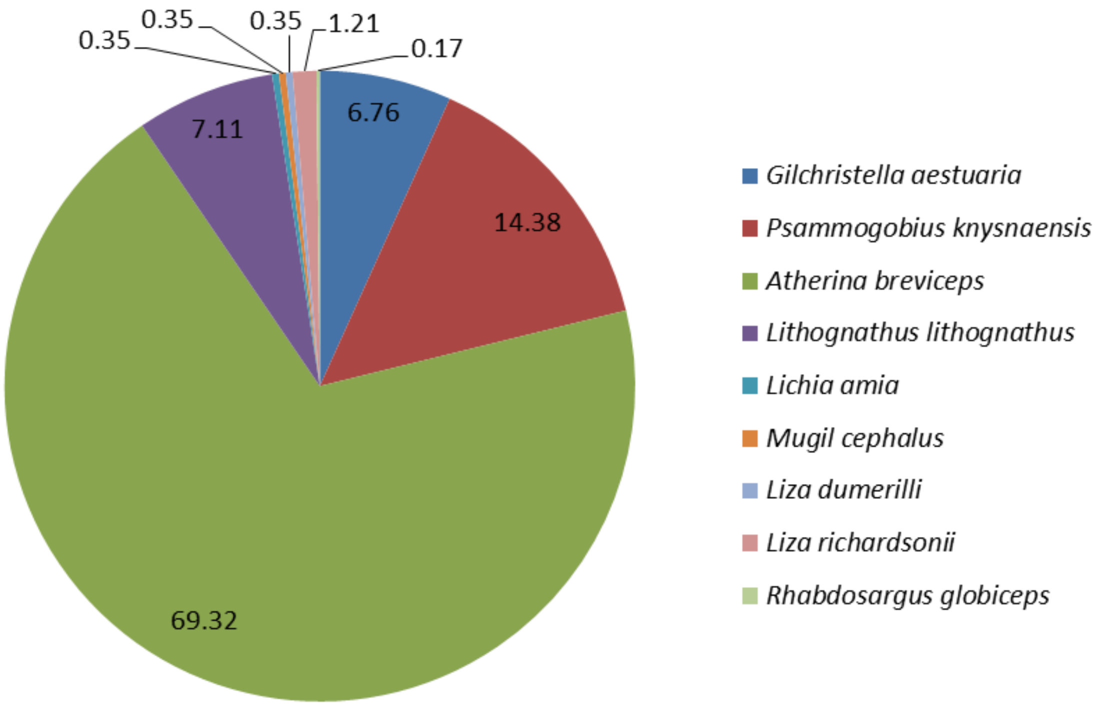

Figure 0.6. Fish species composition in the Rooiels Estuary during the November 2016 survey

1.11.2 Reference icthyofaunal community

The Rooiels Estuary fish community under reference conditions probably differed very little from that described above. There have been insignificant changes in the hydrology, hydrodynamics and water quality of the estuary, and the only major impact in physical habitat relates to the construction of the road bridge. The road bridge may have restricted the natural migration of the estuary channel across the flood plain, but does not appear to have altered the intertidal or subtidal habitats in a way that would have negatively impacted on fish. The reference fish community may have had higher abundance of exploited marine species (such as harders, white steenbras and leervis), the stocks of which have been reduced by fishing throughout their range.

1.11.3 Health of the fish community

The fish currently inhabiting the Rooiels Estuary are largely euryhaline, estuarine residents or estuary associated marine species. The present day fish community is thought to closely resemble that under reference conditions with the exception of a reduction in abundance in exploited species related to fishing pressure throughout their range. The small changes in physical habitat, increase in mouth closure (and no change in water quality) expected under scenario 1 is not expected to have noticeable impacts on fish community composition or abundance (Table 0.24). Increased mouth closure under Scenario 1 would probably occur at the end of the dry summer period and should not negatively impact fish recruitment. The moderate decreases in salinity, changes in physical habitat and increases in mouth closure expected under Scenarios 2 and 3 would probably have a small but noticeable, negative impact on fish abundance and community composition in the estuary. The predicted decrease is salinity and increases in mouth closure would favour estuarine breeders over marine migrants. Most of the currently Rooiels fish fauna are, however, estuarine resident or estuary-dependent species tolerant of a wide range in salinity and recruitment will only likely be negatively impacted if the closed mouth phase becomes more common during Spring (possible under scenario 3). Predicted changes in fish scores under the three scenarios are shown in Table 0.24.

Table 0.24. Similarity scores under the different scenarios.

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Species richness	95	95	90	90	M
b Abundance	80	80	80	75	L
c. Community composition	95	95	90	75	M
Score (min + average(a : c))/2	**85**	**85**	**83**	**71**	**M**
Score (minimum a to c)	**80**	**80**	**80**	**75**	**M**

1.12 Birds

1.12.1 Baseline description

The Rooiels Estuary is classified as a small, temporarily open/closed black water system (Van Niekerk & Turpie 2012) with the general conditions at the estuary seeming to favour certain species of aquatic avifauna (Heineken 1982). The health of the Rooiels Estuary avifaunal community was rated as Good in the National Biodiversity Assessment (van Niekerk & Turpie, 2012); the result of a largely untransformed and natural system. The intertidal sand and mudflats, reeds and sedges, and saline grasses attract invertebrate feeders, waterfowl and passerines.

There is little historic information available on the avifauna of the Rooiels Estuary. Historic counts include those conducted by the Western Cape Wader Study Group (WCWSG) in 1975 and 1981, and by the Estuarine and Coastal Research Unit (ECRU) in 1979 and 1982 (Heineken 1982). The historic counts suggest that the waterbirds, in particular, waders, were scarce (Table 0.25). The highest count was in December 1979 when 118 birds from seven species were recorded. This included 107 Common and Swift Terns. In January 1981 the WCWSG recorded no waders at the estuary, however in March of the same year three Blackbacked Gulls, one Pied Kingfisher and one Cape Wagtail were recorded.

Table 0.25. The number of birds counted on the Rooiels Estuary in 1975 (WCWSG), 1979 (ECRU), 1981 (WCWSG) and 1981 (ECRU). Source: Heinecken (1982) and Underhill & Cooper (1983)

Species	WCWSG* (Dec 1975)	ECRU (Dec 1979)	WCWSG (Jan 1981)	ECRU (March 1981)
Hartlaub's Gull	0	3	No waders recorded	0
Egyptian Goose	0	2		0
Reed Comorant	0	1		0
Blackbacked Gull	0	2		3
Common & Swift Tern	0	107		0

Common Sandpiper	0	1		0
White-fronted Sandplover	1	0		0
Pied Kingfisher	0	0		1
Cape Wagtail	0	0		1
Yellow Bishop	0	2		0
Total number of birds	**1**	**118**	**0**	**5**
Total number of species	**1**	**7**	**0**	**3**

Although the numbers of birds observed in individual counts tend to be low, a bird list published online by Allison Ayre and Helen Jones (www.rooi-els.co.za/index.php/fauna-and-flora/rooiels-birds/all-sightings) which includes all personal bird sightings from 1986 – 2013 shows that a relatively large number of species use the estuary on occasion. A number of estuary-dependent species as defined by Turpie *et al.* (2012) have been recorded, including the Great White Pelican, the Lesser and Greater Flamingo, and the African Black Oystercatcher. Other species recorded include Red-knobbed Coot, Reed and White-breasted Cormorant, African Darter, African Black Duck and Yellow-billed Duck, Little and Yellow-billed Egret, Egyptian and Spur-winged Goose, Common Greenshank, Hartlaub's and Kelp Gull, Little Grebe, Black-headed, Green-backed, Grey, Squacco and Purple Heron, Giant, Half-collared, Malachite and Pied Kingfisher, Blacksmith Lapwing, Common Moorhen, African Openbill, Common Ringed, Grey, Kittlitz's, Three-banded and White-fronted Plover, Common and Curlew Sandpiper, Spotted and Water Thick-knee, and Arctic, Caspian, Common, Little, Sandwich and Swift Terns.

1.12.2 Reference condition

The avifaunal community of the Rooiels Estuary under reference conditions was probably not very different to that described above. The only major change to the physical habitat of the estuary has been the construction of the road bridge in the 1950s. The hydrology, hydrodynamics, water quality, plant communities, invertebrates and fish have not been altered significantly in any way. The road bridge has caused stabilisation and loss of variability in the meandering section of the lower estuary and has caused some loss of subtidal and intertidal area due to infilling around the bridge embankments. This could have slightly reduced the number of waders. Under reference conditions, there would also be an absence of the high levels of human disturbance seen during the holiday periods, which could have had an impact on bird fauna.

1.12.3 Summary of change in birds under different scenarios

A summary of the changes in birds under different scenarios is provided in

Table 0.26. Estimated health scores are provided in Table 0.27. It is, however, difficult to generalise for a system that has limited data. Therefore estimates are of a low confidence.

Table 0.26. Summary of change to birds

Scenario	Summary of changes
1	The reduction in freshwater flows and a slight increase in closed mouth conditions will result in minimal changes to invertebrate abundance and no change to the fish community. As a result, no changes in birds are expected relative to present.
2	Similar to Scenario 1 but slightly more negative response due reduced water flows, an increase of closed estuary incidences, some loss in subtidal and intertidal area, and changes to the invertebrates and fish communities.
3	As the flow rates decrease more substantially under this scenario and the estuary closes more often, the fish, plant and invertebrate communities will change more significantly. It is expected that the bird species richness and abundance would decrease slightly as a result.

Table 0.27. Bird health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Confidence
a. Species richness	95	90	90	87	M
b Abundance	90	88	85	80	M
c. Community composition	90	88	85	80	M
Score (min + average(a : c))/2	**91**	**88**	**86**	**81**	**M**
Score (minimum a to c)	**90**	**88**	**85**	**80**	**M**

1.13 Overall evaluation

1.13.1 Present Ecological Status

Using minimum scores for each component, the overall present ecological status was found to be 92, with abiotic scores being slightly higher than biotic scores. Scores obtained using average-mimimum method were similar for PES and the scenarios and are not summarised here.

Table 0.28. Present ecological status of the Rooiels estuary

Component	Score
Hydology	99
Hydrodynamics and mouth condition	96
Water quality	94
Physical habitat alteration	90
Habitat health score	**95**
Microalgae	95
Macrophytes	83
Invertebrates	95
Fish	80
Birds	90
Biotic health score	**89**
Estuary Health Score	**92**
Ecological Category	**A**

1.13.2 Recommended Ecological Category

Recommended Ecological Category is decided on the basis of conservation importance, using a set of rules. Conservation importance, in turn, comprises biodiversity importance, a score which is taken from an existing dataset, and functional importance, which is decided in the RDM workshop.

Table 0.29. Estuary importance score

Biodiversity importance score	Score	Wt	Estuary Importance (look up remaining scores)	Score	Wt
Plants	80	30	Size	40	15
Invertebrates	40	10	Zonal Type Rarity	10	10
Fish	30	30	Habitat diversity	40	25
Birds	10	30	Biodiversity	65	25
Weighted mean	40		Functional importance	20	25
Max	90				
Biodiversity Importance Score	**65**		**ESTUARY IMPORTANCE SCORE**	**38**	

The biodiversity importance score of the Rooiels estuary is 65. The functional importance was estimated to be 60, based on the fact that the river is a migratory corridor for eels. Using these scores in conjuction with national scores on size, zonal type rarity, and habitat diversity, the overall importance score for the Rooels is 38. This puts it in the category of “low to average importance”.

Since the estuary is not on the list of existing or desired protected areas (Turpie et al. 2012), the rule for REC is to maintain the PES. Therefore the REC is an A category.

1.13.3 Relative contribution of flow and non-flow related impacts on health

The impacts were entirely non-flow related for all components apart from water quality (94% non-flow related). In the case of water quality, there was a very slight impact from residential area; but the main impact was due to change in the level of contact with the sea and upwelled nutrients. If non-flow related impacts were removed, the score would be 99.

1.13.4 Implications of different scenarios for estuary health

The alternative scenarios all reduced health into a B class, with Scenario 3 being at the threshold of the B class.

Table 0.30. Estuary health scores of alternative flow scenarios for the Rooiels estuary

Component	Present	Sc1	Sc2	Sc3
Hydology	99	93	90	87
Hydrodynamics and mouth condition	96	53	40	29
Water quality	94	94	94	92
Physical habitat alteration	90	85	80	75
Habitat health score	**95**	**81**	**76**	**71**
Microalgae	95	90	88	86
Macrophytes	83	80	79	78
Invertebrates	95	93	90	85
Fish	80	80	80	75
Birds	90	88	85	80
Biotic health score	**89**	**86**	**84**	**81**
Estuary Health Score	**92**	**84**	**80**	**76**
Ecological Category	**A**	**B**	**B**	**B**

1.13.5 Overall confidence

The confidence in the abiotic and biotic scores was medium (average 70 and 67, respectively), with the overall level of confidence being “medium” (weighted average = 69). This was in spite of a relatively low amount of past sampling of the system, but the team felt it was relatively simple to understand, especially since the catchment was close to pristine.

1.14 References

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Monthly flows for Reference State

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.333	0.223	0.117	0.060	0.058	0.052	0.087	0.164	2.825	2.959	2.989	2.055	11.922
1921	1.021	0.402	0.149	0.089	0.073	0.065	0.052	0.262	2.275	1.494	2.046	1.434	9.362
1922	0.751	1.006	0.445	0.095	0.024	0.007	0.136	1.451	1.867	1.821	1.635	1.274	10.512
1923	0.796	0.954	0.422	0.089	0.017	0.007	0.017	0.043	2.089	1.177	1.810	1.341	8.762
1924	0.761	0.433	0.177	0.067	0.032	0.015	0.009	0.039	4.032	2.405	1.207	0.984	10.161
1925	0.746	0.461	0.186	0.052	0.020	0.015	0.015	0.394	0.640	1.672	1.570	1.196	6.967
1926	0.883	0.504	0.221	0.104	0.061	0.047	0.074	0.387	0.742	0.841	1.538	1.319	6.721
1927	0.764	0.605	0.322	0.136	0.061	0.054	0.050	0.061	2.360	1.813	1.691	1.817	9.734
1928	1.066	0.463	0.192	0.069	0.035	0.032	0.299	0.446	0.601	1.830	2.076	1.324	8.433
1929	0.699	0.327	0.201	0.112	0.074	0.073	0.074	0.126	0.218	0.432	1.056	2.046	5.438
1930	1.211	0.506	0.203	0.076	0.039	0.028	0.340	0.605	0.603	0.878	1.654	1.680	7.823
1931	1.497	0.738	0.253	0.125	0.104	0.073	0.050	0.439	0.761	1.694	1.442	1.486	8.662
1932	1.040	0.482	0.180	0.074	0.037	0.024	0.024	0.203	2.016	2.641	1.905	1.376	10.002
1933	0.928	0.452	0.156	0.054	0.037	0.030	0.024	0.246	0.670	0.768	0.997	1.183	5.545
1934	1.032	0.543	0.184	0.054	0.024	0.043	0.136	0.573	0.783	1.019	0.984	0.910	6.285
1935	0.631	0.474	0.231	0.151	0.095	0.073	0.060	0.437	0.526	1.356	1.659	1.315	7.008
1936	0.802	0.478	0.439	0.214	0.073	0.069	0.158	0.511	2.598	2.738	1.577	1.010	10.667
1937	0.683	0.363	0.147	0.089	0.060	0.045	0.113	0.686	0.705	0.818	1.205	1.538	6.452
1938	1.029	0.478	0.188	0.069	0.082	0.074	0.136	0.513	0.493	0.580	0.789	0.776	5.207
1939	0.513	0.277	0.128	0.054	0.091	0.082	0.342	0.608	1.215	1.300	1.136	1.019	6.765
1940	0.701	0.573	0.277	0.151	0.089	0.047	0.497	2.840	3.402	3.086	2.976	3.573	18.212
1941	1.758	0.597	0.253	0.126	0.060	0.039	0.061	0.504	3.690	2.022	1.555	1.196	11.861
1942	0.707	0.333	0.147	0.151	0.104	0.110	0.102	0.255	0.759	1.468	2.457	1.668	8.261
1943	0.960	0.538	0.232	0.089	0.039	0.035	0.060	0.404	3.817	2.617	2.732	1.972	13.495
1944	1.265	0.660	0.283	0.106	0.037	0.024	0.099	1.027	3.231	5.083	4.298	1.741	17.854
1945	0.876	0.506	0.210	0.080	0.037	0.065	0.080	0.244	0.402	0.893	1.427	1.813	6.633
1946	1.129	0.463	0.162	0.054	0.020	0.112	0.110	0.283	0.454	2.031	1.821	1.473	8.112
1947	1.029	0.513	0.188	0.065	0.030	0.067	0.087	0.515	0.820	1.360	1.540	2.448	8.662
1948	1.594	0.649	0.218	0.082	0.039	0.024	0.188	0.439	0.618	1.017	1.174	1.352	7.394
1949	0.990	0.805	0.385	0.125	0.045	0.022	0.365	0.283	0.342	3.112	1.713	1.220	9.407
1950	0.928	0.657	0.337	0.184	0.089	0.045	0.193	0.288	2.848	1.934	1.486	1.557	10.546
1951	1.242	0.932	0.400	0.110	0.037	0.032	0.050	0.519	0.551	0.984	1.272	1.146	7.275
1952	0.809	0.471	0.195	0.061	0.022	0.013	1.642	3.675	1.732	1.436	1.840	1.257	13.153
1953	0.724	0.415	0.179	0.065	0.035	0.050	0.192	2.976	2.403	4.529	4.112	1.918	17.598
1954	1.004	0.541	0.236	0.089	0.478	0.240	0.154	0.169	0.474	1.769	3.584	1.895	10.633
1955	1.220	0.705	0.273	0.102	0.047	0.074	0.110	0.660	1.720	1.676	1.793	1.330	9.710
1956	0.967	0.493	0.188	0.074	0.102	0.110	0.149	1.763	2.364	2.850	2.805	1.654	13.519
1957	1.728	0.863	0.223	0.060	0.076	0.087	0.140	0.857	0.843	0.668	1.473	1.088	8.106
1958	0.759	0.484	0.201	0.082	0.045	0.050	1.064	3.540	1.689	0.751	1.538	1.140	11.343
1959	0.802	0.424	0.154	0.058	0.028	0.050	0.076	0.342	1.458	1.056	0.779	0.848	6.075
1960	0.601	0.273	0.119	0.166	0.099	0.043	0.037	0.166	0.737	0.826	1.322	1.620	6.009
1961	1.096	0.471	0.156	0.065	0.043	0.061	0.363	0.329	3.638	2.120	3.065	1.735	13.142
1962	1.460	0.841	0.277	0.089	0.037	0.022	0.024	0.084	0.285	1.282	2.159	1.382	7.942
1963	0.716	0.366	0.192	0.084	0.099	0.080	0.080	0.166	1.198	1.436	1.940	1.356	7.713
1964	0.804	0.543	0.244	0.099	0.171	0.348	0.467	1.176	1.092	1.293	2.029	1.512	9.778
1965	0.962	0.491	0.299	0.149	0.069	0.221	0.305	0.407	1.854	3.714	2.684	1.866	13.021
1966	1.032	0.402	0.136	0.050	0.020	0.020	0.519	0.536	1.665	1.482	1.322	1.144	8.328
1967	0.893	0.523	0.208	0.091	0.069	0.045	0.134	0.843	1.341	2.133	2.141	1.267	9.688
1968	1.122	0.597	0.218	0.106	0.067	0.054	0.151	0.154	0.452	0.578	0.893	0.977	5.369
1969	0.984	0.551	0.184	0.052	0.028	0.020	0.015	0.627	1.304	1.778	2.029	1.458	9.030
1970	0.917	0.469	0.218	0.095	0.037	0.022	0.028	0.177	0.489	1.302	1.784	1.200	6.738
1971	0.664	0.329	0.134	0.074	0.074	0.076	0.218	0.906	0.915	0.863	0.932	0.839	6.024
1972	0.541	0.240	0.104	0.054	0.024	0.020	0.028	0.084	0.140	1.719	1.438	1.196	5.588
1973	0.798	0.379	0.158	0.067	0.032	0.022	0.017	0.359	1.123	1.073	5.565	2.879	12.472
1974	1.196	0.612	0.208	0.080	0.039	0.024	0.110	1.270	1.110	1.994	2.081	1.293	10.017
1975	0.835	0.482	0.188	0.052	0.020	0.039	0.102	0.422	3.199	2.656	1.443	1.185	10.623
1976	0.833	1.166	0.753	0.281	0.141	0.126	0.415	2.513	3.517	4.213	4.790	2.150	20.898
1977	0.804	0.370	0.171	0.082	0.050	0.065	0.099	0.188	0.246	0.459	1.518	1.466	5.518
1978	0.939	0.445	0.193	0.099	0.299	0.179	0.074	1.133	1.546	1.192	1.170	1.237	8.506
1979	1.393	0.714	0.206	0.073	0.052	0.035	0.128	0.798	1.401	1.094	1.237	0.958	8.089
1980	0.640	0.831	0.571	0.783	0.355	0.179	0.275	0.246	0.379	2.665	2.323	2.580	11.827
1981	1.339	0.471	0.186	0.095	0.047	0.030	0.247	0.340	0.843	0.861	0.980	0.790	6.229
1982	0.556	0.314	0.210	0.106	0.203	0.225	0.156	1.555	3.235	3.618	2.016	1.527	13.721
1983	0.950	0.387	0.140	0.054	0.028	0.043	0.136	2.297	1.458	1.436	1.211	1.644	9.784
1984	1.460	0.690	0.441	0.244	0.147	0.560	0.506	0.454	1.003	2.210	2.723	1.672	12.110
1985	0.975	0.482	0.173	0.058	0.050	0.147	0.216	0.275	1.382	1.711	3.199	1.821	10.489
1986	0.824	0.439	0.184	0.087	0.061	0.047	0.117	1.510	1.445	1.464	2.617	1.776	10.571
1987	0.872	0.363	0.184	0.087	0.030	0.020	0.231	0.437	0.701	1.094	1.486	1.304	6.809
1988	0.865	0.418	0.147	0.047	0.035	0.426	0.551	0.848	1.189	1.739	2.305	1.866	10.436
1989	1.337	0.712	0.259	0.087	0.097	0.067	0.751	0.841	1.561	2.628	1.776	1.047	11.163
1990	0.612	0.318	0.141	0.058	0.022	0.015	0.030	0.541	2.284	3.458	1.880	1.523	10.882
1991	1.257	0.619	0.208	0.061	0.052	0.061	0.232	0.491	3.011	2.440	1.667	1.356	11.455
1992	1.704	0.895	0.270	0.084	0.080	0.058	2.033	1.362	1.414	5.057	2.753	1.122	16.832
1993	0.582	0.255	0.154	0.084	0.039	0.032	0.061	0.186	4.053	2.312	1.081	0.947	9.786
1994	0.670	0.326	0.166	0.084	0.035	0.030	0.047	0.511	0.954	1.817	1.773	1.267	7.680
1995	1.129	0.634	0.441	0.193	0.089	0.074	0.082	0.232	2.172	2.100	2.024	1.973	11.143
1996	1.561	0.960	0.551	0.229	0.080	0.037	0.069	0.365	2.383	1.445	1.192	0.870	9.742
1997	0.484	0.441	0.246	0.113	0.052	0.035	0.074	1.540	1.084	1.799	1.475	0.962	8.305
1998	0.578	0.528	0.409	0.180	0.060	0.022	0.188	0.333	0.820	1.237	2.680	2.053	9.088
1999	1.012	0.411	0.147	0.080	0.045	0.082	0.073	0.290	0.536	1.252	1.326	1.488	6.742
2000	0.960	0.400	0.141	0.058	0.032	0.017	0.052	1.014	0.781	3.376	3.727	2.349	12.907
2001	1.282	0.578	0.208	0.407	0.218	0.080	0.140	0.573	0.975	2.111	2.290	1.378	10.240
2002	0.772	0.424	0.188	0.080	0.037	0.134	0.119	0.246	0.273	0.359	1.308	1.287	5.227
2003	0.895	0.437	0.179	0.074	0.030	0.030	0.125	0.125	0.363	0.759	1.003	0.880	4.900
2004	1.079	0.582	0.203	0.112	0.061	0.032	1.043	1.049	1.862	1.503	2.081	1.453	11.060
2005	0.798	0.441	0.179	0.052	0.020	0.017	0.097	0.612	0.709	1.449	2.148	1.378	7.900
2006	0.753	0.437	0.216	0.084	0.080	0.076	0.169	0.768	1.933	2.569	2.249	1.330	10.664
2007	0.841	0.731	0.365	0.121	0.052	0.039	0.047	0.203	0.627	2.894	2.485	3.125	11.530
2008	1.568	1.205	0.571	0.154	0.052	0.022	0.024	0.363	1.533	1.540	1.696	1.575	10.303
2009	1.079	0.764	0.329	0.089	0.030	0.017	0.022	1.092	1.084	0.906	0.928	0.714	7.054

Monthly flows for Present Day

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.333	0.223	0.117	0.060	0.058	0.052	0.087	0.164	2.825	2.959	2.989	2.055	11.922
1921	1.021	0.400	0.147	0.089	0.069	0.061	0.052	0.258	2.242	1.472	2.016	1.415	9.242
1922	0.744	0.991	0.439	0.091	0.024	0.007	0.134	1.427	1.837	1.793	1.613	1.263	10.363
1923	0.789	0.943	0.416	0.087	0.017	0.007	0.017	0.043	2.059	1.160	1.784	1.324	8.646
1924	0.754	0.429	0.171	0.067	0.032	0.015	0.009	0.039	3.995	2.379	1.190	0.973	10.053
1925	0.739	0.454	0.184	0.052	0.020	0.015	0.015	0.387	0.627	1.644	1.546	1.181	6.864
1926	0.872	0.497	0.215	0.102	0.061	0.045	0.072	0.380	0.727	0.826	1.512	1.300	6.609
1927	0.753	0.596	0.318	0.134	0.061	0.054	0.046	0.059	2.328	1.787	1.667	1.793	9.596
1928	1.057	0.459	0.186	0.067	0.031	0.030	0.292	0.437	0.590	1.800	2.044	1.307	8.300
1929	0.692	0.321	0.195	0.110	0.072	0.073	0.072	0.124	0.216	0.423	1.039	2.014	5.351
1930	1.192	0.499	0.199	0.074	0.039	0.028	0.333	0.596	0.590	0.863	1.628	1.654	7.695
1931	1.478	0.731	0.247	0.121	0.102	0.073	0.046	0.432	0.750	1.666	1.420	1.466	8.532
1932	1.027	0.475	0.178	0.072	0.037	0.024	0.024	0.199	1.984	2.602	1.877	1.361	9.860
1933	0.921	0.448	0.154	0.054	0.037	0.030	0.024	0.240	0.657	0.753	0.980	1.163	5.461
1934	1.017	0.536	0.180	0.054	0.022	0.043	0.134	0.560	0.772	1.002	0.962	0.895	6.177
1935	0.620	0.467	0.229	0.149	0.091	0.069	0.060	0.426	0.519	1.334	1.631	1.296	6.891
1936	0.791	0.471	0.430	0.208	0.073	0.067	0.156	0.500	2.559	2.699	1.557	0.999	10.510
1937	0.676	0.357	0.143	0.087	0.060	0.045	0.111	0.675	0.692	0.803	1.185	1.512	6.346
1938	1.014	0.474	0.184	0.067	0.080	0.072	0.134	0.504	0.486	0.571	0.776	0.759	5.121
1939	0.504	0.270	0.126	0.054	0.091	0.080	0.335	0.595	1.196	1.280	1.117	1.004	6.652
1940	0.694	0.564	0.273	0.149	0.087	0.045	0.486	2.803	3.357	3.045	2.941	3.540	17.984
1941	1.751	0.597	0.253	0.124	0.060	0.037	0.059	0.493	3.647	2.000	1.535	1.181	11.737
1942	0.701	0.329	0.143	0.149	0.102	0.106	0.098	0.251	0.744	1.444	2.420	1.646	8.133
1943	0.951	0.534	0.230	0.089	0.039	0.035	0.060	0.395	3.774	2.582	2.693	1.950	13.332
1944	1.256	0.654	0.281	0.104	0.037	0.024	0.097	1.010	3.186	5.023	4.248	1.732	17.652
1945	0.876	0.506	0.208	0.076	0.037	0.061	0.076	0.238	0.395	0.878	1.401	1.783	6.535
1946	1.114	0.459	0.158	0.052	0.020	0.110	0.106	0.277	0.445	1.999	1.793	1.453	7.986
1947	1.018	0.507	0.184	0.065	0.030	0.065	0.087	0.506	0.805	1.338	1.516	2.411	8.532
1948	1.575	0.642	0.216	0.080	0.039	0.024	0.184	0.432	0.605	0.998	1.155	1.330	7.280
1949	0.977	0.794	0.379	0.121	0.045	0.022	0.358	0.277	0.335	3.073	1.691	1.203	9.275
1950	0.917	0.650	0.333	0.180	0.089	0.045	0.187	0.282	2.811	1.906	1.466	1.538	10.404
1951	1.229	0.923	0.394	0.106	0.037	0.032	0.050	0.508	0.542	0.967	1.252	1.129	7.169
1952	0.796	0.464	0.193	0.061	0.020	0.013	1.616	3.630	1.713	1.419	1.818	1.248	12.991
1953	0.720	0.409	0.177	0.065	0.035	0.050	0.186	2.939	2.371	4.471	4.062	1.905	17.390
1954	1.004	0.541	0.232	0.087	0.469	0.236	0.150	0.165	0.463	1.739	3.532	1.875	10.493
1955	1.207	0.699	0.269	0.098	0.047	0.074	0.106	0.645	1.694	1.650	1.769	1.315	9.573
1956	0.954	0.489	0.186	0.072	0.098	0.106	0.147	1.733	2.329	2.807	2.768	1.643	13.332
1957	1.713	0.857	0.223	0.058	0.074	0.083	0.136	0.842	0.828	0.655	1.451	1.073	7.993
1958	0.750	0.477	0.195	0.080	0.045	0.046	1.044	3.495	1.672	0.734	1.518	1.129	11.185
1959	0.795	0.418	0.150	0.054	0.028	0.050	0.074	0.335	1.434	1.039	0.760	0.835	5.972
1960	0.594	0.267	0.117	0.164	0.097	0.043	0.037	0.164	0.722	0.811	1.300	1.594	5.910
1961	1.079	0.467	0.154	0.065	0.043	0.061	0.356	0.322	3.599	2.096	3.022	1.718	12.982
1962	1.445	0.834	0.277	0.089	0.037	0.022	0.024	0.082	0.281	1.260	2.122	1.362	7.835
1963	0.709	0.362	0.186	0.082	0.097	0.080	0.080	0.162	1.176	1.412	1.910	1.337	7.593
1964	0.797	0.536	0.238	0.097	0.165	0.341	0.460	1.156	1.073	1.274	1.999	1.495	9.631
1965	0.955	0.489	0.295	0.147	0.067	0.215	0.299	0.400	1.824	3.662	2.651	1.846	12.850
1966	1.026	0.402	0.134	0.046	0.020	0.020	0.508	0.527	1.637	1.460	1.302	1.129	8.211
1967	0.884	0.519	0.202	0.089	0.067	0.043	0.132	0.826	1.319	2.100	2.111	1.252	9.544
1968	1.109	0.593	0.214	0.104	0.067	0.054	0.149	0.150	0.441	0.567	0.878	0.962	5.288
1969	0.969	0.542	0.180	0.052	0.028	0.020	0.015	0.616	1.282	1.748	1.996	1.438	8.886
1970	0.908	0.463	0.214	0.095	0.037	0.022	0.028	0.171	0.478	1.280	1.754	1.183	6.633
1971	0.655	0.325	0.132	0.072	0.074	0.074	0.214	0.887	0.900	0.846	0.917	0.826	5.922
1972	0.534	0.236	0.102	0.054	0.024	0.020	0.028	0.082	0.136	1.689	1.416	1.176	5.497
1973	0.789	0.372	0.156	0.067	0.032	0.022	0.017	0.352	1.103	1.056	5.513	2.851	12.330
1974	1.185	0.608	0.206	0.076	0.039	0.024	0.106	1.248	1.093	1.962	2.051	1.278	9.876
1975	0.828	0.476	0.184	0.052	0.020	0.037	0.098	0.415	3.156	2.619	1.426	1.174	10.485
1976	0.826	1.151	0.744	0.277	0.139	0.124	0.408	2.478	3.472	4.159	4.747	2.143	20.668
1977	0.804	0.370	0.169	0.082	0.050	0.061	0.097	0.184	0.240	0.448	1.490	1.442	5.437
1978	0.928	0.439	0.191	0.097	0.295	0.177	0.074	1.114	1.520	1.175	1.155	1.222	8.387
1979	1.376	0.707	0.202	0.069	0.052	0.035	0.126	0.783	1.377	1.077	1.220	0.945	7.969
1980	0.633	0.818	0.564	0.772	0.349	0.173	0.269	0.240	0.372	2.628	2.293	2.545	11.656
1981	1.326	0.469	0.184	0.091	0.045	0.030	0.243	0.333	0.828	0.846	0.965	0.779	6.139
1982	0.545	0.310	0.206	0.104	0.199	0.221	0.154	1.531	3.192	3.570	1.994	1.516	13.542
1983	0.944	0.385	0.136	0.054	0.028	0.043	0.134	2.264	1.438	1.414	1.196	1.622	9.658
1984	1.443	0.683	0.437	0.238	0.143	0.549	0.499	0.447	0.984	2.178	2.686	1.653	11.940
1985	0.968	0.478	0.171	0.054	0.046	0.141	0.210	0.269	1.356	1.683	3.149	1.801	10.326
1986	0.817	0.433	0.180	0.083	0.059	0.047	0.113	1.486	1.421	1.442	2.580	1.756	10.417
1987	0.868	0.359	0.178	0.083	0.028	0.020	0.229	0.426	0.690	1.077	1.460	1.285	6.703
1988	0.854	0.411	0.143	0.047	0.035	0.419	0.542	0.833	1.170	1.713	2.272	1.844	10.283
1989	1.324	0.706	0.255	0.087	0.095	0.067	0.738	0.826	1.535	2.589	1.756	1.040	11.018
1990	0.610	0.314	0.135	0.058	0.022	0.015	0.030	0.528	2.249	3.410	1.858	1.508	10.737
1991	1.244	0.617	0.206	0.059	0.050	0.061	0.230	0.482	2.970	2.408	1.647	1.341	11.315
1992	1.684	0.888	0.268	0.082	0.080	0.054	2.007	1.345	1.394	5.001	2.729	1.116	16.648
1993	0.582	0.253	0.150	0.084	0.039	0.030	0.061	0.184	4.010	2.284	1.066	0.938	9.681
1994	0.663	0.322	0.164	0.082	0.035	0.030	0.045	0.500	0.937	1.787	1.747	1.250	7.562
1995	1.114	0.627	0.434	0.191	0.087	0.072	0.080	0.228	2.137	2.068	1.996	1.949	10.983
1996	1.546	0.951	0.545	0.225	0.080	0.037	0.067	0.358	2.350	1.426	1.177	0.861	9.623
1997	0.478	0.434	0.240	0.111	0.050	0.035	0.072	1.516	1.065	1.771	1.456	0.953	8.181
1998	0.571	0.521	0.402	0.176	0.060	0.022	0.184	0.326	0.805	1.218	2.639	2.025	8.949
1999	1.005	0.407	0.143	0.080	0.043	0.082	0.073	0.284	0.527	1.230	1.304	1.466	6.644
2000	0.947	0.393	0.139	0.054	0.030	0.017	0.052	0.997	0.768	3.333	3.675	2.321	12.726
2001	1.275	0.574	0.206	0.396	0.214	0.076	0.136	0.564	0.958	2.078	2.255	1.363	10.095
2002	0.765	0.418	0.184	0.076	0.037	0.132	0.117	0.240	0.267	0.352	1.286	1.267	5.141
2003	0.884	0.430	0.177	0.072	0.030	0.030	0.121	0.121	0.356	0.744	0.983	0.865	4.813
2004	1.062	0.573	0.199	0.110	0.059	0.032	1.024	1.032	1.836	1.483	2.053	1.438	10.901
2005	0.791	0.439	0.177	0.050	0.020	0.017	0.095	0.601	0.698	1.427	2.113	1.361	7.789
2006	0.744	0.430	0.210	0.084	0.076	0.074	0.163	0.753	1.900	2.530	2.219	1.317	10.500
2007	0.834	0.724	0.359	0.119	0.052	0.039	0.045	0.199	0.616	2.851	2.450	3.082	11.370
2008	1.553	1.192	0.564	0.150	0.050	0.022	0.024	0.356	1.509	1.516	1.672	1.553	10.161
2009	1.066	0.753	0.325	0.087	0.030	0.017	0.020	1.072	1.065	0.893	0.909	0.705	6.942

Monthly flows for EWR Scenario 1

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.286	0.176	0.070	0.013	0.011	0.005	0.040	0.117	2.778	2.912	2.942	2.008	11.354
1921	0.974	0.353	0.100	0.042	0.022	0.014	0.005	0.211	2.195	1.425	1.969	1.368	8.674
1922	0.697	0.944	0.392	0.044	0.012	0.004	0.087	1.380	1.790	1.746	1.566	1.216	9.874
1923	0.742	0.896	0.369	0.040	0.009	0.004	0.009	0.022	2.012	1.113	1.737	1.277	8.225
1924	0.707	0.382	0.124	0.020	0.016	0.008	0.005	0.020	3.948	2.332	1.143	0.926	9.627
1925	0.692	0.407	0.137	0.005	0.010	0.008	0.008	0.340	0.580	1.597	1.499	1.134	6.413
1926	0.825	0.450	0.168	0.055	0.014	0.023	0.025	0.333	0.680	0.779	1.465	1.253	6.066
1927	0.706	0.549	0.271	0.087	0.014	0.007	0.023	0.012	2.281	1.740	1.620	1.746	9.052
1928	1.010	0.412	0.139	0.020	0.016	0.015	0.245	0.390	0.543	1.753	1.997	1.260	7.796
1929	0.645	0.274	0.148	0.063	0.025	0.026	0.025	0.077	0.169	0.376	0.992	1.967	4.783
1930	1.145	0.452	0.152	0.027	0.020	0.014	0.286	0.549	0.543	0.816	1.581	1.607	7.188
1931	1.431	0.684	0.200	0.074	0.055	0.026	0.023	0.385	0.703	1.619	1.373	1.419	7.988
1932	0.980	0.428	0.131	0.025	0.019	0.012	0.012	0.152	1.937	2.555	1.830	1.314	9.391
1933	0.874	0.401	0.107	0.007	0.019	0.015	0.012	0.193	0.610	0.706	0.933	1.116	4.989
1934	0.970	0.489	0.133	0.007	0.011	0.022	0.087	0.513	0.725	0.955	0.915	0.848	5.671
1935	0.573	0.420	0.182	0.102	0.044	0.022	0.013	0.379	0.472	1.287	1.584	1.249	6.323
1936	0.744	0.424	0.383	0.161	0.026	0.020	0.109	0.453	2.512	2.652	1.510	0.952	9.942
1937	0.629	0.310	0.096	0.040	0.013	0.023	0.064	0.628	0.645	0.756	1.138	1.465	5.803
1938	0.967	0.427	0.137	0.020	0.033	0.025	0.087	0.457	0.439	0.524	0.729	0.712	4.553
1939	0.457	0.223	0.079	0.007	0.044	0.033	0.288	0.548	1.149	1.233	1.070	0.957	6.084
1940	0.647	0.517	0.226	0.102	0.040	0.023	0.439	2.756	3.310	2.998	2.894	3.493	17.441
1941	1.704	0.550	0.206	0.077	0.013	0.019	0.012	0.446	3.600	1.953	1.488	1.134	11.198
1942	0.654	0.282	0.096	0.102	0.055	0.059	0.051	0.204	0.697	1.397	2.373	1.599	7.565
1943	0.904	0.487	0.183	0.042	0.020	0.018	0.013	0.348	3.727	2.535	2.646	1.903	12.822
1944	1.209	0.607	0.234	0.057	0.019	0.012	0.050	0.963	3.139	4.976	4.201	1.685	17.148
1945	0.829	0.459	0.161	0.029	0.019	0.014	0.029	0.191	0.348	0.831	1.354	1.736	5.996
1946	1.067	0.412	0.111	0.005	0.010	0.063	0.059	0.230	0.398	1.952	1.746	1.406	7.455
1947	0.971	0.460	0.137	0.018	0.015	0.018	0.040	0.459	0.758	1.291	1.469	2.364	7.996
1948	1.528	0.595	0.169	0.033	0.020	0.012	0.137	0.385	0.558	0.951	1.108	1.283	6.775
1949	0.930	0.747	0.332	0.074	0.023	0.011	0.311	0.230	0.288	3.026	1.644	1.156	8.768
1950	0.870	0.603	0.286	0.133	0.042	0.023	0.140	0.235	2.764	1.859	1.419	1.491	9.861
1951	1.182	0.876	0.347	0.059	0.019	0.016	0.003	0.461	0.495	0.920	1.205	1.082	6.661
1952	0.749	0.417	0.146	0.014	0.010	0.007	1.569	3.583	1.666	1.372	1.771	1.201	12.501
1953	0.673	0.362	0.130	0.018	0.018	0.003	0.139	2.892	2.324	4.424	4.015	1.858	16.852
1954	0.957	0.494	0.185	0.040	0.422	0.189	0.103	0.118	0.416	1.692	3.485	1.828	9.925
1955	1.160	0.652	0.222	0.051	0.024	0.027	0.059	0.598	1.647	1.603	1.722	1.268	9.029
1956	0.907	0.442	0.139	0.025	0.051	0.059	0.100	1.686	2.282	2.760	2.721	1.596	12.764
1957	1.666	0.810	0.176	0.011	0.027	0.036	0.089	0.795	0.781	0.608	1.404	1.026	7.425
1958	0.703	0.430	0.148	0.033	0.023	0.023	0.997	3.448	1.625	0.687	1.471	1.082	10.666
1959	0.748	0.371	0.103	0.007	0.014	0.003	0.027	0.288	1.387	0.992	0.713	0.788	5.437
1960	0.547	0.220	0.070	0.117	0.050	0.022	0.019	0.117	0.675	0.764	1.253	1.547	5.397
1961	1.032	0.420	0.107	0.018	0.022	0.014	0.309	0.275	3.552	2.049	2.975	1.671	12.440
1962	1.398	0.787	0.230	0.042	0.019	0.011	0.012	0.035	0.234	1.213	2.075	1.315	7.367
1963	0.662	0.315	0.139	0.035	0.050	0.033	0.033	0.115	1.129	1.365	1.863	1.290	7.025
1964	0.750	0.489	0.191	0.050	0.118	0.294	0.413	1.109	1.026	1.227	1.952	1.448	9.063
1965	0.908	0.442	0.248	0.100	0.020	0.168	0.252	0.353	1.777	3.615	2.604	1.799	12.282
1966	0.979	0.355	0.087	0.023	0.010	0.010	0.461	0.480	1.590	1.413	1.255	1.082	7.742
1967	0.837	0.472	0.155	0.042	0.020	0.022	0.085	0.779	1.272	2.053	2.064	1.205	9.002
1968	1.062	0.546	0.167	0.057	0.020	0.007	0.102	0.103	0.394	0.520	0.831	0.915	4.720
1969	0.922	0.495	0.133	0.005	0.014	0.010	0.008	0.569	1.235	1.701	1.949	1.391	8.428
1970	0.861	0.416	0.167	0.048	0.019	0.011	0.014	0.124	0.431	1.233	1.707	1.136	6.163
1971	0.608	0.278	0.085	0.025	0.027	0.027	0.167	0.840	0.853	0.799	0.870	0.779	5.354
1972	0.487	0.189	0.055	0.007	0.012	0.010	0.014	0.035	0.089	1.642	1.369	1.129	5.035
1973	0.742	0.325	0.109	0.020	0.016	0.011	0.009	0.305	1.056	1.009	5.466	2.804	11.868
1974	1.138	0.561	0.159	0.029	0.020	0.012	0.059	1.201	1.046	1.915	2.004	1.231	9.371
1975	0.781	0.429	0.137	0.005	0.010	0.019	0.051	0.368	3.109	2.572	1.379	1.127	9.983
1976	0.779	1.104	0.697	0.230	0.092	0.077	0.361	2.431	3.425	4.112	4.700	2.096	20.100
1977	0.757	0.323	0.122	0.035	0.003	0.014	0.050	0.137	0.193	0.401	1.443	1.395	4.869
1978	0.881	0.392	0.144	0.050	0.248	0.130	0.027	1.067	1.473	1.128	1.108	1.175	7.819
1979	1.329	0.660	0.155	0.022	0.005	0.018	0.079	0.736	1.330	1.030	1.173	0.898	7.431
1980	0.586	0.771	0.517	0.725	0.302	0.126	0.222	0.193	0.325	2.581	2.246	2.498	11.088
1981	1.279	0.422	0.137	0.044	0.023	0.015	0.196	0.286	0.781	0.799	0.918	0.732	5.628
1982	0.498	0.263	0.159	0.057	0.152	0.174	0.107	1.484	3.145	3.523	1.947	1.469	12.974
1983	0.897	0.338	0.089	0.007	0.014	0.022	0.087	2.217	1.391	1.367	1.149	1.575	9.149
1984	1.396	0.636	0.390	0.191	0.096	0.502	0.452	0.400	0.937	2.131	2.639	1.606	11.372
1985	0.921	0.431	0.124	0.007	0.023	0.094	0.163	0.222	1.309	1.636	3.102	1.754	9.782
1986	0.770	0.386	0.133	0.036	0.012	0.024	0.066	1.439	1.374	1.395	2.533	1.709	9.873
1987	0.821	0.312	0.131	0.036	0.014	0.010	0.182	0.379	0.643	1.030	1.413	1.238	6.206
1988	0.807	0.364	0.096	0.024	0.018	0.372	0.495	0.786	1.123	1.666	2.225	1.797	9.769
1989	1.277	0.659	0.208	0.040	0.048	0.020	0.691	0.779	1.488	2.542	1.709	0.993	10.450
1990	0.563	0.267	0.088	0.011	0.011	0.008	0.015	0.481	2.202	3.363	1.811	1.461	10.277
1991	1.197	0.570	0.159	0.012	0.003	0.014	0.183	0.435	2.923	2.361	1.600	1.294	10.747
1992	1.637	0.841	0.221	0.035	0.033	0.007	1.960	1.298	1.347	4.954	2.682	1.069	16.080
1993	0.535	0.206	0.103	0.037	0.020	0.015	0.014	0.137	3.963	2.237	1.019	0.891	9.173
1994	0.616	0.275	0.117	0.035	0.018	0.015	0.023	0.453	0.890	1.740	1.700	1.203	7.081
1995	1.067	0.580	0.387	0.144	0.040	0.025	0.033	0.181	2.090	2.021	1.949	1.902	10.415
1996	1.499	0.904	0.498	0.178	0.033	0.019	0.020	0.311	2.303	1.379	1.130	0.814	9.084
1997	0.431	0.387	0.193	0.064	0.003	0.018	0.025	1.469	1.018	1.724	1.409	0.906	7.643
1998	0.524	0.474	0.355	0.129	0.013	0.011	0.137	0.279	0.758	1.171	2.592	1.978	8.417
1999	0.958	0.360	0.096	0.033	0.022	0.035	0.026	0.237	0.480	1.183	1.257	1.419	6.102
2000	0.900	0.346	0.092	0.007	0.015	0.009	0.005	0.950	0.721	3.286	3.628	2.274	12.229
2001	1.228	0.527	0.159	0.349	0.167	0.029	0.089	0.517	0.911	2.031	2.208	1.316	9.527
2002	0.718	0.371	0.137	0.029	0.019	0.085	0.070	0.193	0.220	0.305	1.239	1.220	4.602
2003	0.837	0.383	0.130	0.025	0.015	0.015	0.074	0.074	0.309	0.697	0.936	0.818	4.310
2004	1.015	0.526	0.152	0.063	0.012	0.016	0.977	0.985	1.789	1.436	2.006	1.391	10.364
2005	0.744	0.392	0.130	0.003	0.010	0.009	0.048	0.554	0.651	1.380	2.066	1.314	7.297
2006	0.697	0.383	0.163	0.037	0.029	0.027	0.116	0.706	1.853	2.483	2.172	1.270	9.932
2007	0.787	0.677	0.312	0.072	0.005	0.020	0.023	0.152	0.569	2.804	2.403	3.035	10.855
2008	1.506	1.145	0.517	0.103	0.003	0.011	0.012	0.309	1.462	1.469	1.625	1.506	9.665
2009	1.019	0.706	0.278	0.040	0.015	0.009	0.010	1.025	1.018	0.846	0.862	0.658	6.482

Monthly flows for EWR Scenario 2

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.254	0.144	0.038	0.020	0.019	0.017	0.008	0.085	2.746	2.880	2.910	1.976	11.099
1921	0.942	0.321	0.068	0.010	0.023	0.020	0.017	0.179	2.163	1.393	1.937	1.336	8.411
1922	0.665	0.912	0.360	0.012	0.008	0.002	0.055	1.348	1.758	1.714	1.534	1.184	9.553
1923	0.710	0.864	0.337	0.008	0.006	0.002	0.006	0.014	1.980	1.081	1.705	1.245	7.959
1924	0.675	0.350	0.092	0.022	0.011	0.005	0.003	0.013	3.916	2.300	1.111	0.894	9.393
1925	0.660	0.375	0.105	0.017	0.007	0.005	0.005	0.308	0.548	1.565	1.467	1.102	6.165
1926	0.793	0.418	0.136	0.023	0.020	0.015	0.024	0.301	0.648	0.747	1.433	1.221	5.780
1927	0.674	0.517	0.239	0.055	0.020	0.018	0.015	0.020	2.249	1.708	1.588	1.714	8.818
1928	0.978	0.380	0.107	0.022	0.010	0.010	0.213	0.358	0.511	1.721	1.965	1.228	7.505
1929	0.613	0.242	0.116	0.031	0.024	0.024	0.024	0.045	0.137	0.344	0.960	1.935	4.496
1930	1.113	0.420	0.120	0.025	0.013	0.009	0.254	0.517	0.511	0.784	1.549	1.575	6.891
1931	1.399	0.652	0.168	0.042	0.023	0.024	0.015	0.353	0.671	1.587	1.341	1.387	7.664
1932	0.948	0.396	0.099	0.024	0.012	0.008	0.008	0.120	1.905	2.523	1.798	1.282	9.124
1933	0.842	0.369	0.075	0.018	0.012	0.010	0.008	0.161	0.578	0.674	0.901	1.084	4.733
1934	0.938	0.457	0.101	0.018	0.007	0.014	0.055	0.481	0.693	0.923	0.883	0.816	5.388
1935	0.541	0.388	0.150	0.070	0.012	0.023	0.020	0.347	0.440	1.255	1.552	1.217	6.016
1936	0.712	0.392	0.351	0.129	0.024	0.022	0.077	0.421	2.480	2.620	1.478	0.920	9.628
1937	0.597	0.278	0.064	0.008	0.020	0.015	0.032	0.596	0.613	0.724	1.106	1.433	5.487
1938	0.935	0.395	0.105	0.022	0.001	0.024	0.055	0.425	0.407	0.492	0.697	0.680	4.239
1939	0.425	0.191	0.047	0.018	0.012	0.001	0.256	0.516	1.117	1.201	1.038	0.925	5.748
1940	0.615	0.485	0.194	0.070	0.008	0.015	0.407	2.724	3.278	2.966	2.862	3.461	17.086
1941	1.672	0.518	0.174	0.045	0.020	0.012	0.020	0.414	3.568	1.921	1.456	1.102	10.923
1942	0.622	0.250	0.064	0.070	0.023	0.027	0.019	0.172	0.665	1.365	2.341	1.567	7.186
1943	0.872	0.455	0.151	0.010	0.013	0.012	0.020	0.316	3.695	2.503	2.614	1.871	12.533
1944	1.177	0.575	0.202	0.025	0.012	0.008	0.018	0.931	3.107	4.944	4.169	1.653	16.822
1945	0.797	0.427	0.129	0.025	0.012	0.020	0.025	0.159	0.316	0.799	1.322	1.704	5.737
1946	1.035	0.380	0.079	0.017	0.007	0.031	0.027	0.198	0.366	1.920	1.714	1.374	7.149
1947	0.939	0.428	0.105	0.022	0.010	0.022	0.008	0.427	0.726	1.259	1.437	2.332	7.715
1948	1.496	0.563	0.137	0.001	0.013	0.008	0.105	0.353	0.526	0.919	1.076	1.251	6.449
1949	0.898	0.715	0.300	0.042	0.015	0.007	0.279	0.198	0.256	2.994	1.612	1.124	8.441
1950	0.838	0.571	0.254	0.101	0.010	0.015	0.108	0.203	2.732	1.827	1.387	1.459	9.506
1951	1.150	0.844	0.315	0.027	0.012	0.011	0.017	0.429	0.463	0.888	1.173	1.050	6.380
1952	0.717	0.385	0.114	0.020	0.007	0.004	1.537	3.551	1.634	1.340	1.739	1.169	12.218
1953	0.641	0.330	0.098	0.022	0.012	0.017	0.107	2.860	2.292	4.392	3.983	1.826	16.580
1954	0.925	0.462	0.153	0.008	0.390	0.157	0.071	0.086	0.384	1.660	3.453	1.796	9.546
1955	1.128	0.620	0.190	0.019	0.016	0.025	0.027	0.566	1.615	1.571	1.690	1.236	8.703
1956	0.875	0.410	0.107	0.024	0.019	0.027	0.068	1.654	2.250	2.728	2.689	1.564	12.416
1957	1.634	0.778	0.144	0.019	0.025	0.004	0.057	0.763	0.749	0.576	1.372	0.994	7.116
1958	0.671	0.398	0.116	0.001	0.015	0.015	0.965	3.416	1.593	0.655	1.439	1.050	10.335
1959	0.716	0.339	0.071	0.018	0.009	0.017	0.025	0.256	1.355	0.960	0.681	0.756	5.204
1960	0.515	0.188	0.038	0.085	0.018	0.014	0.012	0.085	0.643	0.732	1.221	1.515	5.068
1961	1.000	0.388	0.075	0.022	0.014	0.020	0.277	0.243	3.520	2.017	2.943	1.639	12.159
1962	1.366	0.755	0.198	0.010	0.012	0.007	0.008	0.003	0.202	1.181	2.043	1.283	7.070
1963	0.630	0.283	0.107	0.003	0.018	0.001	0.001	0.083	1.097	1.333	1.831	1.258	6.646
1964	0.718	0.457	0.159	0.018	0.086	0.262	0.381	1.077	0.994	1.195	1.920	1.416	8.684
1965	0.876	0.410	0.216	0.068	0.022	0.136	0.220	0.321	1.745	3.583	2.572	1.767	11.937
1966	0.947	0.323	0.055	0.015	0.007	0.007	0.429	0.448	1.558	1.381	1.223	1.050	7.444
1967	0.805	0.440	0.123	0.010	0.022	0.014	0.053	0.747	1.240	2.021	2.032	1.173	8.682
1968	1.030	0.514	0.135	0.025	0.022	0.018	0.070	0.071	0.362	0.488	0.799	0.883	4.418
1969	0.890	0.463	0.101	0.017	0.009	0.007	0.005	0.537	1.203	1.669	1.917	1.359	8.178
1970	0.829	0.384	0.135	0.016	0.012	0.007	0.009	0.092	0.399	1.201	1.675	1.104	5.865
1971	0.576	0.246	0.053	0.024	0.025	0.025	0.135	0.808	0.821	0.767	0.838	0.747	5.065
1972	0.455	0.157	0.023	0.018	0.008	0.007	0.009	0.003	0.057	1.610	1.337	1.097	4.782
1973	0.710	0.293	0.077	0.022	0.011	0.007	0.006	0.273	1.024	0.977	5.434	2.772	11.607
1974	1.106	0.529	0.127	0.025	0.013	0.008	0.027	1.169	1.014	1.883	1.972	1.199	9.073
1975	0.749	0.397	0.105	0.017	0.007	0.012	0.019	0.336	3.077	2.540	1.347	1.095	9.702
1976	0.747	1.072	0.665	0.198	0.060	0.045	0.329	2.399	3.393	4.080	4.668	2.064	19.721
1977	0.725	0.291	0.090	0.003	0.017	0.020	0.018	0.105	0.161	0.369	1.411	1.363	4.574
1978	0.849	0.360	0.112	0.018	0.216	0.098	0.025	1.035	1.441	1.096	1.076	1.143	7.470
1979	1.297	0.628	0.123	0.023	0.017	0.012	0.047	0.704	1.298	0.998	1.141	0.866	7.155
1980	0.554	0.739	0.485	0.693	0.270	0.094	0.190	0.161	0.293	2.549	2.214	2.466	10.709
1981	1.247	0.390	0.105	0.012	0.015	0.010	0.164	0.254	0.749	0.767	0.886	0.700	5.300
1982	0.466	0.231	0.127	0.025	0.120	0.142	0.075	1.452	3.113	3.491	1.915	1.437	12.595
1983	0.865	0.306	0.057	0.018	0.009	0.014	0.055	2.185	1.359	1.335	1.117	1.543	8.865
1984	1.364	0.604	0.358	0.159	0.064	0.470	0.420	0.368	0.905	2.099	2.607	1.574	10.993
1985	0.889	0.399	0.092	0.018	0.015	0.062	0.131	0.190	1.277	1.604	3.070	1.722	9.470
1986	0.738	0.354	0.101	0.004	0.020	0.016	0.034	1.407	1.342	1.363	2.501	1.677	9.557
1987	0.789	0.280	0.099	0.004	0.009	0.007	0.150	0.347	0.611	0.998	1.381	1.206	5.882
1988	0.775	0.332	0.064	0.016	0.012	0.340	0.463	0.754	1.091	1.634	2.193	1.765	9.439
1989	1.245	0.627	0.176	0.008	0.016	0.022	0.659	0.747	1.456	2.510	1.677	0.961	10.105
1990	0.531	0.235	0.056	0.019	0.007	0.005	0.010	0.449	2.170	3.331	1.779	1.429	10.023
1991	1.165	0.538	0.127	0.020	0.017	0.020	0.151	0.403	2.891	2.329	1.568	1.262	10.492
1992	1.605	0.809	0.189	0.003	0.001	0.018	1.928	1.266	1.315	4.922	2.650	1.037	15.744
1993	0.503	0.174	0.071	0.005	0.013	0.010	0.020	0.105	3.931	2.205	0.987	0.859	8.884
1994	0.584	0.243	0.085	0.003	0.012	0.010	0.015	0.421	0.858	1.708	1.668	1.171	6.779
1995	1.035	0.548	0.355	0.112	0.008	0.024	0.001	0.149	2.058	1.989	1.917	1.870	10.067
1996	1.467	0.872	0.466	0.146	0.001	0.012	0.022	0.279	2.271	1.347	1.098	0.782	8.765
1997	0.399	0.355	0.161	0.032	0.017	0.012	0.024	1.437	0.986	1.692	1.377	0.874	7.366
1998	0.492	0.442	0.323	0.097	0.020	0.007	0.105	0.247	0.726	1.139	2.560	1.946	8.105
1999	0.926	0.328	0.064	0.001	0.014	0.003	0.024	0.205	0.448	1.151	1.225	1.387	5.778
2000	0.868	0.314	0.060	0.018	0.010	0.006	0.017	0.918	0.689	3.254	3.596	2.242	11.993
2001	1.196	0.495	0.127	0.317	0.135	0.025	0.057	0.485	0.879	1.999	2.176	1.284	9.176
2002	0.686	0.339	0.105	0.025	0.012	0.053	0.038	0.161	0.188	0.273	1.207	1.188	4.277
2003	0.805	0.351	0.098	0.024	0.010	0.010	0.042	0.042	0.277	0.665	0.904	0.786	4.015
2004	0.983	0.494	0.120	0.031	0.020	0.011	0.945	0.953	1.757	1.404	1.974	1.359	10.051
2005	0.712	0.360	0.098	0.017	0.007	0.006	0.016	0.522	0.619	1.348	2.034	1.282	7.021
2006	0.665	0.351	0.131	0.005	0.025	0.025	0.084	0.674	1.821	2.451	2.140	1.238	9.611
2007	0.755	0.645	0.280	0.040	0.017	0.013	0.015	0.120	0.537	2.772	2.371	3.003	10.569
2008	1.474	1.113	0.485	0.071	0.017	0.007	0.008	0.277	1.430	1.437	1.593	1.474	9.387
2009	0.987	0.674	0.246	0.008	0.010	0.006	0.007	0.993	0.986	0.814	0.830	0.626	6.187

Monthly flows for EWR Scenario 3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.223	0.113	0.007	0.015	0.015	0.013	0.022	0.054	2.715	2.849	2.879	1.945	10.846
1921	0.911	0.290	0.037	0.022	0.017	0.015	0.013	0.148	2.132	1.362	1.906	1.305	8.155
1922	0.634	0.881	0.329	0.023	0.006	0.002	0.024	1.317	1.727	1.683	1.503	1.153	9.277
1923	0.679	0.833	0.306	0.022	0.004	0.002	0.004	0.011	1.949	1.050	1.674	1.214	7.745
1924	0.644	0.319	0.061	0.017	0.008	0.004	0.002	0.010	3.885	2.269	1.080	0.863	9.158
1925	0.629	0.344	0.074	0.013	0.005	0.004	0.004	0.277	0.517	1.534	1.436	1.071	5.904
1926	0.762	0.387	0.105	0.026	0.015	0.011	0.018	0.270	0.617	0.716	1.402	1.190	5.515
1927	0.643	0.486	0.208	0.024	0.015	0.014	0.012	0.015	2.218	1.677	1.557	1.683	8.547
1928	0.947	0.349	0.076	0.017	0.008	0.008	0.182	0.327	0.480	1.690	1.934	1.197	7.210
1929	0.582	0.211	0.085	0.028	0.018	0.018	0.018	0.014	0.106	0.313	0.929	1.904	4.222
1930	1.082	0.389	0.089	0.019	0.010	0.007	0.223	0.486	0.480	0.753	1.518	1.544	6.595
1931	1.368	0.621	0.137	0.011	0.026	0.018	0.012	0.322	0.640	1.556	1.310	1.356	7.372
1932	0.917	0.365	0.068	0.018	0.009	0.006	0.006	0.089	1.874	2.492	1.767	1.251	8.859
1933	0.811	0.338	0.044	0.014	0.009	0.008	0.006	0.130	0.547	0.643	0.870	1.053	4.469
1934	0.907	0.426	0.070	0.014	0.006	0.011	0.024	0.450	0.662	0.892	0.852	0.785	5.094
1935	0.510	0.357	0.119	0.039	0.023	0.017	0.015	0.316	0.409	1.224	1.521	1.186	5.732
1936	0.681	0.361	0.320	0.098	0.018	0.017	0.046	0.390	2.449	2.589	1.447	0.889	9.300
1937	0.566	0.247	0.033	0.022	0.015	0.011	0.001	0.565	0.582	0.693	1.075	1.402	5.208
1938	0.904	0.364	0.074	0.017	0.020	0.018	0.024	0.394	0.376	0.461	0.666	0.649	3.963
1939	0.394	0.160	0.016	0.014	0.023	0.020	0.225	0.485	1.086	1.170	1.007	0.894	5.489
1940	0.584	0.454	0.163	0.039	0.022	0.011	0.376	2.693	3.247	2.935	2.831	3.430	16.780
1941	1.641	0.487	0.143	0.014	0.015	0.009	0.015	0.383	3.537	1.890	1.425	1.071	10.626
1942	0.591	0.219	0.033	0.039	0.026	0.027	0.025	0.141	0.634	1.334	2.310	1.536	6.909
1943	0.841	0.424	0.120	0.022	0.010	0.009	0.015	0.285	3.664	2.472	2.583	1.840	12.281
1944	1.146	0.544	0.171	0.026	0.009	0.006	0.024	0.900	3.076	4.913	4.138	1.622	16.572
1945	0.766	0.396	0.098	0.019	0.009	0.015	0.019	0.128	0.285	0.768	1.291	1.673	5.464
1946	1.004	0.349	0.048	0.013	0.005	0.028	0.027	0.167	0.335	1.889	1.683	1.343	6.886
1947	0.908	0.397	0.074	0.016	0.008	0.016	0.022	0.396	0.695	1.228	1.406	2.301	7.463
1948	1.465	0.532	0.106	0.020	0.010	0.006	0.074	0.322	0.495	0.888	1.045	1.220	6.179
1949	0.867	0.684	0.269	0.011	0.011	0.006	0.248	0.167	0.225	2.963	1.581	1.093	8.120
1950	0.807	0.540	0.223	0.070	0.022	0.011	0.077	0.172	2.701	1.796	1.356	1.428	9.199
1951	1.119	0.813	0.284	0.027	0.009	0.008	0.013	0.398	0.432	0.857	1.142	1.019	6.117
1952	0.686	0.354	0.083	0.015	0.005	0.003	1.506	3.520	1.603	1.309	1.708	1.138	11.926
1953	0.610	0.299	0.067	0.016	0.009	0.013	0.076	2.829	2.261	4.361	3.952	1.795	16.283
1954	0.894	0.431	0.122	0.022	0.359	0.126	0.040	0.055	0.353	1.629	3.422	1.765	9.213
1955	1.097	0.589	0.159	0.025	0.012	0.019	0.027	0.535	1.584	1.540	1.659	1.205	8.446
1956	0.844	0.379	0.076	0.018	0.025	0.027	0.037	1.623	2.219	2.697	2.658	1.533	12.131
1957	1.603	0.747	0.113	0.015	0.019	0.021	0.026	0.732	0.718	0.545	1.341	0.963	6.838
1958	0.640	0.367	0.085	0.020	0.011	0.012	0.934	3.385	1.562	0.624	1.408	1.019	10.063
1959	0.685	0.308	0.040	0.014	0.007	0.013	0.019	0.225	1.324	0.929	0.650	0.725	4.934
1960	0.484	0.157	0.007	0.054	0.024	0.011	0.009	0.054	0.612	0.701	1.190	1.484	4.783
1961	0.969	0.357	0.044	0.016	0.011	0.015	0.246	0.212	3.489	1.986	2.912	1.608	11.861
1962	1.335	0.724	0.167	0.022	0.009	0.006	0.006	0.021	0.171	1.150	2.012	1.252	6.871
1963	0.599	0.252	0.076	0.021	0.024	0.020	0.020	0.052	1.066	1.302	1.800	1.227	6.455
1964	0.687	0.426	0.128	0.024	0.055	0.231	0.350	1.046	0.963	1.164	1.889	1.385	8.343
1965	0.845	0.379	0.185	0.037	0.017	0.105	0.189	0.290	1.714	3.552	2.541	1.736	11.585
1966	0.916	0.292	0.024	0.012	0.005	0.005	0.398	0.417	1.527	1.350	1.192	1.019	7.152
1967	0.774	0.409	0.092	0.022	0.017	0.011	0.022	0.716	1.209	1.990	2.001	1.142	8.401
1968	0.999	0.483	0.104	0.026	0.017	0.014	0.039	0.040	0.331	0.457	0.768	0.852	4.125
1969	0.859	0.432	0.070	0.013	0.007	0.005	0.004	0.506	1.172	1.638	1.886	1.328	7.916
1970	0.798	0.353	0.104	0.024	0.009	0.006	0.007	0.061	0.368	1.170	1.644	1.073	5.613
1971	0.545	0.215	0.022	0.018	0.019	0.019	0.104	0.777	0.790	0.736	0.807	0.716	4.763
1972	0.424	0.126	0.026	0.014	0.006	0.005	0.007	0.021	0.026	1.579	1.306	1.066	4.602
1973	0.679	0.262	0.046	0.017	0.008	0.006	0.004	0.242	0.993	0.946	5.403	2.741	11.343
1974	1.075	0.498	0.096	0.019	0.010	0.006	0.027	1.138	0.983	1.852	1.941	1.168	8.809
1975	0.718	0.366	0.074	0.013	0.005	0.009	0.025	0.305	3.046	2.509	1.316	1.064	9.446
1976	0.716	1.041	0.634	0.167	0.029	0.014	0.298	2.368	3.362	4.049	4.637	2.033	19.343
1977	0.694	0.260	0.059	0.021	0.013	0.015	0.024	0.074	0.130	0.338	1.380	1.332	4.336
1978	0.818	0.329	0.081	0.024	0.185	0.067	0.019	1.004	1.410	1.065	1.045	1.112	7.154
1979	1.266	0.597	0.092	0.017	0.013	0.009	0.016	0.673	1.267	0.967	1.110	0.835	6.858
1980	0.523	0.708	0.454	0.662	0.239	0.063	0.159	0.130	0.262	2.518	2.183	2.435	10.331
1981	1.216	0.359	0.074	0.023	0.011	0.008	0.133	0.223	0.718	0.736	0.855	0.669	5.020
1982	0.435	0.200	0.096	0.026	0.089	0.111	0.044	1.421	3.082	3.460	1.884	1.406	12.249
1983	0.834	0.275	0.026	0.014	0.007	0.011	0.024	2.154	1.328	1.304	1.086	1.512	8.570
1984	1.333	0.573	0.327	0.128	0.033	0.439	0.389	0.337	0.874	2.068	2.576	1.543	10.615
1985	0.858	0.368	0.061	0.014	0.012	0.031	0.100	0.159	1.246	1.573	3.039	1.691	9.146
1986	0.707	0.323	0.070	0.021	0.015	0.012	0.003	1.376	1.311	1.332	2.470	1.646	9.281
1987	0.758	0.249	0.068	0.021	0.007	0.005	0.119	0.316	0.580	0.967	1.350	1.175	5.611
1988	0.744	0.301	0.033	0.012	0.009	0.309	0.432	0.723	1.060	1.603	2.162	1.734	9.117
1989	1.214	0.596	0.145	0.022	0.024	0.017	0.628	0.716	1.425	2.479	1.646	0.930	9.837
1990	0.500	0.204	0.025	0.015	0.006	0.004	0.008	0.418	2.139	3.300	1.748	1.398	9.760
1991	1.134	0.507	0.096	0.015	0.013	0.015	0.120	0.372	2.860	2.298	1.537	1.231	10.193
1992	1.574	0.778	0.158	0.021	0.020	0.014	1.897	1.235	1.284	4.891	2.619	1.006	15.492
1993	0.472	0.143	0.040	0.021	0.010	0.008	0.015	0.074	3.900	2.174	0.956	0.828	8.637
1994	0.553	0.212	0.054	0.021	0.009	0.008	0.011	0.390	0.827	1.677	1.637	1.140	6.534
1995	1.004	0.517	0.324	0.081	0.022	0.018	0.020	0.118	2.027	1.958	1.886	1.839	9.810
1996	1.436	0.841	0.435	0.115	0.020	0.009	0.017	0.248	2.240	1.316	1.067	0.751	8.491
1997	0.368	0.324	0.130	0.001	0.013	0.009	0.018	1.406	0.955	1.661	1.346	0.843	7.069
1998	0.461	0.411	0.292	0.066	0.015	0.006	0.074	0.216	0.695	1.108	2.529	1.915	7.783
1999	0.895	0.297	0.033	0.020	0.011	0.021	0.018	0.174	0.417	1.120	1.194	1.356	5.552
2000	0.837	0.283	0.029	0.014	0.008	0.004	0.013	0.887	0.658	3.223	3.565	2.211	11.728
2001	1.165	0.464	0.096	0.286	0.104	0.019	0.026	0.454	0.848	1.968	2.145	1.253	8.823
2002	0.655	0.308	0.074	0.019	0.009	0.022	0.007	0.130	0.157	0.242	1.176	1.157	3.952
2003	0.774	0.320	0.067	0.018	0.008	0.008	0.011	0.011	0.246	0.634	0.873	0.755	3.720
2004	0.952	0.463	0.089	0.028	0.015	0.008	0.914	0.922	1.726	1.373	1.943	1.328	9.756
2005	0.681	0.329	0.067	0.013	0.005	0.004	0.024	0.491	0.588	1.317	2.003	1.251	6.769
2006	0.634	0.320	0.100	0.021	0.019	0.019	0.053	0.643	1.790	2.420	2.109	1.207	9.330
2007	0.724	0.614	0.249	0.009	0.013	0.010	0.011	0.089	0.506	2.741	2.340	2.972	10.274
2008	1.443	1.082	0.454	0.040	0.013	0.006	0.006	0.246	1.399	1.406	1.562	1.443	9.095
2009	0.956	0.643	0.215	0.022	0.008	0.004	0.005	0.962	0.955	0.783	0.799	0.595	5.943

2 APPENDIX 2. RDM STUDY FOR THE ONRUS ESTUARY

2.1 Introduction

This RDM report forms part of a larger study to undertake the Classification of and determine the Resource Quality Objectives for significant water resources within the Breede-Gouritz Water Management Area (BGWMA, i.e. the Water Resources Classification System (WRCS) as prescribed by Regulation 810 in terms of section 12(1) of the National Water Act (1998)). The WRCS is a step-wise process whereby water resources are categorized according to specific classes that represent a management vision of a particular catchment by taking into account the current state of the water resource and defining the ecological, social and economic aspects that are dependent on the resource. The resulting WRC classes are then used to set specific Resource Quality Objectives (RQOs) which are numerical and/or narrative descriptive statements of conditions which should be met in the receiving water resources in order to ensure that the water resource is protected. A detailed understanding of the links between the quantity and quality of freshwater that an estuary receives is required to establish the RQOs for that particular system. A system for determining the ecological water requirements for estuaries (and hence links between the quantity and quality of freshwater that an estuary receives) has been developed, termed the "Methods for the Determination of the Ecological Reserve for Estuaries" the most recent version of which was published in 2012 (DWA 2012). This process includes determining the Present Ecological Status (current health state) of the system, the Recommended Ecological Category (REC, a desired future health state that will allow for protection and management of the resource), and the quantity and quality of freshwater inflows and other conditions required to maintain the system in the REC, and implications of a range of alternative flow scenarios.

Reserve determination (or RDM) studies have been completed for all of the significant estuaries within the BGWMA apart from Onrus and Rooiels estuaries. This study was thus undertaken by a team of experts to determine the Ecological Reserve for the Onrus estuary as a necessary input to the Classification process (Table 2.1).

Table 2.1. Project team

Specialist	Affiliation	Area of responsibility
Dr Barry Clark	Anchor Environmental Consultants (Pty) Ltd	Study leader
Gerald Howard	Aurecon South Africa (Pty) Ltd	Hydrology
Andre Görgens	Aurecon South Africa (Pty) Ltd	Hydrology
Ms Lara van Niekerk	CSIR	Physical processes, hydrodynamics
Dr Susan Taljaard	CSIR	Water quality
Prof Janine Adams	Nelson Mandela Metropolitan University	Microalgae and macrophytes
Dr Bruce Mostert	Anchor Environmental Consultants (Pty) Ltd	Invertebrates
Dr Ken Hutchings	Anchor Environmental Consultants (Pty) Ltd	Fish
Dr Stephen Lamberth	Independent	Fish
Dr Jane Turpie	Anchor Environmental Consultants	Birds & overall method & editing

2.2 Delineation

Delineation of the Onrus estuary was based on the National Estuary Layer. The area of "estuary functional zone" below the 5 m contour and the open water area were estimated to be 15.1 ha and 3.5 ha, respectively, making the Onrus one of the smallest estuaries in the Brede-Gouritz WMA (Figure 2.1). The geographical boundaries for the study were defined as follows:

Downstream boundary:	Estuary mouth 34°25'6.97"S; 19°10'43.44"E
Upstream boundary:	34°24'45.45"S; 19°11'3.75"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

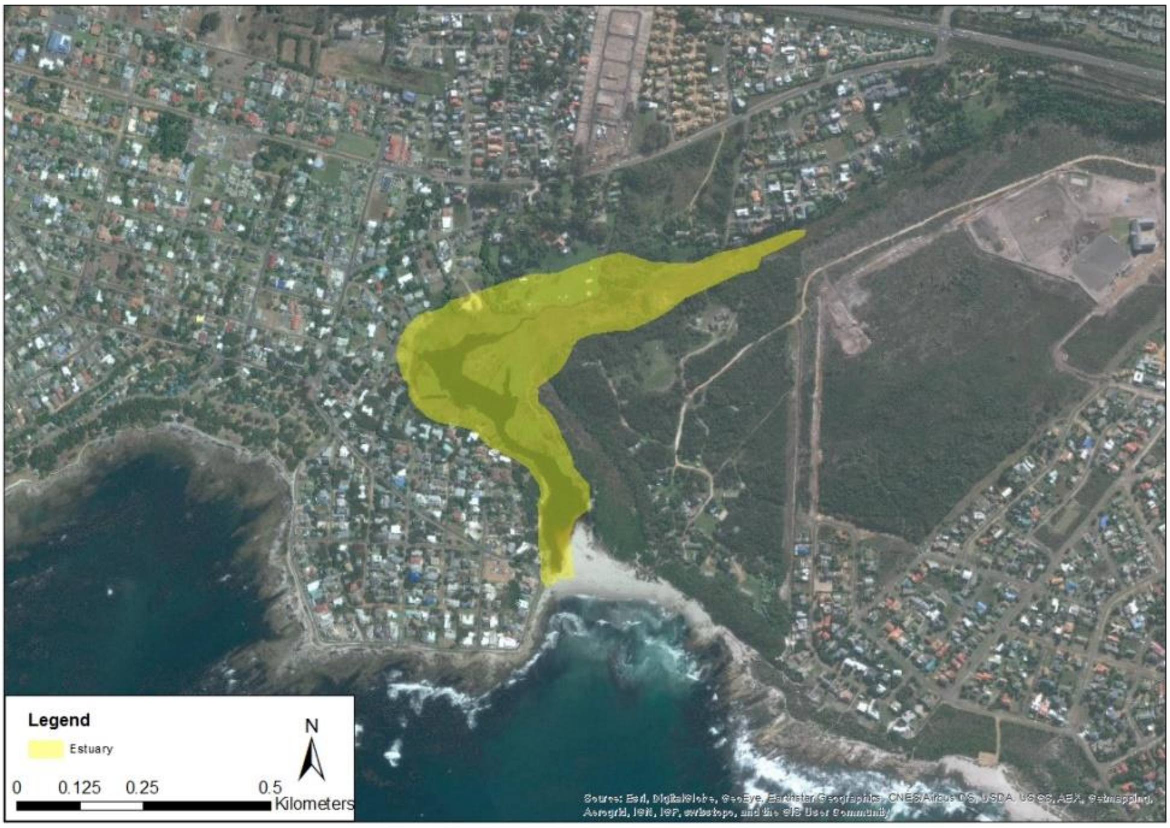

Figure 2.1. Extent of the Onrus Estuary.

2.3 Overall context and pressures

The Onrus catchment (Figure 2.2) lies within the Overstrand Local Municipality (OLM, part of the Overberg District Municipality, ODM) in the Western Cape Province and is included in the Breede-Gouritz Catchment Management Area. The Onrus River rises in the Babilonstoring Mountains and flows 16 km through the Hemel en Aarde Valley before crossing the narrow coastal plain to discharge into the sea via Onrus Lagoon, which is situated approximately 7 km northwest of Hermanus. The catchment falls within the Fynbos Biome, but most of the area has been transformed through urban development, invasive alien vegetation and agriculture (Heinecken & Damstra 1983). The catchment is located within the winter rainfall region, although orographic rain originating from the mountain ranges close to the coast result in local concentrations of rainfall (Heinecken & Damstra 1983). Rainfall on the coastal plain is generally lower than in the mountainous areas of the catchment, where Hermanus experiences a mean of approximately 600 mm per annum.

Agriculture (primarily viticulture) is the main land use in the valley, while urban development is limited to the coastal plain. The river course is heavily overgrown in places with invasive alien vegetation, including eucalypt plantations. The average annual growth rate of the OLM population based on the years from 2001 to 2011 is 3.8% and pressures on the Onrus River system and estuary are expected to increase over time (Overstrand Municipality 2012).

Figure 2.2. Onrus estuary catchment.

2.4 Hydrology

2.4.1 Present and Reference State

Simulated freshwater flow sequences for the Onrus estuary were generated for natural and present-day conditions (land use, water use etc) using the Water Resources Simulation Model 2000 (WRSM 2000) (Pitman) rainfall-runoff model. Monthly flow sequences are presented in Appendix 1-5 while summary flow data are presented in Table 2.2 (Reference conditions) and Table 2.3 (Present day conditions). There has been a significant change in mean annual runoff (MAR) between Reference (9.17 Mm^3/a) and Present (4.75 Mm^3/a) (51.8% reduction in MAR) mostly linked with agricultural use of water in the catchment and water use from the municipal De Bos Dam, which was built in 1976 approximately 9 km upstream of the estuary mouth. This dam constitutes the primary freshwater resource supplying potable water to the Overstrand region and has a storage capacity of 6 Mm^3 with an annual supply capacity of approximately 3.3 Mm^3 (Du Plessis 1995). The Municipality has been allocated 2.8 million m^3 (Overstrand Municipality 2014, Ninham Shand 1973, Ninham Shand 1987) with an additional 0.47 Mm^3 reserved for compensation of downstream water users. To maintain normal river flow downstream of the dam, it was calculated that 0.23 Mm^3 per month would have to be released between October and April each year, totalling 1.6 Mm^3 (Ninham Shand 1987). While 0.47 Mm^3 was released annually for downstream users, the 1.6 Mm^3 annual compensation release to ensure normal river flow has not been implemented.

Table 2.2. Simulated monthly flows (in 106 m^3) under REFERENCE CONDITIONS.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	3.761	4.541	1.773	1.205	2.352	1.304	4.369	4.350	5.540	6.337	7.354	5.676
90%ile	1.830	1.261	0.375	0.331	0.364	0.265	1.045	2.337	3.132	3.617	4.711	3.251
80%ile	1.076	0.650	0.166	0.104	0.104	0.160	0.366	1.027	1.963	2.475	3.574	1.823
70%ile	0.749	0.335	0.131	0.090	0.090	0.101	0.245	0.717	1.011	1.835	2.408	1.404
60%ile	0.525	0.227	0.124	0.090	0.076	0.076	0.166	0.403	0.698	1.253	1.767	1.002

50%ile	0.318	0.190	0.110	0.083	0.076	0.076	0.124	0.238	0.563	0.894	1.446	0.869
40%ile	0.273	0.166	0.107	0.076	0.069	0.069	0.097	0.179	0.427	0.629	1.102	0.641
30%ile	0.246	0.159	0.097	0.076	0.069	0.062	0.076	0.131	0.329	0.444	0.684	0.474
20%ile	0.234	0.145	0.090	0.069	0.055	0.055	0.068	0.109	0.208	0.377	0.475	0.330
10%ile	0.200	0.131	0.089	0.061	0.055	0.054	0.055	0.076	0.123	0.255	0.274	0.255
1%ile	0.145	0.090	0.054	0.040	0.034	0.034	0.034	0.046	0.076	0.122	0.175	0.162

Table 2.3. Simulated monthly flows (in 106 m^3) under PRESENT CONDITIONS.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	2.016	2.716	0.923	0.561	1.124	0.643	2.230	2.214	2.969	3.313	4.336	3.555
90%ile	1.172	0.647	0.169	0.139	0.160	0.112	0.473	1.135	1.583	1.809	2.522	1.492
80%ile	0.539	0.328	0.090	0.069	0.062	0.083	0.166	0.472	0.938	1.155	1.674	1.075
70%ile	0.380	0.170	0.076	0.062	0.055	0.062	0.112	0.328	0.492	0.904	1.165	0.647
60%ile	0.265	0.131	0.072	0.055	0.048	0.048	0.083	0.189	0.320	0.593	0.873	0.515
50%ile	0.190	0.110	0.069	0.048	0.048	0.041	0.062	0.110	0.269	0.418	0.614	0.418
40%ile	0.172	0.097	0.062	0.048	0.041	0.041	0.055	0.090	0.200	0.294	0.528	0.328
30%ile	0.145	0.090	0.062	0.041	0.039	0.034	0.041	0.069	0.152	0.219	0.325	0.239
20%ile	0.131	0.083	0.055	0.041	0.034	0.034	0.041	0.062	0.102	0.185	0.235	0.185
10%ile	0.109	0.076	0.048	0.034	0.033	0.028	0.033	0.047	0.062	0.137	0.159	0.144
1%ile	0.076	0.054	0.034	0.027	0.027	0.021	0.021	0.027	0.047	0.068	0.095	0.081

Taking into account the anticipated demand for water from the growing population in the Greater Hermanus Area, it was anticipated that the Municipality's annual allocation of 2.8 Mm^3 from the De Bos Dam would be reached by about 1997 (Ninham Shand 1991). The Overstrand Municipality submitted an application for a higher water allocation to the Department of Water Affairs and Forestry (DWAF now Department of Water and Sanitation). Permission to increase the municipal allocation was denied by DWAF, which instead assisted the municipality in initiating the Greater Hermanus Water Conservation Programme in November 1996. This included a water demand management component that relied on a block tariff system for water consumption, and the removal of alien vegetation carried out by the Working for Water programme.

Despite the implementation of the Water Conservation Programme, the Municipality was drawing 4 Mm^3 of water from the dam by 2006 (Overstrand Municipality 2010). From mid-2007 however, the surface water supply was supplemented by groundwater from the Gateway Wellfield. Subsequently, the Camphill and Volmoed Wellfields were established in the Hemel en Aarde Valley to augment the water supply from the De Bos Dam and the Gateway Wellfield in Hermanus. Consequently, the Municipality has not exceeded the permitted allocation of 2.8 Mm^3 since 2011 (P. Robinson, Pers Comm.).

There is no gauge measuring outflow through the outlet pipe, which can be opened or closed with a valve. In April 2013 the flow rate was crudely estimated (using a 20 ℓ bucket and stopwatch) at 8 ℓ/s, which translates to an annual release of approximately 0.25 Mm^3. It is therefore unlikely that enough water is released for the environmental reserve downstream of the dam.

According to the DWAF (1996) estimates, the portion of the Onrus River catchment below the De Bos Dam contributes some 42% of the natural MAR. The Antjies River tributary and a number of small streams flow into the Onrus River below the dam, while groundwater from the sandy (primary) aquifer is also believed to help sustain water levels in the estuary.

A B

Figure 2.3 (A) The outflow from the De Bos Dam into the Onrus River in March 2013, and (B) the spillway down which water flows when the dam overflows.

Using the Mean Annual Runoff figures from the initial De Bos Dam Yield Study (Ninham Shand 1987), the CSIR (1991) estimated that the flood flow rates in the Onrus River for a 1:5, 1:20 and 1:50 year flood event were 75, 121 and 157 m^3/sec. If the extreme scenario was assumed, with the dam retaining all flow, the estimated flood flow rates from the remainder of the catchment would be 44, 71 and 94 m^3/sec. The authors concluded that the flow rates have been reduced by less than 40%.

2.4.2 EWR scenarios

Although there are no firm plans for increased (or decreased) utilisation of water in the Onrus River catchment, a number of hypothetical scenarios were constructed to examine likely impacts of further decreases (transfers out of the catchment) as well as some increases (restoration) in flow on the health of the Onrus estuary. Restoration of flows was assumed to be achieved through removal of Invasive Alien plants (IAPs) and or reduction in water use for irrigation and/or domestic use. The following scenarios were considered:

- **Scenario 1:** Steady state reduction in baseflow of 0.001 m^3/s (equivalent to reduction in MAR of ~7.8% from Present and 52.3% from Reference)
- **Scenario 2:** Steady state reduction in baseflow of 0.002 m^3/s (equivalent to reduction in MAR of ~13.4% from Present and 55.2% from Reference)
- **Scenario 3:** Restoration of 50% of baseflow (equivalent to reduction in MAR of ~24.1% from Reference)
- **Scenario 4:** No change in flow but improve the quality of the influent water by eliminating sewage spills into the estuary (e.g. by upgrading pump stations and septic/conservancy tank systems)

Summary data on MAR for the Reference, Present Day and EWR scenarios is presented in Table 2.4, while monthly flow distributions for the EWR scenarios 1-3 are presented in

Table 2.5 - Table 2.7, and simulated monthly flow data attached at the end of this appendix. EWR Scenarios 1 and 2 are designed to investigate the impact of further reduction in runoff to the estuary resulting from, for example runoff river abstraction. Scenario 3 is designed to investigate the impacts of restoration in baseflow through, for example clearing of alien vegetation in the catchment and our reduction in use of water for irrigation and/or domestic use. Scenario 4 is designed to investigate impacts of improvements in water quality in the estuary through upgrades to waste water reticulation infrastructure.

Table 2.4. Summary of the scenarios evaluated in this study

Scenario name	Description	MAR (x 106 m^3)	Percentage of natural flows
Natural	Reference condition	9.17	100%
Present	Present day conditions	4.75	48.2%
Scenario 1	- 7.8% of Present	4.37	47.7%
Scenario 2	- 13.4% of Present	4.11	44.8%
Scenario 3	50% reduction in abstraction relative to Present day	6.95	75.9%
Scenario 4	Present day flows with improved quality of influent water	4.75	48.2%

Table 2.5. Simulated monthly flows (in 106 m3) under SCENARIO 1.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.985	2.685	0.891	0.529	1.092	0.611	2.198	2.182	2.937	3.281	4.304	3.523
90%ile	1.141	0.615	0.138	0.108	0.128	0.081	0.442	1.104	1.552	1.777	2.490	1.460
80%ile	0.508	0.297	0.058	0.037	0.030	0.051	0.134	0.440	0.906	1.123	1.642	1.043
70%ile	0.348	0.138	0.044	0.030	0.023	0.030	0.081	0.297	0.461	0.873	1.134	0.616
60%ile	0.233	0.099	0.040	0.023	0.016	0.016	0.051	0.157	0.288	0.561	0.842	0.483
50%ile	0.158	0.078	0.037	0.016	0.016	0.014	0.030	0.078	0.237	0.386	0.582	0.386
40%ile	0.140	0.065	0.030	0.016	0.014	0.014	0.023	0.058	0.168	0.263	0.497	0.297
30%ile	0.113	0.058	0.030	0.013	0.009	0.009	0.014	0.037	0.120	0.187	0.293	0.208
20%ile	0.099	0.051	0.023	0.009	0.008	0.009	0.009	0.030	0.070	0.153	0.203	0.153
10%ile	0.078	0.044	0.016	0.009	0.002	0.002	0.009	0.016	0.030	0.106	0.127	0.113
1%ile	0.044	0.023	0.002	0.002	0.002	0.002	0.002	0.009	0.016	0.037	0.063	0.050

Table 2.6. Simulated monthly flows (in 106 m3) under SCENARIO 2.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.953	2.653	0.859	0.498	1.061	0.580	2.167	2.150	2.906	3.249	4.272	3.492
90%ile	1.109	0.584	0.106	0.076	0.097	0.049	0.410	1.072	1.520	1.746	2.459	1.429
80%ile	0.476	0.265	0.027	0.021	0.018	0.021	0.103	0.409	0.875	1.092	1.611	1.011
70%ile	0.317	0.107	0.021	0.018	0.018	0.018	0.049	0.265	0.429	0.841	1.102	0.584
60%ile	0.202	0.068	0.020	0.016	0.016	0.016	0.021	0.126	0.257	0.530	0.810	0.452
50%ile	0.126	0.047	0.018	0.016	0.014	0.014	0.020	0.047	0.206	0.354	0.551	0.354
40%ile	0.109	0.034	0.016	0.014	0.014	0.014	0.017	0.027	0.137	0.231	0.465	0.265
30%ile	0.082	0.027	0.013	0.014	0.011	0.011	0.014	0.020	0.089	0.156	0.262	0.176

20%ile	0.068	0.020	0.011	0.013	0.011	0.011	0.011	0.016	0.039	0.121	0.172	0.121
10%ile	0.046	0.013	0.006	0.011	0.009	0.009	0.009	0.013	0.018	0.074	0.096	0.081
1%ile	0.013	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.012	0.012	0.032	0.018

Table 2.7. Simulated monthly flows (in 106 m3) under SCENARIO 3.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.921	2.621	0.828	0.466	1.029	0.548	2.135	2.119	2.874	3.218	4.241	3.460
90%ile	1.078	0.552	0.075	0.045	0.065	0.024	0.379	1.041	1.489	1.714	2.427	1.397
80%ile	0.445	0.234	0.021	0.017	0.016	0.016	0.071	0.377	0.843	1.060	1.579	0.980
70%ile	0.285	0.075	0.019	0.016	0.014	0.014	0.023	0.234	0.397	0.810	1.071	0.553
60%ile	0.170	0.036	0.017	0.014	0.012	0.012	0.017	0.094	0.225	0.498	0.779	0.420
50%ile	0.095	0.023	0.017	0.012	0.012	0.010	0.016	0.022	0.174	0.323	0.519	0.323
40%ile	0.077	0.021	0.016	0.012	0.010	0.010	0.014	0.017	0.105	0.200	0.434	0.234
30%ile	0.050	0.019	0.016	0.010	0.009	0.009	0.010	0.016	0.057	0.124	0.230	0.145
20%ile	0.036	0.015	0.014	0.010	0.009	0.008	0.009	0.012	0.017	0.090	0.140	0.090
10%ile	0.022	0.008	0.012	0.009	0.008	0.007	0.007	0.010	0.014	0.043	0.064	0.050
1%ile	0.002	0.002	0.008	0.007	0.007	0.002	0.002	0.002	0.002	0.017	0.002	0.015

2.4.3 Hydrology health score for present day & EWR scenarios

Reduction in MAR for the Onrus Estuary for the Present day and EWR Scenarios 1-4 is estimated at 48.2, 47.7, 44.8, 75.9, and 48.2%, respectively. The reduction is the size of the 1:10, 1:20 and 1:50 year floods are estimated at 40, 41 and 35%, respectively, for the Present day and Scenarios 1, 2 and 4 and at 20, 21 and 18%, respectively, for Scenario 3.

Hydrological health for Present and the EWR scenarios was assessed on the basis of the overall change in MAR and in flood frequency. Results are presented in Table 2.8. Confidence in this assessment was rated as low as simulated flows have not been properly calibrated against gauged data.

Table 2.8. Hydrology health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. % similarity in MAR	48	45	76	48	48	L
b. Change in flood frequency	61	61	81	62	61	L
Score (min + average(a : b))/2	**52**	**51**	**49**	**77**	**52**	**L**
Score min (a to b)	**48.2**	**47.7**	**44.8**	**75.9**	**48.2**	**L**

2.5 Hydrodynamics

The Onrus Estuary is classified as a temporarily open/closed system (Van Niekerk & Turpie, 2012). DWS water level data (G4T011) and personal observations indicate that the mouth is at times in a closed state with a large sandbar. The average crest height is estimated to be +2.8 m MSL (CSIR 1991). However, due to its small size the estuary is most often in a semi-closed state as it can fill and overtop at relatively low inflow rates by means of a narrow channel that forms on the western edge of the sandbar. This narrow channel serves as an overflow, rather than a tidal inlet, and seawater only penetrates during high storm spring tides as evident from kelp in the lower reaches of the estuary. With the arrival of sufficiently large floods, however, the overflow channel scours deep enough to allow for a brief period of tidal fluctuations, i.e. Open State. The sandbar starts rebuilding on the seaward side as sand is deposited back on the beach by wave action and usually closes within ten days, reverting back to an overflow channel. The Onrus Estuary can therefore be regarded as being in a "perched" semi-closed state for the majority of the time, with the estuary outlet higher than the tidal range.

Water level data for the Onrus Estuary from 1994 to 2015 from the DWS water level gauge G4T011 is shown in
Figure 2.4 and
Figure 2.5 (blue lines). River inflow data from DWS Flow Gauge G4H033 (red lines) provides an indication of the inflow patterns. Unfortunately the flow gauge is situated above the De Bos Dam, i.e. it does not reflect the lower 40% of the catchment or the abstraction from the dam. A relative correction of +0.2 m was applied to the water level data as this gauge has not been surveyed to MSL. The correction was estimated from plotting tide data against predicted tide data.

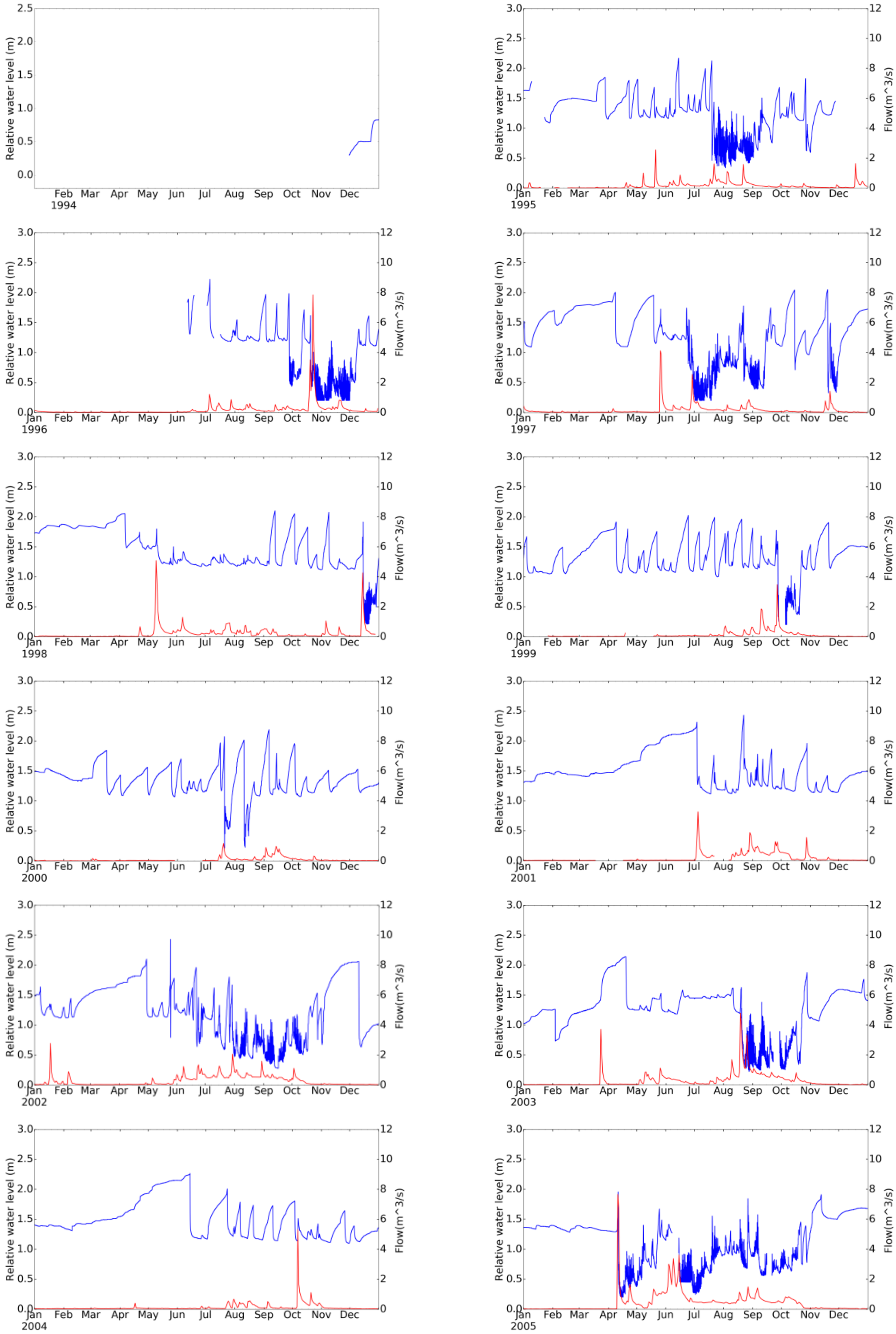

Figure 2.4. **Onrus Estuary water levels, DWS water level gauge G4T011, (Blue line) and river inflow at DWS Flow Gauge G4H033 (Red line) from 1994 to 2005 (Source: Van Niekerk *et al.* 2016).**

Figure 2.5. Onrus Estuary water levels, DWS water level gauge G4T011, (Blue line) and river inflow at DWS Flow Gauge G4H033 (Red line) from 2006 to 2015 (Source: Van Niekerk *et al.* 2016).

Data from the Onrus Estuary water level gauge indicates that the sandbar is still regularly breached when floods are large enough. The estuary drained at least 24 times between 1994 and 2015 (

Figure 2.4 and

Figure 2.5). It is not known whether these were natural events as opposed to (unauthorized) artificial breaches. No breaching occurred during the 2010-2011 drought, but in October 2012 a deep channel was scoured open following a period of heavy rain that resulted in the De Bos Dam overflowing

(Figure 2.6). The estuary experienced tidal fluctuations in water level for a short period until the sandbar started rebuilding (S Matthews, personal observation, 2012).

An overlay of river flow above the dam (green line) and estuary water level (blue line) shows how Onrus Lagoon responds to rainfall events and seasonal flow (Figure 2.7). Although most of the river flow is retained by the De Bos Dam, it can be expected that the flow pattern reflects that of streams flowing into the Onrus River below the dam. The estuary was relatively full in October, before a flood event caused the sandbar to break open. The water level dropped rapidly as the lagoon drained, but the mouth closed within a week and the water level quickly rose again to the pre-breaching level. The overflow channel then opened, which maintains the water level at approximately 1 m (depth at the gauge). At the end of January, the overflow channel closed and the water level rose. It remained at this high level until the onset of winter rains in June and July, when runoff increased again, re-opening the overflow channel.

The De Bos Dam has attenuated flood flows to some extent and is thought to have reduced the frequency at which the sandbar (berm) separating the estuary from the sea is breached. The lower flows are likely to have resulted in the mouth closing sooner after breaching than prior to the commissioning of the dam.

The water level data indicate that the highest number of breaching events occur in winter and spring (July to October), while mouth closure is likely to occur about one to two months later in Spring and Summer (August and December) (Source: Van Niekerk *et al*. 2016).

Figure 2.6 The Onrus Estuary Mouth in the Open State (23 October 2012) following a flood induced breaching on 19 October 2012 (Photo: S Mathews)

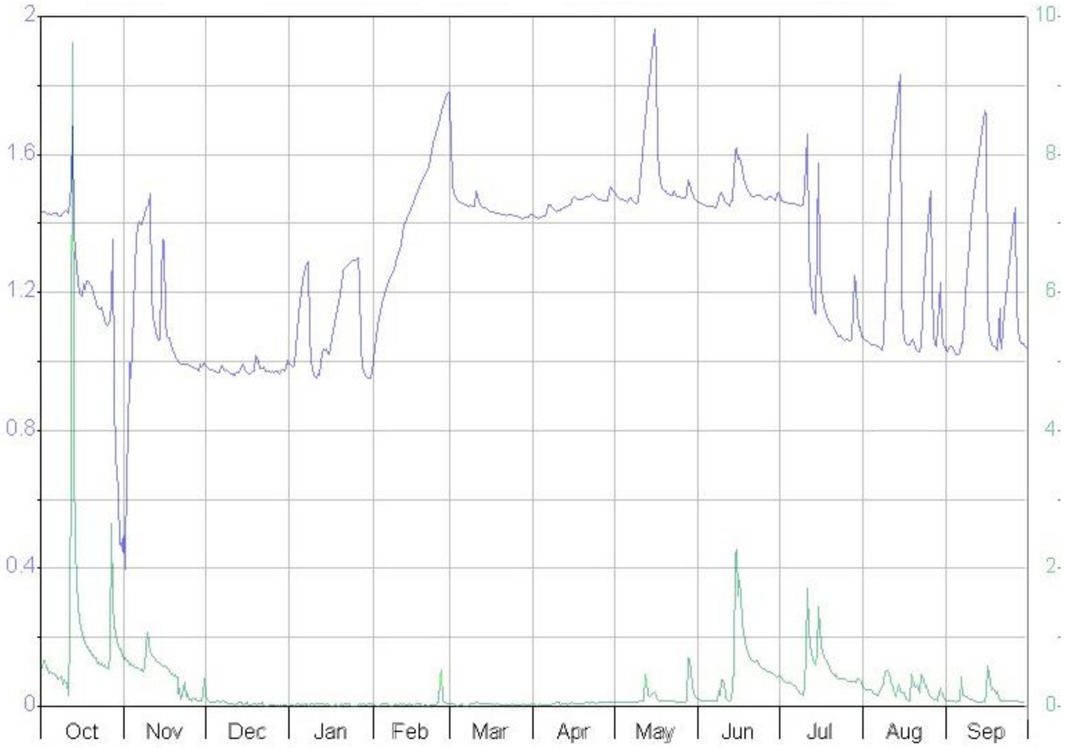

Figure 2.7 Onrus Estuary water level (blue line) and river flow above the dam (green line) and for a one-year period starting October 2009 corresponding with Figure 2.6 above. (Source: DWS).

Table 2.9. Overall summary of the mouth behaviour and relative water levels in the Onrus Estuary (Source: Van Niekerk et al 2016).

Breaching (open)		Closure	
Date	**Water level (m)**	**Date**	**Water level (m)**
19/07/1995	2.13	21/09/1995	0.76
27/09/1996	1.98	10/10/1996	0.74
20/10/1996	1.64	07/12/1996	0.67
22/06/1997	1.74	14/09/1997	0.79
19/11/1997	2.04	30/11/1997	0.72
15/12/1998	1.91	30/12/1998	0.91
26/09/1999	1.78	20/10/1999	0.52
20/07/1999	2.07	27/07/1999	0.7
08/08/1999	2.01	16/08/1999	0.72
29/07/2002	1.07	17/10/2002	0.76
19/08/2003	1.63	21/10/2003	0.58
11/04/2005	1.96	29/10/2005	1.04
27/07/2007	2.23	09/09/2007	1.2
07/10/2007	1.77	21/10/2007	1.01
21/11/2007	2.03	10/12/2007	0.78
15/09/2008	1.51	22/12/2008	0.96
13/07/2009	1.24	03/08/0.98	
27/10/2009	1.59	04/11/2009	1.37
08/10/2011	2.25	14/10/2011	1.09
19/10/2012	1.97	11/11/2012	1.05
09/08/2013	1.62	27/12/2013	0.92
05/01/2014	1.85	28/01/2014	0.82
16/02/2014	1.65	06/03/2014	0.96
15/06/2014	1.95	30/10/2014	1.11

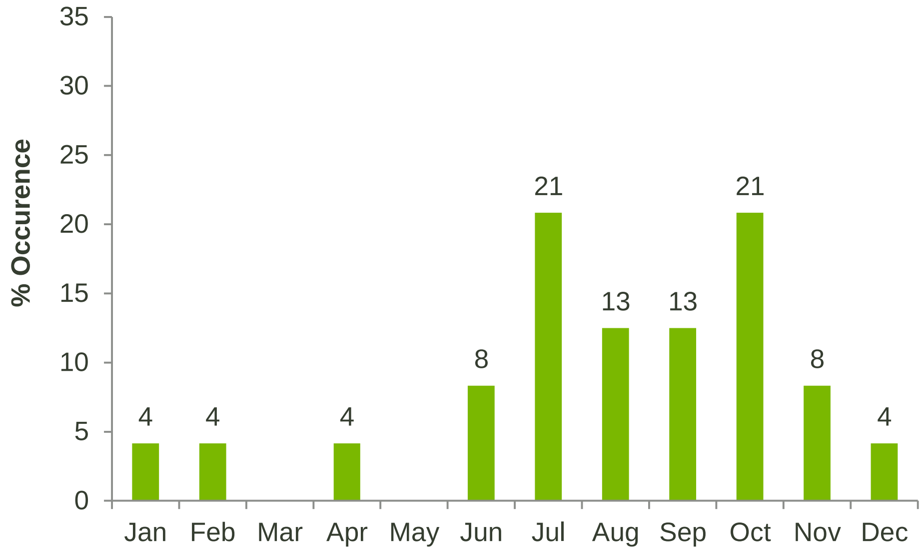

Figure 2.8. **Summary of the occurrence of mouth breaching events (Source: Van Niekerk *et al.* 2016).**

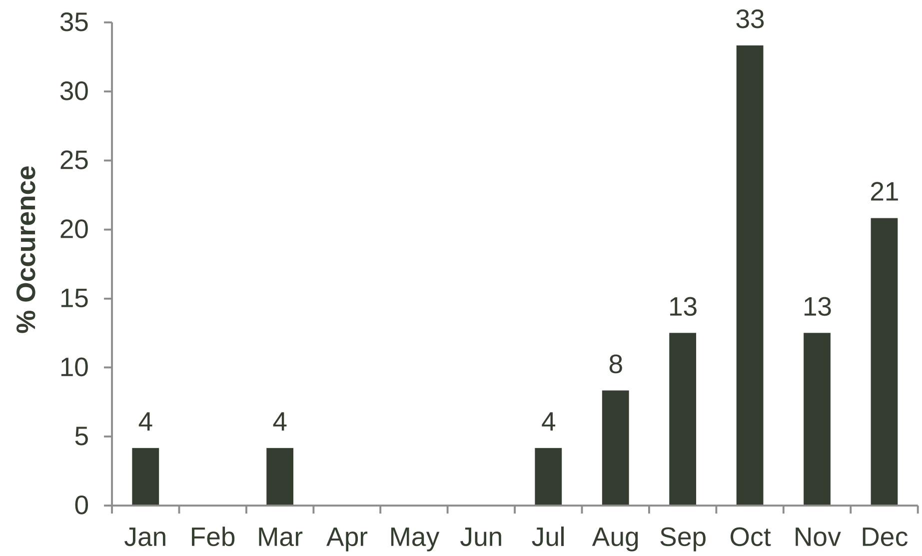

Figure 2.9. **Summary of the relative occurrence of mouth closure (Source: Van Niekerk *et al.* 2016).**

Three abiotic states (***Closed***, ***Semi-Closed*** and ***Open)*** were identified for the Onrus Estuary based on personal observations, photographs and the DWS water level data (Figure 2.8 and Figure 2.9, Table 2.9). However it is impossible to estimate the occurrence/duration of these abiotic states with a high degree of certainty as a result of high variability in the water level associated with the closed to semi-closed state and the difficulty in identifying the presence of the small/shallow outflow channel on old aerial photographs and satellite imagery.

Table 2.10 below represents a best estimate based on available time and data resources.

Table 2.10. Characteristic abiotic states in the Onrus Estuary.

Abiotic State	Water level (m) associated with abiotic state	State duration	Estimated occurrence from water level data	Salinity
Closed (no connectivity)	> 1.6	Weeks to months	7%	<5
Semi-closed (with an outflow to the sea)	0.7 - 1.6	Months	64%	5-10
Open (with tidal exchange)	< 0.7m	Days to weeks	29%	25-30

The occurrence of the various abiotic states under the Present State was superimposed on the simulated runoff time series data for the Present State to determine flow ranges associated with each state. These flow ranges were then used to estimate the frequency of occurrence of the various Abiotic States under the Reference Condition, and Alternative Flow Scenarios. From this analysis it was estimated that there has been a 13% increase in the occurrence of mouth closure from Reference to Present, with a concomitant 13% decrease in the open state (Table 2.11). Overall the estuary has experienced a significant loss of connectivity to the sea from Reference to Present.

Table 2.11. The occurrence of the Abiotic States under the Reference Condition, Present State and Alternative scenarios 1 to 4.

Abiotic State	Flow range (m^3/s)	% Occurrence					
		Reference	Present	Sc 1	Sc 2	Sc 3	Sc 4
Closed	<0.0015	1.5	14.6	38.5	48.9	6.9	14.6
Semi-closed	0.01-0.0015	55.4	55.9	33.7	24.4	55.9	55.9
Open	> 0.01	43.1	29.4	27.8	26.7	37.1	29.4

The shifts in the hydrodynamics are largely due to changes in the flow regime of the system. There are unconfirmed reports of artificial breaching by children and adults during summer, but this can only be done at high water levels when the system is close to natural breaching. This is thus not considered a major modification of the ecological condition of the system. Table 2.12 provides the corresponding hydrodynamics EHI scores for the Onrus Estuary.

Table 2.12. Hydrodynamic health scores for Present Day and the four alternative scenarios relative to the Reference Condition.

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Mouth condition & abiotic states	86	63	53	94	86	M
Hydrodynamics and mouth conditions score	**86**	**63**	**53**	**94**	**86**	**M**

2.6 Water quality

For the purposes of this study, the open water area of the Onrus Estuary was defined as a single zone. Three abiotic states were considered namely:

- Closed
- Semi-closed
- Open

No measured data on water quality for the Reference condition (i.e. prior to anthropogenic influences) could be obtained for this estuary. However, historical information suggests that the Onrus estuary has always been a freshwater-dominated system, where instantaneous salinity varied from 0-4 PSU during the closed state to 31.7 PSU when the estuary was open to the sea (e.g. in 1994, Heinecken & Damstra 1983, S. Lamberth, pers. comm., Sue Matthews Overstrand Municipality 2013). Under Present Day conditions, the average salinity in the estuary is expected to be somewhat lower due to the increase in closed mouth conditions and the associated decrease in marine connectivity (overall 13% reduction in the open state).

Considering the catchment of the system, it can be assumed that on average, the open water areas of the estuary under the Reference condition were clear (suspended solids <5 mg/ℓ), well-oxygenated (dissolved oxygen ~8 mg/ℓ) and oligotrophic (DIN <50 mg/ℓ and DIP < 10 mg/ℓ) (e.g. De Villiers and Thiart 2007). Currently though, the water quality in the estuary is subject to anthropogenic impacts, specifically surface runoff from urbanised area around the systems and regular overflow from low lying sewage pump stations (Massie & Clark 2016).

The only available water quality data for the system were collected in November 1979 (when there was still no real evidence of the impact from sewage overflow) (Heinecken & Damstra 1983) (Table 2.13). Since this time though, water quality is expected to have deteriorated markedly as a result of increased anthropogenic influence (increased urban development and overflow from sewage pump stations), particularly during the closed state (mostly impacted by sewage pump station overflow).

Table 2.13. Available data on water quality in Onrus Estuary (November 1979). Source: Heinecken & Damstra 1983. Locations of sampling stations are indicated on Figure 2.10.

Location	Salinity (PSU)	DO (mg/ℓ)	NOx-N (µg/ℓ)	NH4-N (µg/ℓ)	DIN (µg/ℓ)	PO4-P (µg/ℓ)
Onrus River	0	13.2	10	11	20	7
A2: channel	1	10.2	43	25	68	59
B5: channel	0	12.1				
E1: channel	0	10.3	19	11	30	56
F3: channel	0	10.8	39	11	50	56
G3: blind arm	0	9.7	80	19	99	103

Based on very limited data and information, and expert opinion, characteristic water quality conditions under each of the abiotic states (closed, semi-closed, open) for the Reference, Present and the alternative scenarios were estimated. Results are presented in Table 2.14.

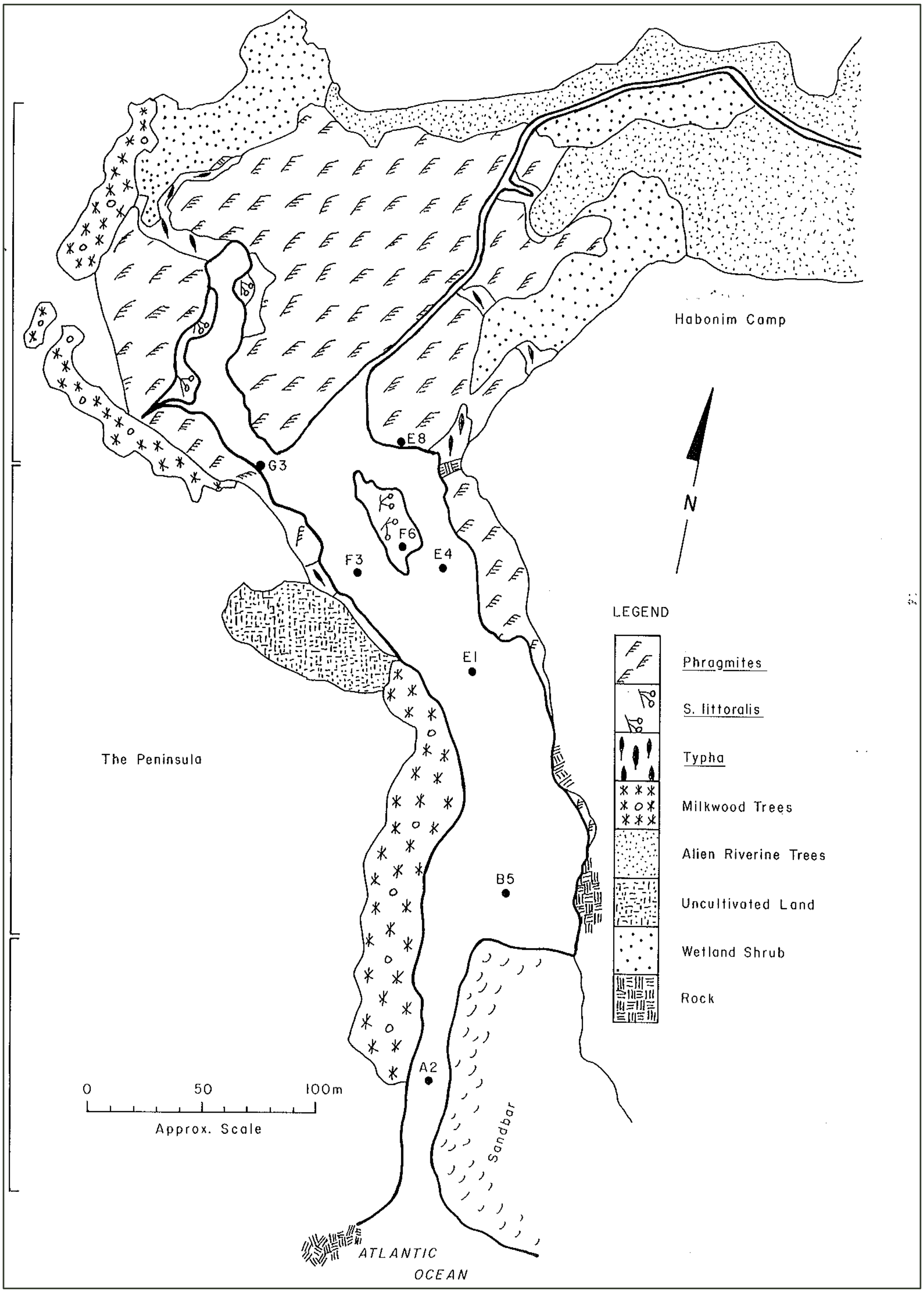

Figure 2.10.Location of sample stations used by Heinecken & Damstra (1983)

Table 2.14. Characteristic water quality conditions for each of the abiotic states (closed, semi-closed, open) estimated for the Reference, Present and the alternative scenarios, based on limited data and expert opinion.

Salinity (PSU)	Reference	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State 1: Closed	5	5	5	5	5	5
State 2: Semi-closed	15	10	10	10	10	10
State 3: Open	30	25	25	25	25	25
DIN (µg/ℓ)	Reference	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State 1: Closed	50	500	500	500	500	200
State 2: Semi-closed	50	300	300	300	300	150
State 3: Open	50	100	100	100	100	100
DIP (µg/ℓ)	Reference	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State 1: Closed	10	80	80	80	80	30
State 2: Semi-closed	10	50	50	50	50	20
State 3: Open	10	20	20	20	20	10
DO (mg/ℓ)	Reference	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State 1: Closed	8	3	3	3	3	5
State 2: Semi-closed	8	6	6	6	6	7
State 3: Open	8	8	8	8	8	8
TSS (mg/ℓ)	Reference	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4
State 1: Closed	5	30	30	30	30	20
State 2: Semi-closed	5	10	10	10	10	10
State 3: Open	5	10	10	10	10	10

The most extreme modifications in water quality are expected under State 1 (closed) when low river inflow and long residence time will result in the highest nutrient build-up and lowest dissolved oxygen (during algal blooms large diurnal variation can be expected, ranging from supersaturation during the day to hypoxia/anoxia at night) linked to sewage pump station overflow and urban runoff. Highest total suspended solid (TSS) concentrations are also expected during the closed state associated with algal blooms (phytoplankton). The improvement in nutrient, DO and TSS conditions in Scenario 4 is associated with improvement in WQ related to eliminating overflow from sewage pump station. However this small system still receives diffuse urban runoff from adjacent areas which will still have a marked influence on in situ water quality, especially during the closed state (State 1).

The anticipated frequency of occurrence of the various states under each of the scenarios is presented in Table 2.17.

Table 2.15. Anticipated frequency of occurrence of the various states under the Reference state, Present day and the various EWR scenarios.

Abiotic State	Flow range (m^3/s)	% Occurrence					
		Reference	Present	Sc 1	Sc 2	Sc 3	Sc 4
Closed	< 0.0015	1.5	14.6	38.5	48.9	6.9	14.6
Semi-closed	0.0015-0.01	55.4	55.9	33.7	24.4	55.9	55.9
Open	>0.01	43.1	29.4	27.8	26.7	37.1	29.4

Estimated average water quality conditions in the estuary under various scenarios is presented in Table 2.16. Water quality health scores for the present and EWR scenarios are presented in Table

2.17. A summary of changes in water quality for the present and EWR scenarios is presented in Table 2.18.

Table 2.16. Estimated average water quality conditions under the Reference state, Present day and the various EWR scenarios.

Scenario	Salinity	DIN (µg/ℓ)	DIP (µg/ℓ)	DO (mg/ℓ)	TSS (mg/ℓ)
Reference	21	50	10	8	5
Present	14	270	46	6	13
Scenario 1	12	321	59	5	18
Scenario 2	12	344	46	5	20
Scenario 3	15	239	46	7	11
Scenario 4	14	129	16	7	10

Table 2.17. Water quality scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
1	**Salinity**	86	63	53	94	86	M
2	**General water quality**						
	a) Nutrient (DIN/DIP) concentrations	34	29	27	35	67	L
	b) Dissolved oxygen	87	81	78	90	96	L
	c) Total suspended solids	56	44	40	61	66	L
	d) Toxic substances	70	60	60	70	75	L
Water quality score*		**56**	**46**	**42**	**58**	**74**	L

**Score = (0.6 x S + 0.4 x min (a to d))*

Table 2.18 Summary of changes water quality for the Present EWR scenarios

Parameter	Summary Of Changes
Salinity	⇩ due to decrease in the open mouth conditions that allows for the ingress of salt water. Scenario 3 shows a slight improvement from present in that it allow for more open conditions.
Inorganic nutrients (DIN/DIP)	⇧⇧ due to nutrient input from sewage overflow and diffuse urban runoff. Slight improvement in Scenario 4 - mitigating sewage pump station overflows.
Dissolved oxygen	⇩ due to organic loading from sewage overflow and diurnal variation associated with eutrophication caused by nutrient input. Reduction in DO in Scenarios 1 and 2 related to increase in occurrence of State 1 (closed) – longer residence time results in lower average DO concentrations. Slight improvement in Scenario 3 relates to the marked reduction in State 1 (closed). Improvement in Scenario 4 relates to mitigating sewage pump station overflows and septic/conservancy tanks.
Suspended solids	⇧ due to higher phytoplankton biomass associated with nutrient inputs and algal blooms. Slight improvement Scenario 3 relates to marked reduction in State 1 (closed state) – less algal blooms thus reducing TSS. Improvement in Scenario 4 relates to mitigating sewage pump station overflows and septic/conservancy tanks..
Toxic substances in estuary	⇧ due to urban runoff and sewage overflow. Slight improvement in Scenario 4 relates to mitigating sewage pump station overflows and septic/conservancy tanks.

2.7 Physical habitat

Marine sediments (coarse sand) may enter the lower part of the lagoon during extreme storm events but generally do not penetrate further than 100 m upstream of the estuary mouth (Heinecken & Damstra 1983). Beyond 100 m marine sediment is replaced by finer, catchment-derived sediment with a higher percentage of organic mud (CSIR 1991). Anecdotal information suggested that a flood following a fire in the late 1940s or early 1950s had resulted in the sudden silting-up of Onrus Lagoon, but more intensive farming activity in the catchment since that time would also have increased the sedimentation rate. Average deposition of catchment-derived sediment for the period 1940 to 1990 was approximately 1 200 m^3 per year (CSIR 1991). The De Bos Dam acts as a sediment trap and therefore most of the sediment deposits originate from the lower catchment below the dam. Over the past 20 years, agricultural development has remained relatively stable and sedimentation rates are not expected to have increased substantially over this period.

The shape of the estuary, together with the relatively low inflow and the reduction of winter spates by the De Bos Dam would result in very little scouring or flushing of accumulated sediment (Heineken & Damstra 1983). However, simulation of scenarios for flow rates under natural conditions as well as for impoundment of all inflow by the De Bos Dam indicated that flow rates for 1:5, 1:20 and 1:50 year flood events was reduced by less than 40% (CSIR 1991). It was concluded that this would have not significantly impacted on siltation or scouring of the estuary. These findings would need to be re-evaluated in light of the revised estimates of natural and present day MAR.

In 1991, most of the lagoon was above mean sea level (MSL) and only about 1 m deep, but there was a basin of approximately 1.5 m depth opposite 'the peninsula'. It was proposed that the estuary be dredged to restore open water in the Onrus Estuary, which had been severely invaded by the common reed *Phragmites australis*. The aim was to remove 45 000 m^3 of sediment to create channels 40-60 m wide and 1.5 m deep to increase flow velocities during floods and hence reduce sedimentation rates (CSIR 1991). It was also anticipated that some deeper holes excavated to -2 m MSL would aid in trapping sediment (CSIR 1993).

The dredging was conducted in 1993, and succeeded in removing about 30 000 m^3 of sediment. A bathymetric survey conducted immediately after the dredging was completed indicated that the Onrus Lagoon discharges into a small cove with a steeply sloped pocket beach on an exposed, high-energy coastline. The net annual longshore sediment transport is considered to be minimal due to the rocky coastline on both sides of the short beach (CSIR 1991). An analysis of shoreline change using a series of aerial photographs from 1938-1991 showed no apparent long-term erosion or accretion trend and was therefore identified to be in a dynamically stable state (CSIR 1991). Accretion at one end of the beach was usually accompanied by erosion at the other end, indicating that sand was moving alternatively from one end of the beach to the other, with the beach acting as a closed system. Consequently, short-term seasonal variation in shoreline position occurs, with the beach accreting in summer and eroding during winter storms (CSIR 1991). The south-easterly wind in summer may remove and deposit up to 3000 m^3 of sand per year from the beach into the estuary and a gradual accumulation of beach sand can be expected in the long term (CSIR 1991).

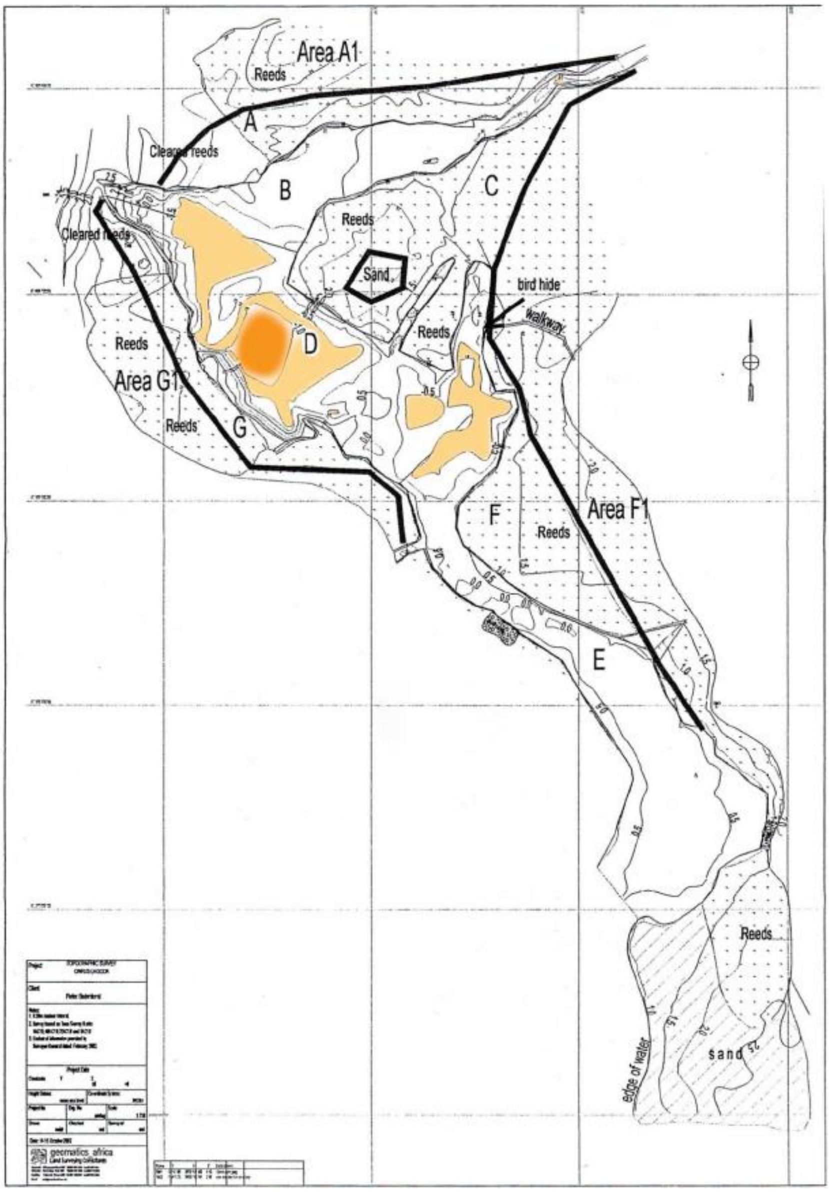

Figure 2.11. Bathymetry of the Onrus Estuary (2002). The coloured areas indicate the deepest section (Dark Orange - 1 m and Light Orange -0.5m MSL) (Source: Massie & Clark 2016)

Overall the Onrus Estuary shows signs of significant infilling and shallowing throughout the system, resulting from loss of floods (and associated scouring) and poor land-use practises causing an increase in sediments from the catchment and the ingress of reeds increasing the sediment trapping efficiency.

The supratidal and intertidal sediment structure is expected to be relatively similar to that under the Reference Condition, but there has been a significant increase in the organic sediment fraction (personal observations, L van Niekerk) in the subtidal areas of the estuary as a result of contamination by raw sewage. At present the organics are evident as a thick layer of consolidated sludge that coats the bottom of the system. The extent of this sludge layer is not known but deemed to be extensive as evidenced by its presence in fish sampling gear at a few sites.

The most dramatic change experienced in the system was from Reference to Present. Additional infilling of the subtidal habitat in the lower reaches is expected under Scenario 1 and 2 due to the reduction in baseflows that assist with sediment scouring in the lower reaches. Scenario 3 may result in a slight increase in sediment scouring, therefore an overall improvement in intertidal habitat in comparison to Reference.

Table 2.19 below provides a summary of the EHI scores for the physical habitat of the Onrus Estuary.

Table 2.19. Physical habitat scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Supratidal area and sediments	60	60	60	60	60	M
b. Intertidal areas and sediments	60	60	60	60	60	M
c. Subtidal area and sediments	50	45	40	55	50	M
d. Estuary bathymetry/water volume	50	50	50	50	50	M
Score (min + average(a : d))/2	**53**	**49**	**46**	**53**	**53**	**M**
Score min (a to d)	**50**	**45**	**40**	**50**	**50**	**M**

2.8 Microalgae

2.8.1 Microalgal groups

Microalgae are an important source of food for fish and microfauna and occur as phytoplankton in the water column, as benthic microalgae on sediment surfaces and attached to macrophytes as epiphytes. Flagellates, which are usually numerically dominant in the water column use their flagellae to maintain their position in the water column. Flagellates can be either autotrophic or heterotrophic (consumers rather than photosynthetically active). The green microalgae are a diverse group that can be present in high abundance.

Harrison (1962) reported a lack of filamentous and free-living green algae in the estuary. An analysis of dense detritus from an algal bloom in June 2012 indicated a mixed assemblage of diatoms and four species of blue-green algae (Massie & Clark 2016). Cyanophytes (blue green algae) are non-flagellated photosynthetic bacteria that are often abundant under freshwater nutrient rich conditions. Some cyanophytes are nitrogen fixers, which is beneficial in oligotrophic estuaries. Some species produce toxins which can be harmful if present in high concentration. Although not necessarily numerically dominant, diatoms have relatively large cells and mostly occur on the sediment surface until disturbance or high flow suspends them in the water column. Some diatoms migrate within the water column diurnally.

Although there was is little information on the microalgae of the Onrus Estuary it is understood that prolonged periods of mouth closure can result in high nutrient levels that would encourage the proliferation of macroalgae and blooms of microalgae (Massie & Clark 2016). Poor water quality is due to inputs from the sewage lines, stormwater inputs and agricultural return flow. Blooms of the filamentous green macroalgae *Cladophora* spp. have been observed in the estuary.

2.8.2 Description of factors influencing microalgae

The factors influencing the different microalgal groups are summarised in Table 2.20. Based on these considerations, the expected influence of the different abiotic states on microalgae can be described.

Table 2.20. Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings

Variable	Microalgal response
Open water area	Proportional reduction of phytoplankton with loss of open water area.
Salinity	Different microalgal species occur across the salinity gradient and thus are useful indicators of prevailing conditions.
Mouth condition	The intertidal zone is often rich in microphytobenthos. Under closed mouth more stable sediment conditions MPBs are also abundant when the water is clear and depth is less than 1 m.
Water flow rate	Under water high flow benthic microalgae are suspended in the water column. Many diatoms that are commonly benthic (epipelic) are common. This is especially the case where the fine sediment fraction is suspended due to turbulence.
Water retention time	Biomass elevated in high retention states.
Floods	Temporary reduction in microalgal biomass as a result of flooding.
Turbidity	High turbidity can limit benthic microalgal biomass but usually not phytoplankton biomass as the cells move into the photic zone in shallow estuaries due to wind mixing and vertical migration.
Water quality	Low nutrient conditions are characterised by maximum species diversity. Diversity decreases at high nutrient concentrations but biomass increases.
Toxins	Literature indicates that there is an unspecified adverse effect with certain toxins
Macrophyte community structure	Microalgae particularly diatoms attached to submerged and emergent macrophytes.
Oxygen levels	Decay of phytoplankton blooms can lower oxygen concentrations.

2.8.3 Reference condition

Relative change from Reference to Present State are summarised in Table 2.21.

Table 2.21. Summary of relative changes from reference to present condition.

Reference condition Key drivers	Change
⇩ river flow ⇧ mouth closure	⇧ Phytoplankton and benthic microalgal biomass due to greater water retention time.
⇩intertidal habitat due to development & disturbance	⇩ Habitat for intertidal benthic microalgae.
⇧ nutrient enrichment	⇧ Phytoplankton and benthic microalgal biomass as well as epiphytes on expanding reeds. Possibility of nuisance toxic species (HABs – harmful algal blooms) that will outcompete other species.
Total Change	⇧ Microalgal biomass, ⇩species richness

2.8.4 Microalgae health

Health scores are summarised in Table 2.22. About 20 % of the impact on microalgae was thought to be non-flow related.

Table 2.22. Microalgae component health score

Variable	Summary of change	Score	Confidence
1. Species richness	Shift from oligotrophic to nutrient enriched ecosystem, species richness decreases. Increase in mouth closure and shift to more freshwater species. Possible occurrence of nuisance toxic species.	60	L
2. Abundance	Reduced freshwater inflow, increases residence time resulting in an increase in biomass of both phytoplankton and benthic microalgae compared to natural conditions. Nutrient rich closed mouth conditions would favour microalgal blooms.	50	L
3. Community composition	Potential shift from diatoms and Chlorophytes to Cyanophytes (blue-green algae) which occur in standing water and outcompete other microalgal groups under nutrient rich, freshwater conditions.	40	L
Biotic component health score		**40**	**L**
% of impact non-flow related		**20**	

2.8.5 Change in microalgae under different scenarios

Estimated health scores are provided in Table 2.23. A summary of the changes in microalgae under different scenarios is provided in Table 2.24.

Table 2.23. Microalgae health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	60	55	50	65	70	L
b Abundance	50	45	40	55	60	L
c. Community composition	40	35	30	45	50	L
Score (min + average(a : c))/2	**45**	**40**	**35**	**50**	**55**	**L**
Score min (a to c)	**40**	**35**	**30**	**45**	**50**	**L**

Table 2.24. Summary of change in microalgae under different scenarios

Scenario	Summary of changes
1	Increase in closed mouth conditions, decrease in salinity and increase in nutrients. This will increase microalgal biomass and decrease species richness. There could be competition from macroalgae and cycles between phytoplankton and macroalgal dominance.
2	Nutrients remain high and there is an increase in mouth closure and residence time thus increasing microalgal biomass and decreasing species richness. There is the possibility of occurrences of harmful algal blooms.
3	Mouth conditions are closer to the reference condition than present because 50% of the baseflow is restored; however the nutrients are still high and therefore there is only a small improvement in conditions compared to the present state.
4	For this scenario all conditions are similar to present but there are no longer sewage spills. Microalgal blooms in response to this will therefore decrease.

2.9 Macrophytes

2.9.1 Macrophyte groups

The main habitats and macrophytes groups present in the Onrus Estuary are listed in Table 2.25. The estuary has been encroached by reeds (6.6 ha in 2014) since the 1940/50s. Little other macrophyte habitat is present. Records indicate the presence of the submerged macrophyte pondweed *Potamogeton pectinatus*. Some coastal forest with milkwood *Siderxylon inerme* remains at the mouth.

Table 2.25 Macrophyte habitats and functional groups recorded in the estuary (spp. examples in italics).

Habitat type	Defining features, typical/dominant species	Area (ha)
Open surface water area	Serves as habitat for phytoplankton.	2.59
Sand and mudflats	Sand/mud banks provide a possible area for microphytobenthos to inhabit.	1.86
Reeds and sedges	Common reed *Phragmites australis* and bulrush *Typha capensis* are dominant.	6.57

2.9.2 Baseline description

The present area of the different macrophyte habitats and their distribution within the 5 m contour around the estuary is shown in Figure 2.12. Dense monospecific stands of common reed *Phragmites australis* occur on the banks of the estuary (Figure 2.13). In some areas bulrush *Typha capensis* replaces *Phragmites*. The reeds fringing the banks of the mouth were short and sparse compared to the dense stands occurring in the middle and upper reaches of the estuary. Some clumps of *Schoenoplectus scirpoides* were present amongst the reeds.

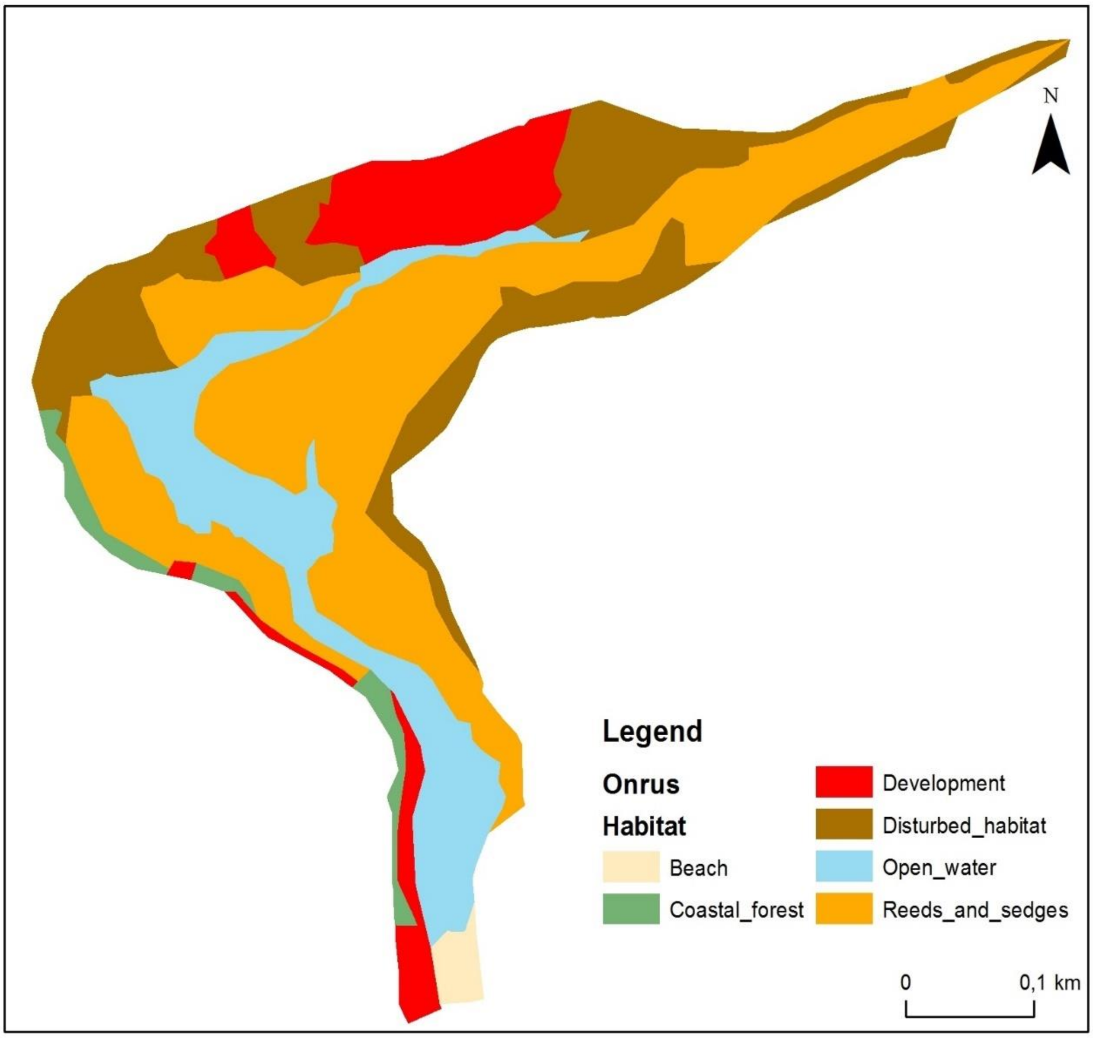

Figure 2.12. Distribution of macrophyte habitats at Onrus Estuary in 2016 based on a field survey and 2014 aerial photography.

Heineken & Damstra (1983) identified pondweed *Potamogeton pectinatus* and the algae *Chara* growing together in the bottom sediments of the shallower upper northern part of the lagoon. According to Massie & Clark (2016) red water fern *Azolla filliculoides* has been occasionally recorded in the estuary. The indigenous blue water lily, *Nymphaea nouchali*, was noted in the estuary in the summer of 2011. In July 2016 the estuary was accessed by foot and no submerged macrophytes were noted.

A narrow strip of coastal forest dominated by milkwoods *Sideroxylon inerme,* bush tick berry *Osteospermum monilifera* (previously *Chrysanthemoides monilifera*) and invasive rooikrans *Acacia cylops* occurred along the western bank of the estuary. A small percentage of this habitat has been removed due to residential houses and gardens which back onto the estuary. A sedge similar in appearance to young *Phragmites,* possibly *Ficinia nodosa* (previously *Scirpus nodosus*), fringed the open water in front of the coastal forest.

Typical coastal dune vegetation occurred at the mouth of the estuary and behind the reeds on the eastern bank. Dune forest represented *by Carpobrotus acinaciformis, Euclea racemosa, Metalasia* *muricata* and *Searsia gluaca* occurred behind the coastal dune vegetation, bordering on the reserve. Wetland species and invasive Kikuyu grass, *Pennisetum clandestinum*, was noticeable in the undergrowth of this vegetation. A number of weedy, garden escapees and invasive plants were prevalent in the disturbed habitat near the Habonim camp.

Mouth area

Lower reaches

View of the middle reaches.

Large reed beds with view towards the sea.

Figure 2.13. Photographs of the Onrus Estuary (July 2016).

Table 2.26. Effect of abiotic characteristics and processes, as well as other biotic components on macrophyte habitats

Process	Macrophytes
Mouth condition (provide temporal implications where applicable)	The estuary is perched and therefore the frequency and duration of mouth breaching would influence removal of sediment and reed habitat. Salt marsh does not occur due to lack of intertidal habitat and saline conditions.
Retention times of water masses	Low flow and long water retention times encourages the establishment of submerged macrophytes and macroalgae in the Onrus Estuary.
Flow velocities (e.g. tidal velocities or river inflow velocities)	Low river and no tidal flows enables the establishment of submerged macrophytes and macroalgae. High flow velocity during floods would remove reeds.
Total volume and/or estimated volume of different salinity ranges	The estuary is fresh, except for short periods during open mouth conditions following flooding events. This limits the establishment of salt marsh habitat. The lack of a salinity gradient restricts species richness.
Floods	Large floods are important for breaching of the sandbar at the mouth and enables mixing of water to reduce nutrient concentrations. During floods some of the accumulated sediment and reeds are removed from the estuary.
Salinity	Because the estuary has little tidal influence macrophyte diversity is low Historically it has been a more freshwater system.
Turbidity	Submerged macrophytes have been recorded in calm areas amongst the reeds.
Dissolved oxygen	The estuary is well oxygenated. Input of organic matter from decaying reeds during closed mouth conditions could result in localized low oxygen concentrations.
Nutrients	Low salinity together with high nutrient inputs would increase macrophyte growth particularly reeds and sedges that have increased in abundance since reference conditions. This can be related to sedimentation and nutrient input from sewage spills and urban run-off. These fringing reeds and sedges play an important role in nutrient uptake.
Sediment characteristics (including sedimentation)	Sedimentation and shallowing of the estuary particularly in the middle and upper reaches would encourage the growth and expansion of reeds and sedges into the main water channel.
Other biotic components	Cattle grazing on the reeds has been recorded in the past. Invasive plants were common.

Table 2.27 Summary of macrophyte responses to different abiotic states

State	Response
Closed	Progressive shallowing and further reed encroachment. Growth of submerged macrophytes and macroalgae.
Semi-closed	Macrophytes will change in response to water level fluctuations with reeds expanding when water level is low.
Open	Submerged macrophytes and macroalgae will be lost due to scouring and tidal flow. Some reed habitat may be removed due to scouring.

2.9.3 Reference condition

Reed encroachment has been problematic in the estuary since the 1940/50s following sedimentation due to erosion from catchment activities and reduced freshwater inflow which prevents the breaching of the mouth and scouring of the estuary. The dense rhizomes of the *Phragmites* roots further encourage siltation. Nutrient enrichment from catchment activities and sewage spills further encourages reed growth. Although dredged in 1993/4 to remove accumulated sediment and reeds, reeds are still abundant. Table 2.28 summarises management and changes in reed habitat over time in the estuary. Disturbance and development has led to a decrease in natural vegetation surrounding the estuary and resulted in invasion by garden escapees and invasive plant species. Table 2.29 summarises the main changes in macrophytes at the Onrus Estuary over time.

Table 2.28. History of management of reed encroachment at Onrus Estuary (source Massie & Clark 2016)

Year	Action
1938	61% of the estuary area was open water. Reeds confined to isolated patches on the northern shore.
1961	Reeds has spread along the northern shorelines
1973	Water body largely covered by reeds
1989	Open water reduced to only 25% of the total estuary area
1993	Reed beds comprised 3.8 ha. Dredging of the estuary to remove accumulated sediment and 1.5 ha of reeds.
2002	Rehabilitation report showed no significant sedimentation since dredging except for some sedimentation that occurred during a flood shortly after the dredging.
2012	Residents cleared the *Phragmites* stand present on the eastern side of the estuary and planted arum lilies on the reed rhizomes. Some of this habitat was taken over by *Typha* and the remaining cleared areas by *Commelina* sp. supressing reed growth

Table 2.29. Summary of relative changes in macrophytes from Reference Condition to Present state

Drivers	Changes
⇩ river flow	⇧ sedimentation and reed growth
⇧ nutrients	⇧ growth of all macrophytes
⇧ mouth closure	⇧ residence time of water, reed and macroalgal growth
⇧development, disturbance and invasive plants	⇩floodplain habitats

2.9.4 Macrophyte health

The health of the macrophytes was assessed in terms of species richness, abundance and community composition. Change in species richness was measured as the loss in the average species richness expected during a sampling event, excluding species thought to not have occurred under Reference conditions (

Table 2.30). Abundance was measured as the change in area cover of macrophyte habitats (% similarity = 100*present area cover / reference area cover; 100*11.44/15.05= 76%. Floodplain of the Onrus Estuary (3.26 ha) has been removed by disturbance and development. Reed encroachment (156% increase) has significantly reduced open water habitat. Under natural conditions invasive plant species would not have occurred in the system. These impacts have resulted in a community composition score of 49% (

Table 2.30). At least 75% of the macrophyte changes that have occurred in the Onrus Estuary are due to flow related impacts (Table 2.31). Change in community composition was assessed using a similarity index which is based on estimates of the area cover of each macrophyte habitat in the reference and present state. (Czekanowski's similarity index: $\sum$ (min (ref,pres) / ($\sum$ref + $\sum$pres)/2)). The macrophytes are 49% similar to what they were under reference conditions.

Table 2.30. Summary of how the macrophytes in the Present condition have changed relative to the Reference condition.

Estuary habitat	Reference	Area (ha) in 2016	Minimum
Open water	6.59	2.59	2.59
Reeds and sedges	2.57	6.57	2.57
Coastal forest	0.78	0.42	0.42
Floodplain	3.26		0
Sand/mud banks	1.86	1.86	1.86
Development		3.42	0
Disturbed habitat		0.19	0
TOTAL	**15.05**	**15.05**	**7.44**
Community Composition	7.44/15.05= 49 % similarity		

Table 2.31. Similarity scores of macrophytes in the Present condition relative to the Reference condition.

Variable	Change from natural	Score	Confidence
1. Species richness	Species have been lost because of the less dynamic environment, reed encroachment, disturbance of the floodplain areas and presence of invasive species.	80	M
2. Abundance	Development and disturbance has resulted in the loss of indigenous vegetation.	76	M
3. Community composition	Open water habitat has been lost to encroachment by reeds and sedges. Floodplain habitat has been lost due to development and invasive plant growth. Nutrient enrichment encourages the growth of macroalgae and invasive floating aquatic macrophytes.	49	M
Macrophyte health score		**49%**	**M**
% of impact non-flow related - 75% change due to nutrient enrichment and changes in flow		25%	

2.9.5 Summary of change in macrophytes under different scenarios

A summary of the changes in macrophytes under different scenarios is provided in Table 2.32. Estimated health scores are provided in Table 2.33.

Table 2.32. Summary change in macrophytes under different scenarios

Scenario	Summary of changes
1	There is an increase in closed mouth conditions and nutrients which will encourage the spread of reeds, growth of macroalgae and invasive floating aquatic macrophytes such as the water fern.
2	Conditions will be similar to Scenario 1 but a slightly more severe response as the mouth will stay closed for longer
3	Restoration of base flow may assist with scouring of the estuary and increase mouth breaching, resulting in less sedimentation and reduced residence time, which will limit the spread of reeds in the estuary. Slightly more saline conditions will also control the spread of reeds and invasive floating aquatic macrophytes and improve species richness. Habitat loss due to development and disturbance remains the same so there is no improvement in the abundance score.
4	Reduced nutrient enrichment will reduce the growth of reeds and macroalgae. Slight improvement from present as less reed growth. However there is still sedimentation and shallowing in the estuary. Habitat loss due to development and disturbance remains the same so there is no improvement in the abundance or species richness score.

Table 2.33. Macrophyte health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	80	75	70	85	80	M
b Abundance	76	73	72	76	76	M
c. Community composition	49	44	40	54	52	M
Score (min + average(a : c))/2	**59**	**54**	**50**	**63**	**61**	**M**
Score min (a to c)	**49**	**44**	**40**	**54**	**52**	**M**

2.10 Invertebrates

2.10.1 Baseline condition

Estuarine invertebrates can be divided into a number of sub-groups based on where they reside in the estuary. Zooplankton live mostly in the water column, benthic organisms live in the sediments on the bottom and sides of the estuary channel, and hyperbenthic organisms live just above the sediment surface. Benthic organisms are frequently further subdivided into intertidal (those living between the high and low water marks on the banks of the estuary) and sub-tidal groups (those living below the low water mark).

There is no available information on the Zooplankton inhabiting the Onrus estuary (Heineken & Damstra 1983) and very limited information on benthic and hyperbenthic invertebrate. The invertebrate information is restricted to the 1983 CSIR report on the Estuaries of the Cape (Heineken & Damstra 1983) and forms the baseline description of the Onrus estuary. The 1979-1980 survey identified 23 benthic and hyperbenthic invertebrate species from six taxonomic classes (Heineken & Damstra 1983; Table 2.34). The seaward end of Onrus estuary was predominantly inhabited by the sandprawn *Callichirus kraussi* in shallow areas, while Crown crabs, *Hymenosoma orbiculare* occurred in slightly deeper water (Heineken & Damstra 1983). Amphipods, polychaetes, tanaids and chironomid larvae were also present in this area (Table 2.34).

The upper parts of the estuary were characterised by muddy substrate which was inhabited by Amphipods, polychaetes and chironomid larvae but in relatively low numbers. Mussels (*Brachidontes virgiliae)* attach to waterlogged branches and submerged rocks. In the upper reaches the amphipod, *Americorrophium triaeonyx* and tanaid, *Tanais stanfordi* were abundant with polychaetes, amphipods, isopods Corixidae sp. and Chironomid larvae being present. The anoxic blind arm supported populations the polychaete, *Ceratonereis keiskama*; amphipod, *Americorrophium triaeonyx*; along with Chironomid larvae. The submerged algae *Chara* and macrophyte *Potamageton pectinatus,* provided habitat for several species of invertebrates (Heineken & Damstra 1983; Table 2.34), although there were no noted submerged macrophytes in July 2016, which indicated the loss of this habitat type. Additionally, the island of *Scirpus littoralis* provided habitat for amphipods, isopods and numerous insect larvae while the *Phragmites* spp. reed beds hosted a similar suite of invertebrates as well as two species of Arachnida (Heineken & Damstra 1983; Table 2.34).

Subsequent to the 1979-1980 survey dredging was conducted in 1993, removing about 30 000 m^3 of sediment (Massie & Clark 2016). In this process the island of *Scirpus littoralis* has been removed as well as a large area of *Phragmites* spp*.* reed beds (Figure 2.10). Dredging would have further impacted the submerged *Chara* and *Potamageton pectinatus* habitats as well as soft sediments used by benthic organisms as habitat and with no indication of subsequent recovery estimating the level of submerged habitat loss is difficult. However, based on the information available, the health condition of invertebrates in the Onrus Estuary was rated as fair (Turpie *et al.* 2012) and a significant amount of macrophyte habitat was still present, indicating that invertebrate populations reliant on this would not be significantly affected. Prawn holes have disappeared from the lower reaches of the estuary (Massie & Clark 2016). Due to the predominately semi-closed state of the estuary the salinity would consistently range between 5 - 10 ppt (

Table 2.10) which is below the requirements for *C. kraussi* breeding (minimum of 17 ppt; Massie & Clarke 2016) this would lead to their disappearance. Crown crabs, *Hymenosoma orbiculare* would still be present in the lower reaches of the estuary as this species has been recorded in salinities as low as 1 ppt (Massie & Clarke 2016).

2.10.2 Reference condition

Under reference conditions the estuary would have had regular estuarine breaches due to high flow rates. Estuarine breaches would ensure input of seawater into the system which would have allowed the presence and persistence of marine invertebrate taxa (e.g. *C. kraussi*) both through increased salinities and recruitment from the marine environment. Scouring of the estuarine habitat under high flow rate regimes would prevent the build-up of dense anoxic muds which generally exclude benthic organisms. The *Scirpus littoralis* and *Phragmites* spp. reed beds would've been present in the reference condition providing habitat for invertebrates.

Table 2.34. List of invertebrates found at the Onrus estuary and associated habitats (Realative abundance: Rare = 1, Present = 2 – 10, Common = 11 – 50, Abundant = > 50 specimens collected; Heineken & Damstra 1983), SS = Sandy substrate, MS = muddy substrate

Class	SS	MS	Rock in MS	Log in MS	*Chara*	*Potamogeton pectinatus*	Blind arm	Decomposing kelp	*Phragmites* bed	*Scirpus littoralis* Island
Polychaeta										
Ceratonereis keiskama	P	C		P			P			R
Crustacea (sub-phylum)										
Americorrophium triaeonyx	C	C	C	A	P	P	P		R	R
Melita zeylanica			R	R					P	P
Pseudosphaeroma barnardi			P	A						
Cirolana africana				P					C	
Tanais stanfordi	P		P	C	A			R		
Callichirus kraussi	P									
Hymenosoma orbiculare	P									
Insecta										
Crocothemis erythraea					R					
Zygopteran nymph					P					
Cloeon lacunosum									R	
Coleopteran										R
Gyrinidae adult		R							C	P
Hydrophilide larvae										P
Corixidae			C						C	
Chironomus sp. 1 larvae								P	C	C
Chironomus sp. 2 larvae	R	R			R		P	P	C	C
Chironomid larvae	P	C		R	C	C	C	P		P
Chironomid larvae	R	R		R	C	P	P			R
Arachnida										
Araneae 1									R	
Araneae 2									R	
Gastropoda										
Helicon juveniles	P									
Bivalvia										
Brachidontes virgiliae		P	A	A		P				C

The health of the invertebrates was assessed in terms of species richness, abundance and community composition. Changes in species richness, abundances, and community composition could only be estimated as there has been no subsequent invertebrate survey since the 1979-1980 survey.

2.10.3 Summary of change in invertebrates under different scenarios

A summary of the changes in invertebrates under different scenarios is provided in Table 2.35. Estimated health scores are provided in Table 2.36.

Table 2.35. Summary of change to invertebrates

Scenario	Summary of changes
1	There is an increase in closed mouth conditions which will lead to a decrease in marine taxa (richness and abundance) due to low salinities. The lack of full breaching events would also prevent the recolonisation of marine taxa leading to lower invertebrate species richness and abundance. There will likely be in increase of estuarine and freshwater taxa under this scenario with their distributions shifting closer to the mouth. There will be less scouring events and increased nutrient loads leading to an increase in organic sludge throughout the system creating an uninhabitable anoxic benthic environment, thereby decreasing benthic invertebrate species richness and abundance, negatively affecting community composition.
2	Similar to Scenario 1 but more severe response due to lack of breaching and build-up of anoxic sediment.
3	Restoration of base flow would assist with some scouring of the estuary and increase mouth breaching, resulting in the recolonisation of marine invertebrates and some restoration of the benthic habitat. Estuarine and freshwater taxa numbers would likely decrease and distributions would move towards their reference state further away from the mouth of the estuary. Higher salinities would encourage the persistence of marine and estuarine taxa in the lower reaches of the estuary. Species richness, abundance and community composition scores would all increase.
4	Reduced nutrient loads would decrease the anoxic sediment over time (with the aid of flood events that would scour the estuary) this would partially restore the benthic environment for invertebrate species increasing abundances. The marine taxa would still be excluded due to low salinities and lack of breaching. There would be small improvements in abundance scores.

Table 2.36. Invertebrate health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	55	50	45	70	65	M
b Abundance	65	60	55	75	70	L
c. Community composition	55	50	50	70	65	M
Score (min + average(a : c))/2	**57**	**52**	**47.5**	**71**	**66**	**M**
Score min (a to c)	**55**	**50**	**45**	**70**	**65**	**M**

2.11 Fish

2.11.1 Baseline description

Three studies have reported on the icthyofauna of the Onrus Estuary; these include data collected during the 1980 ECRU survey (Heineken & Damstra 1983), by Harrison (1999) in 1994 and by Turpie & Clark (2007) in 2006. A total of 10 species have been identified in these (Table 2.37). These include three estuarine resident species, Estuarine round herring *Gilchristella aestuaria*, Knysna sand goby *Psammagobius knysnaensis* and Silverside *Atherina breviceps* that breed in estuaries (the latter two also have marine breeding populations). Juvenile flathead mullet *Mugil cephalus* are dependent on estuaries as nursery areas, whilst juvenile southern mullet *Liza richardsonii* and white stumpnose *Rhabdosargus globiceps* occur in estuaries but are generally more common at sea. The freshwater mullet *Myxus capensis* breeds at sea, but uses estuaries as nursery areas and spends much of its adult life in rivers (catadromy). Both Cape galaxias *Galaxias zebratus* and Mozambique tilapia *Oreochromis mossambicus* are euryhaline freshwater fish, although the latter has expanded its range, being native to the more tropical waters of Kwa-Zulu Natal and Eastern Cape. The freshwater fish Cape kurper *Sandelia capensis* was only recorded in 1980.

Table 2.37. Relative abundance (average number per haul) of fish species list sampled in the Onrus Estuary during surveys conducted in 1980 (Heinecken & Damstra 1983), 1994 (Harrison 1999) and 2006 (Turpie & Clark 1997). EDC: Estuarine Dependence Category (Whitfield 1999).

Species	Common name	EDC	1980	1994	2006
Gilchristella aestuaria	Estuarine round herring	IA	<10	5	433
Atherina breviceps	Silverside	IB			1
Psammogobius knysnaensis	Knysna sandgobi	IB	>50	18	315
Mugil cephalus	Flathead mullet	IIA		36	0.250
Liza richardsonii	Southern mullet	IIC	<50	515	313
Rhabdosargus globiceps	White stumpnose	IIC	<10		5
Sandelia capensis	Cape kurper	IV	<10		
Galaxias zebratus	Cape galaxias	IV	<10		
Oreochromis mossambicus	Mozambique tilapia	IV			12
Myxus capensis	Freshwater mullet	VB		1	1

In September 1994, the estuary mouth was open and salinity 200 m upstream of the mouth measured 31.7 ppt (Harrison 1999). Concurrently, the estuary had just been dredged and was likely to be a highly disturbed at the time. In these conditions, the estuary was dominated by mullet, where *L. richardsonii* and *M. cephalus* represented 96% of four seine hauls with 90% and 6% respectively. The few large *M. cephalus* contributed the same biomass as *L. richardsonii*, together making up 91% of the total biomass caught. In comparison, *G. aestuaria* and *P. knysnaensis* were very scarce (Figure 2.14). The range of size classes of *M. cephalus* and *L. richardsonii* represented during this survey suggests regular recruitment of these species, indicating that the system was being utilised as a juvenile nursery area. The majority of specimens of *P. knysnaensis* were almost fully grown, which indicates that the Onrus was still a viable habitat for resident estuarine species.

The Onrus Estuary was sampled in March 2006, most likely during closed or semi-closed mouth conditions and 13 years after the estuary was dredged for the purpose of combating reed encroachment (Turpie & Clark 2007). Consequently, the estuary had much greater open water area than when Harrison had sampled, and the habitat would have had a chance to recover since 1993. In total, eight species were caught in four seine hauls (Figure 2.15). It is evident that compared to dredged and open mouth conditions in 1994, the species composition was dominated by estuarine resident species including *G. aestuaria* and *P. knysnaensis* making up 69% of the total abundance. *L. richardsonii* was also very abundant with 29% and represented 73% of the total biomass recorded. Catadromous *M. capensis* and freshwater fish *O. mossambicus* were not very abundant but represented 4% of the total biomass, which is much higher than in 1994.

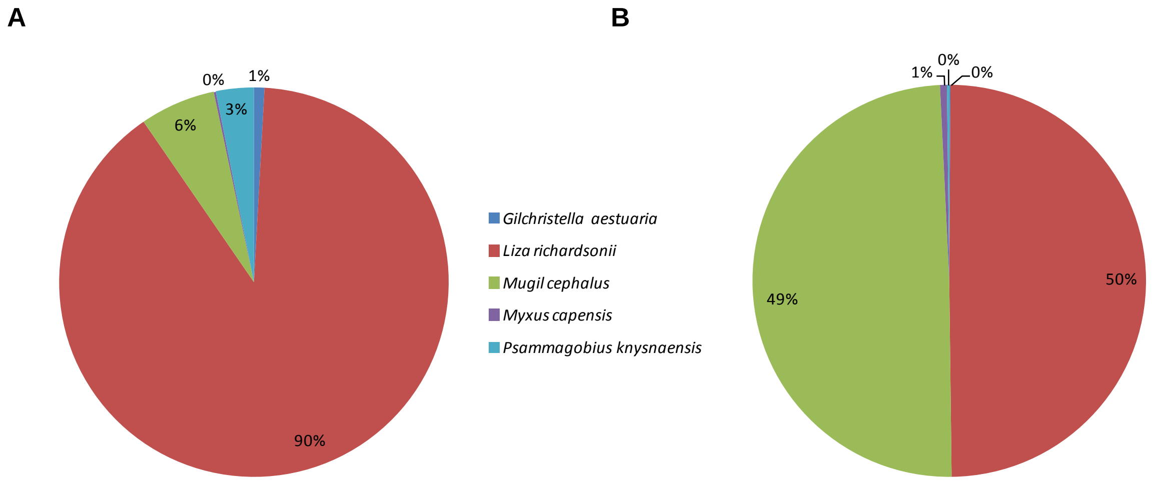

Figure 2.14. Fish species composition of the Onrus Estuary in September 1994 during open mouth conditions. Figure A and B show relative abundance and biomass, respectively (Data source: Harrison 1999).

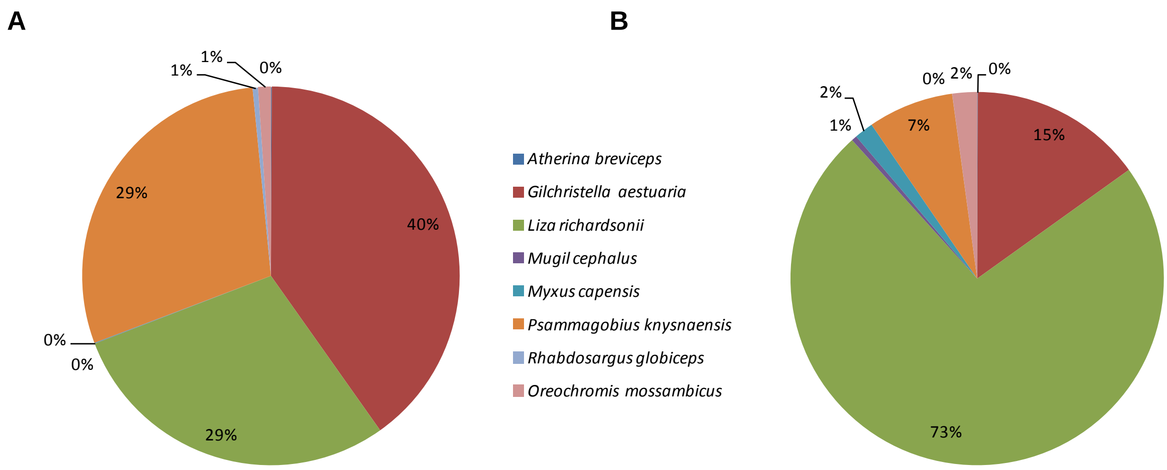

Figure 2.15 Fish species composition (based on abundance) of the Onrus Estuary in March 2006 during suspected closed mouth conditions (Data source: Turpie & Clark 2007).

2.11.2 Reference icthyofaunal community

Under reference conditions, the estuary was probably tidal just under half the time (43% open mouth phase), whilst marine connectivity was maintained during the semi-closed phase for much of the remaining time. Sandy marine derived sediments were probably more common in the lower estuary; the water was oligotrophic and clear and open water habitat was much greater than at present. These conditions would have provided suitable foraging and nursery areas for adults and juveniles of a wide range of marine migrant species, both estuary-associated marine species as well as marine ‘vagrants’ – e.g. white steenbras *Lithognathus lithognathus*, leervis *Lichia amia*, white stumpnose *Rhabdosargus globiceps* and elf *Pomatomus saltatrix*. These species, together with sand (as opposed to mud) associated estuarine resident species such as the Cape sole *Heteromycteris capensis* and knysna sand goby *Psammogobius knysnaensis* were most likely present, or much more abundant in the estuary under reference conditions. As with the present day condition, mullet species (mostly *Liza richardsonii, Myxus capensis,* and *Mugil cephalus,* probably also *L. dumerilii*) would have been very important in the system. It is possible that mullet were more abundant due to the greater open water habitat available under reference conditions. Alternatively the waters were clear and oligotrophic, and the decreased productivity and increased predation by piscivorous marine fish may have had negative impacts on mullet (and other shoaling species such as silversides and estuarine roundherring) abundance under reference conditions. The silverside *Atherina breviceps* would probably have been more abundant in the clear, marine influenced water, whilst *Gilchristella aestuaria* (currently the most abundant species) would have probably been less dominant. Cape kurper and Cape galaxias would probably only rarely entered the estuary during floods when freshwater conditions dominated. Mozambique tilapia would not have been found and eels *Anguilla mossambica* and *A. marmorata* elvers and adults would probably have migrated through the estuary on a regular basis (their existence in the system under present conditions is unknown).

2.11.3 Fish health

Under present conditions, the mouth of the Onrus is predominantly closed or semi-closed (~70 % occurrence), but usually breaks open for short periods after heavy rainfall several times during the year (section 2.5). A narrow channel that mostly functions as an overflow from the estuary can scour deeper, resulting in brief periods of tidal influence before it closes again (section 2.5). During closed or semi-closed mouth conditions seawater only enters the estuary via the overflow at spring tides. When the mouth is closed, seawater may enter the lagoon when waves break over the sand bar particularly during storm conditions (Heinecken & Damstra, 1983). The fish composition described above demonstrates that even with limited interaction between the sea and the estuary, the Onrus Estuary does still play a role in recruitment of larval and juvenile marine fish. It is possible that the removal of large areas of the common reed *Phragmites australis* in 1993/1994 temporarily improved the fish nursery function of the Onrus Estuary, but ongoing sedimentation and regrowth of reeds has negated much of the improvement in habitat associated with the dredging.

The reduced flow, reduced open water area and depth, reduced seawater penetration (and hence salinity), increased nutrients and organically enriched, muddy sediments are anticipated to have caused a reduction in species richness and significantly altered the fish community composition (Table 2.38). In particular estuarine dependent marine species (Category IIb species) were probably present under reference conditions, but have been absent in all surveys conducted over the last 3 decades. Reduced recruitment due to limited connectivity with sea and reductions in open water habitat (due to siltation and reed encroachment) strongly suggest that present day fish abundance is much less than under reference conditions (Table 2.38).

Scenarios 1 and 2 see moderately reduced MAR but substantially decreased open mouth states leading to even more limited connectivity with the marine environment as well as further habitat loss associated with siltation and increase in muddy sediments. Ichthyofaunal diversity and abundance is expected to decline further and to become dominated by freshwater (mostly alien) species, although populations of some estuarine breeding species e.g. *G. aestuaria* may not be negatively affected. Provided dissolved oxygen levels stay above 5 mg/l, the predicted increases in turbidity and nutrient concentrations under scenarios 1 and 2 (see section 2.6) will increase productivity and favour a few species that can feed effectively under these conditions e.g. *L. richardsonii*. However, the more turbid, freshwater conditions anticipated under scenarios 1 and 2 will negatively impact species that are visual predators e.g. *L. amia, P saltatrix* and *A. breviceps* and will probably preclude estuarine dependent marine species or marine vagrants that prefer clear water. Overall fish health is expected to decline progressively from present day conditions under scenarios 2 and 3 (Table 2.38).

Scenario 3 sees a significant increase in runoff from present day conditions, and results in a much greater occurrence of open mouth conditions. This will improve connectivity with the marine environment and may aid recruitment of marine species (category II and III). Improvements in water quality and physical habitat under scenario 3 are, however, moderate with only slight increases in salinity and scouring of sediments anticipated. Only small improvements in fish health are therefore anticipated under scenario 3 (Table 2.38). Anticipated improvements in water quality under scenario 4 are substantial, but salinity, mouth state and physical habitat is expected to remain similar to present day conditions. Fish health is expected to remain unchanged from the present day situation under scenario 4 (Table 2.38).

Table 2.38. Fish health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	65	50	45	70	65	M
b Abundance	50	45	40	60	60	L
c. Community composition	65	40	30	70	65	M
Score (min + average(a : c))/2	**55**	**43**	**34**	**63**	**62**	**M**
Score (minimum a to c)	**50**	**40**	**30**	**60**	**60**	**M**

2.12 Birds

2.12.1 Baseline description

The Onrus Estuary is classified as a small, black water, sandy estuary, where very few bird species are expected to occur (Turpie & Clark, 2007). Due to the lack of tidal influence and flood plain habitats, the estuary is not particularly important for waterbird species. The health of the Onrus Estuary avifaunal community was rated as Fair in the National Biodiversity Assessment (van Niekerk & Turpie, 2012), which is likely explained by the reduced flow rates resulting in increased mouth closure, as well as poor water quality and human disturbance.

Very little historic information is available on the avifauna of the Onrus Estuary. In November 1979 a total of 28 bird species were recorded by Damstra (1980) including the relatively uncommon Pied Avocet, Swift Tern and Water Thick-knee as well as Pied Kingfisher and Malachite Kingfisher. However, only one single count of all waterbirds exists for the estuary carried out by Underhill & Cooper (1983). During this count in January 1981 a total of 10 waterbirds from four species were counted including five Red-knobbed Coots, one Water Thick-knee, three Hartlaub's Gulls and one Cape Wagtail. None of the species recorded are estuary-dependent species as defined by Turpie *et al.* (2012). The dense reed beds in the middle and upper reaches of the estuary support a high density of breeding passerines, including Yellow and Southern Red Bishops and Cape Weavers. The dense reed beds provide shelter and food. Red-knobbed Coots are the most common waterfowl in the estuary and feed on the *Potamogetan* and *Chara* beds (Heineken & Damstra 1983).

2.12.2 Reference condition

Under reference conditions the estuary would have had higher freshwater flows and scouring of the estuary, resulting in greater connection with the marine environment. The reference condition would not have had the increased erosion and nutrient enrichment from catchment activities that has encouraged reed bed growth, and as a result more flood plain habitats that would have been favoured by invertebrate feeders and other waterfowl, would have been present. A higher incidence of breaching would have contributed to a more favourable environment for marine invertebrates and the scouring of the estuarine habitats would have prevented the build-up of anoxic muds. As a result it is expected that under reference condition invertebrate feeding birds such as terns, gulls and waders would have been slightly more abundant than they are under present conditions. It is possible that increased marine connectivity which provided a more suitable foraging and nursery areas for adult and juvenile fish species compared to present day contributed to a more abundant and diverse piscivore community.

Under reference conditions, there would also be an absence of the high levels of human disturbance seen during the holiday periods, which could have had a significant impact on bird fauna. However, the waterbird community at this estuary would not have ever been particularly abundant or diverse.

2.12.3 Summary of change in birds under different scenarios

A summary of the changes in birds under different scenarios is provided in Table 2.39. Estimated health scores are provided in Table 2.40. It is, however, difficult to generalise for a system that has small numbers of birds, and for which numbers are naturally variable. Therefore estimates are of a low confidence.

Table 2.39. Summary of change to birds

Scenario	Summary of changes
1	Moderately reduced MAR but a significant decrease in open mouth states resulting in more limited marine connectivity. Further habitat loss, increased siltation, and decreases in benthic invertebrates and marine fish species. The decreases in food availability and habitat diversity will lead to a slight decrease in bird community composition and species richness.
2	Similar to Scenario 1 but a further decrease in bird community composition and species richness, as well as abundance.
3	Improved hydrology (moving back towards reference) as baseflows are restored, leading to increased scouring of the estuary and mouth breaching, improved benthic marine invertebrates and fish closer to natural. This would lead to a small increase in the number of piscivore species. Bird abundance, species richness and community composition expected to increase slightly as a result.
4	Expected improvements in water quality under scenario 4 are substantial, but mouth state and physical habitat is expected to remain similar to present day conditions. Fish health is expected to remain unchanged from the present day and invertebrate abundance is expected to increase only slightly. No significant changes in birds expected relative to present.

Table 2.40. Bird health scores for Present Day and the four alternative scenarios relative to the Reference Condition

Variable	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	70	68	65	75	75	L
b Abundance	65	60	55	70	70	L
c. Community composition	70	65	55	75	75	L
Score (min + average(a : c))/2	**67**	**62**	**57**	**72**	**72**	**L**
Score (minimum a to c)	**65**	**60**	**55**	**70**	**70**	**L**

2.13 Overall evaluation

2.13.1 Present Ecological Status

Using minimum scores for each component, the overall present ecological status was found to be 92, with abiotic scores being slightly higher than biotic scores. Scores obtained using average-mimimum method were similar for PES and the scenarios and are not summarised here.

Table 2.41. Present ecological status of the Rooiels estuary

Component	Score
Hydology	48
Hydrodynamics and mouth condition	86
Water quality	56
Physical habitat alteration	50
Habitat health score	**60**
Microalgae	40
Macrophytes	49
Invertebrates	55
Fish	50
Birds	65
Biotic health score	**52**
Estuary Health Score	**56**
Ecological Category	**D**

2.13.2 Recommended Ecological Category

Recommended Ecological Category is decided on the basis of conservation importance, using a set of rules. Conservation importance, in turn, comprises biodiversity importance, a score which is taken from an existing dataset, and functional importance, which is decided in the RDM workshop.

Table 2.42. Estuary importance score

Biodiversity importance score	Score	Wt	Estuary Importance (look up remaining scores)	Score	Wt
Plants	70	30	Size	70	15
Invertebrates	10	10	Zonal Type Rarity	10	10
Fish	40	30	Habitat diversity	60	25
Birds	50	30	Biodiversity	60	25
Weighted mean	49		Functional importance	20	25
Max	70				
Biodiversity Importance Score	**60**		**ESTUARY IMPORTANCE SCORE**	**46**	

The biodiversity importance score of the Onrus estuary is 60. The functional importance was estimated to be 20, given its small size and lack of connection to the sea. Using these scores in conjunction with national scores on size, zonal type rarity, and habitat diversity, the overall importance score for the Onrus is 46. This puts it in the category of “low to average importance”.

Since the estuary is not on the list of existing or desired protected areas (Turpie et al. 2012), the rule for REC is to maintain the PES. Therefore the REC is a D category.

2.13.3 Relative contribution of flow and non-flow related impacts on health

The impacts were entirely non-flow related for all components apart from water quality (94% non-flow related). In the case of water quality, there was a very slight impact from residential area; but the main impact was due to change in the level of contact with the sea and upwelled nutrients. If non-flow related impacts were removed, the score would be 99.

2.13.4 Implications of different scenarios for estuary health

Scenario 1 and 2 led a an overall reduction in health from 56 to 42, but did not take the estuary below a D category. Scenarios 3 (increased flows) and 4 (increased water quality) both increased health to a similar degree, which put the estuary into a C category.

Table 2.43. Estuary health scores of alternative flow scenarios for the Rooiels estuary

Component	Present	Sc1	Sc2	Sc3	Sc4
Hydology	48	48	45	76	48
Hydrodynamics and mouth condition	86	63	53	94	86
Water quality	56	46	42	58	74
Physical habitat alteration	50	45	40	50	50
Habitat health score	**60**	**50**	**45**	**70**	**65**
Microalgae	40	35	30	45	50
Macrophytes	49	44	40	54	52
Invertebrates	55	50	45	70	65
Fish	50	40	30	60	60
Birds	65	60	55	70	70
Biotic health score	**52**	**46**	**40**	**60**	**59**
Estuary Health Score	**56**	**48**	**42**	**65**	**62**
Ecological Category	**D**	**D**	**D**	**C**	**C**

2.13.5 Overall confidence

The confidence in the abiotic and biotic scores was medium (average 65 and 63, respectively), with the overall level of confidence being “medium” (weighted average = 64).

2.14 References

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Monthly flows for Reference State

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.179	0.331	0.166	0.055	0.069	0.034	0.103	0.055	7.210	4.506	5.099	3.795	21.602
1921	0.959	0.179	0.124	1.021	0.359	0.090	0.083	0.124	5.106	1.835	7.300	2.546	19.726
1922	0.241	4.485	1.566	0.110	0.097	0.090	1.870	4.244	2.712	9.481	6.479	1.428	32.803
1923	0.290	2.525	0.890	0.124	0.103	0.097	0.097	0.124	3.629	1.332	1.056	0.524	10.791
1924	0.255	0.297	0.124	0.097	0.090	0.076	0.069	0.076	4.485	2.277	0.524	0.428	8.798
1925	1.332	0.545	0.124	0.090	0.076	0.069	0.069	0.166	0.290	2.463	1.166	0.311	6.701
1926	3.761	1.387	0.124	0.090	0.076	0.076	0.069	0.324	0.324	0.145	1.808	0.759	8.943
1927	0.179	0.200	0.110	0.069	0.055	0.055	0.048	0.048	0.621	0.255	0.200	0.580	2.420
1928	0.255	0.131	0.062	0.041	0.034	0.034	0.131	0.124	0.117	1.490	0.690	0.200	3.309
1929	0.145	0.090	0.145	0.069	0.041	0.145	0.076	0.110	0.124	0.124	0.669	0.780	2.518
1930	0.359	0.166	0.090	0.055	0.048	0.041	1.035	0.407	0.090	0.911	2.104	0.869	6.175
1931	1.690	0.649	0.110	0.076	0.124	0.069	0.062	0.497	0.476	0.331	0.186	1.780	6.050
1932	0.745	0.131	0.090	0.069	0.055	0.048	0.048	0.124	1.594	0.945	2.180	0.869	6.898
1933	0.200	0.124	0.076	0.055	0.055	0.048	0.048	0.055	0.097	0.759	1.014	1.449	3.980
1934	0.738	0.200	0.090	0.069	0.055	0.048	0.214	0.918	0.621	0.566	0.345	0.469	4.333
1935	0.269	0.159	0.090	0.455	0.166	0.055	0.055	0.131	0.442	0.635	0.421	0.380	3.258
1936	0.248	0.269	0.214	0.069	0.055	0.055	0.062	0.055	0.690	2.684	1.000	0.531	5.932
1937	0.311	0.145	0.090	0.069	0.055	0.262	0.276	0.545	0.331	0.435	0.642	2.905	6.066
1938	1.277	0.221	0.110	0.076	0.166	0.138	0.110	0.269	0.145	0.800	2.325	0.911	6.548
1939	0.235	0.145	0.090	0.069	2.180	0.821	0.366	0.179	0.835	0.580	0.255	0.324	6.079
1940	0.214	0.531	0.200	0.076	0.062	0.055	1.891	2.449	2.111	2.870	1.490	3.761	15.710
1941	1.470	0.200	0.131	0.103	0.090	0.076	0.076	1.325	1.470	0.497	0.442	0.359	6.239
1942	0.255	0.159	0.166	2.698	0.945	0.110	0.159	0.221	0.179	0.366	0.835	1.290	7.383
1943	0.511	0.166	0.110	0.076	0.069	0.055	0.055	0.731	2.650	0.945	3.629	6.210	15.207
1944	1.828	0.179	0.110	0.090	0.076	0.069	0.221	5.209	3.105	3.933	5.444	1.615	21.879
1945	1.766	0.676	0.131	0.097	0.090	0.690	0.255	0.110	0.248	0.359	0.276	2.305	7.003
1946	0.925	0.159	0.097	0.076	0.069	0.241	0.110	0.097	0.124	2.249	0.925	0.235	5.307
1947	0.255	0.152	0.090	0.069	0.055	0.221	0.159	0.076	0.235	0.600	0.304	0.269	2.485
1948	3.153	1.132	0.103	0.076	0.055	0.055	0.359	0.200	0.159	0.255	0.766	0.455	6.768
1949	0.207	1.000	0.366	0.069	0.055	0.048	0.469	0.179	0.076	0.380	0.200	0.524	3.573
1950	0.731	1.635	0.600	0.380	0.131	0.055	1.021	0.469	5.334	4.740	3.560	5.610	24.266
1951	1.946	0.235	0.131	0.097	0.090	0.076	0.090	0.124	0.345	1.111	3.015	2.995	10.255
1952	1.069	1.801	0.655	0.110	0.090	0.076	1.546	0.711	0.352	1.704	1.325	0.421	9.860
1953	0.228	0.248	0.110	0.083	0.076	0.069	0.179	2.905	1.656	5.527	6.162	1.677	18.920
1954	0.255	0.179	0.110	0.090	3.740	1.290	0.097	0.103	0.435	1.863	4.216	1.449	13.827
1955	0.904	0.380	0.124	0.090	0.076	0.090	0.076	2.284	1.960	1.290	2.256	0.835	10.365
1956	0.352	0.166	0.110	0.090	0.076	0.200	0.166	2.615	4.485	3.685	4.409	2.794	19.148
1957	3.153	0.987	0.124	0.103	0.090	0.221	0.179	2.194	0.959	0.221	1.173	0.621	10.025
1958	0.311	0.179	0.110	0.090	0.076	0.076	3.484	2.325	0.511	0.235	2.056	0.849	10.302
1959	0.669	0.290	0.110	0.090	0.076	0.138	0.076	0.200	0.731	0.421	0.214	0.207	3.222
1960	0.166	0.110	0.110	0.331	0.110	0.055	0.048	0.152	0.214	0.331	0.600	0.945	3.172
1961	0.552	0.179	0.076	0.062	0.055	0.145	0.566	0.235	2.836	1.194	5.196	1.856	12.952
1962	3.381	1.304	0.131	0.124	0.090	0.076	0.090	0.179	0.214	0.821	1.635	0.621	8.666
1963	0.228	0.193	0.103	0.076	0.069	0.380	0.166	0.110	2.035	1.228	4.754	1.759	11.101
1964	0.255	0.380	0.145	0.083	0.076	0.166	0.290	0.304	0.186	0.448	0.393	0.241	2.967
1965	0.207	0.138	0.090	0.069	0.055	0.055	0.055	0.090	0.076	0.635	4.540	3.250	9.260
1966	0.759	0.131	0.090	0.069	0.055	0.055	1.249	0.655	1.090	0.690	1.628	0.752	7.223
1967	0.304	0.186	0.103	0.076	0.069	0.062	0.055	0.241	0.690	0.400	0.614	0.331	3.131
1968	0.241	0.131	0.076	0.055	0.055	0.055	0.200	0.090	0.221	0.152	0.145	0.131	1.552
1969	0.200	0.097	0.048	0.034	0.407	0.145	0.034	0.034	0.235	0.683	1.132	0.497	3.546
1970	0.276	0.138	0.076	0.055	0.041	0.041	0.041	0.241	0.511	1.090	3.898	1.345	7.753
1971	0.207	0.200	0.103	0.076	0.110	0.090	0.531	0.745	0.448	0.386	2.381	1.035	6.312
1972	0.235	0.138	0.090	0.069	0.055	0.055	0.055	0.076	0.110	0.311	0.241	0.255	1.690
1973	0.145	0.090	0.055	0.041	0.034	0.034	0.034	0.780	0.366	0.110	6.251	4.030	11.970
1974	1.069	0.221	0.097	0.076	0.062	0.055	0.055	0.780	0.338	0.621	1.601	0.676	5.651
1975	0.290	0.159	0.090	0.062	0.055	0.076	0.083	0.166	4.340	1.835	1.470	1.035	9.661
1976	0.462	0.414	0.166	0.090	0.614	0.235	0.241	1.049	0.911	4.775	4.616	1.263	14.836
1977	0.241	0.166	0.207	0.090	0.076	0.076	0.166	0.090	0.097	2.035	1.870	1.304	6.418
1978	0.504	0.166	0.103	0.083	1.704	0.600	0.076	0.821	0.545	0.366	0.380	0.255	5.603
1979	0.483	0.214	0.090	0.069	0.055	0.055	0.048	0.159	1.035	0.421	0.179	0.166	2.974
1980	0.207	0.766	0.297	0.980	0.876	0.290	1.021	0.400	0.124	1.649	1.339	1.684	9.633
1981	0.614	0.159	0.103	0.076	0.069	0.062	1.132	0.428	0.614	0.338	0.483	0.311	4.389
1982	0.200	0.124	0.076	0.055	0.704	0.262	0.062	2.781	2.236	2.560	2.470	0.980	12.510
1983	0.255	0.159	0.097	0.076	0.076	0.069	0.110	2.629	0.994	0.490	0.304	0.455	5.714
1984	1.014	0.386	0.455	0.380	0.110	0.152	0.655	0.248	0.110	3.602	1.456	0.276	8.844
1985	0.780	0.331	0.110	0.076	0.069	0.193	0.145	0.076	0.331	0.428	7.790	3.340	13.669
1986	0.566	0.248	0.110	0.083	0.069	0.069	0.366	0.269	0.580	0.393	3.464	2.808	9.025
1987	0.711	0.145	0.097	0.076	0.069	0.062	0.235	0.166	0.380	0.331	1.325	0.655	4.252
1988	0.235	0.138	0.083	0.069	0.055	1.414	3.919	1.290	1.345	4.375	4.519	3.360	20.802
1989	1.849	0.455	0.131	0.103	0.428	0.159	0.897	1.090	2.470	3.609	1.180	0.297	12.668
1990	0.235	0.159	0.110	0.090	0.076	0.076	0.069	0.131	0.635	2.525	0.966	0.255	5.327
1991	3.761	1.366	0.117	0.090	0.076	0.076	0.138	0.414	1.973	0.904	1.566	2.104	12.585
1992	2.160	0.655	0.124	0.097	0.090	0.083	3.105	1.256	0.655	5.948	4.209	0.938	19.320
1993	0.207	0.145	0.166	0.090	0.083	0.076	0.103	0.228	5.299	1.980	1.014	0.476	9.867
1994	0.283	0.159	0.269	0.124	0.076	0.124	0.124	0.856	0.621	1.725	2.815	0.938	8.114
1995	0.324	0.179	0.966	0.331	0.090	0.076	0.069	0.069	0.490	0.918	0.483	0.393	4.388
1996	1.414	1.069	0.311	0.097	0.076	0.069	0.062	1.842	1.325	0.380	0.511	0.297	7.453
1997	0.186	0.345	0.131	0.076	0.069	0.055	0.290	2.553	1.000	0.566	1.435	0.593	7.299
1998	0.200	1.249	2.049	0.607	0.090	0.076	0.359	0.221	0.131	0.138	1.132	3.726	9.978
1999	1.277	0.145	0.097	0.076	0.069	0.317	0.124	0.076	0.179	0.883	0.511	0.980	4.734
2000	0.435	0.131	0.090	0.069	0.055	0.055	0.145	0.200	0.090	2.870	2.629	1.394	8.163
2001	0.545	0.166	0.097	0.635	0.235	0.069	0.366	0.511	0.925	2.249	3.167	1.069	10.034
2002	0.241	0.159	0.103	0.076	0.069	0.856	0.311	1.021	0.414	0.145	4.706	1.815	9.916
2003	0.290	0.166	0.103	0.083	0.069	0.069	0.103	0.069	0.228	0.780	0.386	0.221	2.567
2004	3.498	1.256	0.138	0.235	0.083	0.069	8.011	3.029	3.374	1.290	1.739	0.752	23.474
2005	0.235	0.166	0.110	0.090	0.076	0.069	0.110	0.800	0.359	2.594	3.153	0.973	8.735
2006	0.345	0.200	0.110	0.083	0.076	0.076	0.241	0.241	1.477	2.939	3.160	0.980	9.928
2007	0.304	3.409	1.201	0.110	0.090	0.090	0.083	0.083	0.435	2.180	2.056	3.264	13.305
2008	1.104	4.996	1.739	0.110	0.090	0.090	0.083	0.152	0.814	1.490	1.504	1.345	13.517
2009	0.835	0.283	0.124	0.090	0.076	0.069	0.069	0.235	0.711	0.552	0.248	0.207	3.499

Monthly flows for Present Day

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.097	0.152	0.090	0.041	0.048	0.034	0.055	0.041	3.988	2.291	3.208	3.271	13.316
1921	0.580	0.103	0.076	0.469	0.166	0.062	0.062	0.076	2.719	0.987	4.030	1.428	10.758
1922	0.172	3.202	0.821	0.076	0.069	0.062	0.897	2.146	1.414	6.893	6.031	1.145	22.928
1923	0.186	1.249	0.455	0.076	0.069	0.069	0.062	0.083	1.849	0.697	0.607	0.283	5.685
1924	0.159	0.159	0.083	0.062	0.048	0.041	0.041	0.041	2.339	1.145	0.269	0.228	4.615
1925	0.614	0.269	0.076	0.055	0.048	0.041	0.041	0.076	0.131	1.194	0.573	0.179	3.297
1926	1.842	0.690	0.076	0.055	0.048	0.041	0.041	0.145	0.152	0.090	0.862	0.386	4.428
1927	0.090	0.097	0.062	0.041	0.034	0.034	0.034	0.028	0.283	0.124	0.097	0.262	1.186
1928	0.131	0.069	0.041	0.028	0.021	0.021	0.062	0.062	0.062	0.697	0.331	0.110	1.635
1929	0.076	0.055	0.069	0.041	0.028	0.069	0.041	0.062	0.062	0.069	0.311	0.366	1.249
1930	0.186	0.090	0.048	0.034	0.028	0.028	0.462	0.193	0.055	0.421	0.945	0.421	2.911
1931	0.787	0.324	0.069	0.048	0.062	0.041	0.034	0.221	0.221	0.159	0.110	0.856	2.932
1932	0.380	0.076	0.048	0.041	0.034	0.028	0.028	0.062	0.745	0.448	0.925	0.407	3.222
1933	0.110	0.069	0.048	0.034	0.028	0.028	0.028	0.028	0.048	0.345	0.469	0.635	1.870
1934	0.352	0.110	0.055	0.041	0.028	0.028	0.090	0.414	0.290	0.276	0.186	0.235	2.105
1935	0.152	0.083	0.055	0.186	0.076	0.034	0.034	0.062	0.200	0.297	0.207	0.193	1.579
1936	0.138	0.131	0.103	0.048	0.034	0.034	0.041	0.041	0.317	1.304	0.504	0.269	2.964
1937	0.179	0.083	0.055	0.041	0.034	0.110	0.117	0.248	0.166	0.214	0.304	1.214	2.765
1938	0.573	0.138	0.069	0.048	0.076	0.069	0.055	0.124	0.076	0.380	1.021	0.442	3.071
1939	0.138	0.083	0.055	0.041	1.028	0.380	0.166	0.097	0.393	0.290	0.159	0.186	3.016
1940	0.131	0.255	0.097	0.041	0.034	0.034	0.890	1.166	1.007	1.277	0.724	2.229	7.885
1941	0.856	0.117	0.076	0.069	0.055	0.048	0.048	0.621	0.690	0.262	0.235	0.207	3.284
1942	0.152	0.083	0.083	1.304	0.455	0.062	0.083	0.110	0.097	0.179	0.393	0.566	3.567
1943	0.255	0.097	0.062	0.041	0.034	0.028	0.028	0.324	1.283	0.469	1.690	3.409	7.720
1944	1.042	0.097	0.069	0.062	0.055	0.041	0.097	2.760	1.573	1.815	3.774	1.097	12.482
1945	1.228	0.366	0.083	0.069	0.069	0.311	0.131	0.069	0.131	0.186	0.159	1.069	3.871
1946	0.469	0.090	0.062	0.048	0.041	0.103	0.062	0.055	0.062	1.090	0.455	0.124	2.661
1947	0.138	0.083	0.055	0.041	0.034	0.097	0.076	0.048	0.117	0.283	0.159	0.145	1.276
1948	1.573	0.573	0.069	0.048	0.034	0.034	0.152	0.097	0.076	0.124	0.359	0.235	3.374
1949	0.117	0.455	0.166	0.041	0.034	0.028	0.200	0.083	0.041	0.179	0.103	0.241	1.688
1950	0.338	0.766	0.283	0.166	0.069	0.034	0.462	0.221	2.843	2.201	1.946	4.733	14.062
1951	1.449	0.152	0.076	0.062	0.062	0.055	0.055	0.069	0.166	0.524	1.297	1.352	5.319
1952	0.531	0.883	0.338	0.076	0.055	0.048	0.718	0.338	0.172	0.807	0.600	0.235	4.801
1953	0.124	0.124	0.062	0.048	0.041	0.041	0.083	1.428	0.807	2.601	3.547	1.277	10.183
1954	0.152	0.097	0.076	0.062	1.898	0.649	0.062	0.062	0.214	0.890	1.842	0.676	6.680
1955	0.476	0.221	0.076	0.055	0.048	0.048	0.048	1.104	0.938	0.580	0.931	0.400	4.925
1956	0.207	0.110	0.069	0.055	0.048	0.097	0.083	1.277	2.242	1.808	2.546	2.256	10.798
1957	2.753	0.586	0.076	0.069	0.062	0.110	0.097	1.069	0.483	0.131	0.573	0.331	6.340
1958	0.193	0.103	0.069	0.048	0.048	0.041	1.753	1.132	0.262	0.138	0.897	0.414	5.098
1959	0.345	0.166	0.069	0.048	0.041	0.062	0.041	0.090	0.331	0.207	0.117	0.110	1.627
1960	0.090	0.062	0.062	0.138	0.055	0.034	0.028	0.069	0.097	0.159	0.283	0.421	1.498
1961	0.269	0.090	0.048	0.034	0.028	0.062	0.241	0.110	1.401	0.593	2.449	0.918	6.243
1962	1.918	0.738	0.083	0.076	0.062	0.055	0.055	0.090	0.110	0.386	0.718	0.311	4.602
1963	0.138	0.103	0.062	0.048	0.041	0.159	0.083	0.062	0.980	0.593	2.194	0.849	5.312
1964	0.172	0.207	0.083	0.055	0.048	0.083	0.124	0.145	0.103	0.221	0.200	0.138	1.579
1965	0.117	0.076	0.055	0.041	0.034	0.028	0.034	0.048	0.048	0.297	2.270	1.470	4.518
1966	0.359	0.083	0.055	0.041	0.034	0.034	0.566	0.297	0.504	0.345	0.669	0.352	3.339
1967	0.179	0.110	0.062	0.041	0.034	0.034	0.034	0.103	0.317	0.193	0.290	0.179	1.576
1968	0.131	0.069	0.048	0.034	0.034	0.028	0.090	0.048	0.103	0.076	0.076	0.069	0.806
1969	0.097	0.055	0.034	0.021	0.159	0.069	0.021	0.021	0.103	0.311	0.524	0.255	1.670
1970	0.145	0.076	0.048	0.034	0.028	0.028	0.028	0.103	0.228	0.504	1.670	0.621	3.513
1971	0.124	0.110	0.062	0.048	0.055	0.048	0.235	0.345	0.221	0.200	0.980	0.469	2.897
1972	0.145	0.076	0.055	0.041	0.034	0.028	0.028	0.041	0.055	0.145	0.117	0.124	0.889
1973	0.076	0.048	0.034	0.028	0.028	0.021	0.021	0.352	0.172	0.062	3.395	1.925	6.162
1974	0.483	0.131	0.062	0.048	0.041	0.034	0.034	0.359	0.166	0.290	0.738	0.345	2.731
1975	0.166	0.090	0.055	0.034	0.028	0.041	0.041	0.076	2.249	0.938	0.614	0.462	4.794
1976	0.248	0.214	0.090	0.055	0.269	0.103	0.110	0.483	0.435	2.125	2.519	0.752	7.403
1977	0.152	0.097	0.110	0.062	0.055	0.048	0.083	0.055	0.062	0.987	0.890	0.586	3.187
1978	0.262	0.097	0.069	0.055	0.787	0.276	0.041	0.373	0.255	0.179	0.193	0.152	2.739
1979	0.241	0.110	0.055	0.041	0.034	0.028	0.028	0.069	0.469	0.207	0.097	0.083	1.462
1980	0.103	0.345	0.131	0.428	0.386	0.131	0.469	0.200	0.069	0.787	0.614	0.724	4.387
1981	0.311	0.090	0.062	0.048	0.041	0.034	0.511	0.200	0.283	0.172	0.235	0.166	2.153
1982	0.097	0.069	0.048	0.034	0.297	0.110	0.041	1.373	1.076	1.090	1.290	0.552	6.077
1983	0.179	0.090	0.062	0.055	0.048	0.041	0.055	1.290	0.497	0.241	0.172	0.235	2.965
1984	0.490	0.200	0.200	0.159	0.062	0.076	0.297	0.124	0.062	1.835	0.745	0.166	4.416
1985	0.386	0.179	0.069	0.048	0.041	0.090	0.069	0.048	0.152	0.207	4.126	1.697	7.112
1986	0.290	0.145	0.076	0.062	0.055	0.048	0.166	0.131	0.276	0.200	1.525	1.297	4.271
1987	0.380	0.090	0.062	0.048	0.041	0.034	0.103	0.083	0.179	0.166	0.600	0.324	2.110
1988	0.131	0.076	0.048	0.034	0.034	0.642	1.953	0.649	0.642	2.173	2.567	2.698	11.647
1989	1.380	0.262	0.076	0.062	0.186	0.083	0.414	0.504	1.201	1.615	0.573	0.179	6.535
1990	0.131	0.090	0.069	0.055	0.041	0.041	0.041	0.062	0.290	1.221	0.483	0.145	2.669
1991	1.925	0.704	0.069	0.055	0.048	0.041	0.069	0.186	0.938	0.442	0.655	0.876	6.008
1992	1.166	0.400	0.076	0.055	0.055	0.048	1.539	0.614	0.311	2.870	2.277	0.580	9.991
1993	0.117	0.083	0.090	0.062	0.055	0.048	0.055	0.110	2.815	1.049	0.448	0.255	5.187
1994	0.172	0.097	0.131	0.069	0.048	0.062	0.069	0.393	0.297	0.773	1.159	0.435	3.705
1995	0.193	0.110	0.448	0.152	0.048	0.048	0.041	0.041	0.228	0.428	0.241	0.200	2.178
1996	0.669	0.511	0.152	0.055	0.041	0.034	0.034	0.869	0.621	0.200	0.255	0.172	3.613
1997	0.103	0.159	0.069	0.041	0.034	0.034	0.124	1.242	0.490	0.283	0.607	0.290	3.476
1998	0.110	0.586	0.959	0.290	0.048	0.041	0.152	0.103	0.076	0.076	0.531	1.690	4.662
1999	0.614	0.083	0.062	0.048	0.041	0.131	0.062	0.048	0.090	0.414	0.255	0.442	2.290
2000	0.221	0.076	0.048	0.041	0.034	0.028	0.062	0.090	0.048	1.421	1.214	0.614	3.897
2001	0.276	0.103	0.062	0.269	0.103	0.041	0.159	0.241	0.428	0.973	1.421	0.531	4.607
2002	0.152	0.090	0.062	0.048	0.041	0.373	0.145	0.469	0.207	0.076	2.477	0.959	5.099
2003	0.172	0.090	0.069	0.055	0.041	0.041	0.055	0.041	0.110	0.359	0.193	0.124	1.350
2004	1.766	0.642	0.076	0.110	0.048	0.041	4.471	1.649	1.677	0.731	1.180	0.400	12.791
2005	0.145	0.090	0.069	0.062	0.055	0.048	0.062	0.366	0.179	1.277	1.352	0.448	4.153
2006	0.207	0.124	0.069	0.048	0.041	0.041	0.110	0.117	0.697	1.283	1.435	0.504	4.676
2007	0.186	1.732	0.621	0.069	0.055	0.055	0.048	0.048	0.200	1.049	0.931	1.449	6.443
2008	0.531	2.656	0.918	0.069	0.062	0.055	0.048	0.076	0.380	0.704	0.662	0.580	6.741
2009	0.407	0.166	0.069	0.048	0.041	0.041	0.041	0.103	0.324	0.262	0.138	0.103	1.743

Monthly flows for EWR Scenario 1

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.065	0.120	0.058	0.009	0.016	0.002	0.023	0.009	3.956	2.259	3.176	3.239	12.937
1921	0.548	0.071	0.044	0.437	0.134	0.030	0.030	0.044	2.687	0.955	3.998	1.396	10.379
1922	0.140	3.170	0.789	0.044	0.037	0.030	0.865	2.114	1.382	6.861	5.999	1.113	22.549
1923	0.154	1.217	0.423	0.044	0.037	0.037	0.030	0.051	1.817	0.665	0.575	0.251	5.306
1924	0.127	0.127	0.051	0.030	0.016	0.009	0.009	0.009	2.307	1.113	0.237	0.196	4.236
1925	0.582	0.237	0.044	0.023	0.016	0.009	0.009	0.044	0.099	1.162	0.541	0.147	2.918
1926	1.810	0.658	0.044	0.023	0.016	0.009	0.009	0.113	0.120	0.058	0.830	0.354	4.049
1927	0.058	0.065	0.030	0.009	0.002	0.002	0.002	0.014	0.251	0.092	0.065	0.230	0.825
1928	0.099	0.037	0.009	0.014	0.011	0.011	0.030	0.030	0.030	0.665	0.299	0.078	1.316
1929	0.044	0.023	0.037	0.009	0.014	0.037	0.009	0.030	0.030	0.037	0.279	0.334	0.888
1930	0.154	0.058	0.016	0.002	0.014	0.014	0.430	0.161	0.023	0.389	0.913	0.389	2.567
1931	0.755	0.292	0.037	0.016	0.030	0.009	0.002	0.189	0.189	0.127	0.078	0.824	2.553
1932	0.348	0.044	0.016	0.009	0.002	0.014	0.014	0.030	0.713	0.416	0.893	0.375	2.878
1933	0.078	0.037	0.016	0.002	0.014	0.014	0.014	0.014	0.016	0.313	0.437	0.603	1.562
1934	0.320	0.078	0.023	0.009	0.014	0.014	0.058	0.382	0.258	0.244	0.154	0.203	1.761
1935	0.120	0.051	0.023	0.154	0.044	0.002	0.002	0.030	0.168	0.265	0.175	0.161	1.200
1936	0.106	0.099	0.071	0.016	0.002	0.002	0.009	0.009	0.285	1.272	0.472	0.237	2.585
1937	0.147	0.051	0.023	0.009	0.002	0.078	0.085	0.216	0.134	0.182	0.272	1.182	2.386
1938	0.541	0.106	0.037	0.016	0.044	0.037	0.023	0.092	0.044	0.348	0.989	0.410	2.692
1939	0.106	0.051	0.023	0.009	0.996	0.348	0.134	0.065	0.361	0.258	0.127	0.154	2.637
1940	0.099	0.223	0.065	0.009	0.002	0.002	0.858	1.134	0.975	1.245	0.692	2.197	7.506
1941	0.824	0.085	0.044	0.037	0.023	0.016	0.016	0.589	0.658	0.230	0.203	0.175	2.905
1942	0.120	0.051	0.051	1.272	0.423	0.030	0.051	0.078	0.065	0.147	0.361	0.534	3.188
1943	0.223	0.065	0.030	0.009	0.002	0.014	0.014	0.292	1.251	0.437	1.658	3.377	7.376
1944	1.010	0.065	0.037	0.030	0.023	0.009	0.065	2.728	1.541	1.783	3.742	1.065	12.103
1945	1.196	0.334	0.051	0.037	0.037	0.279	0.099	0.037	0.099	0.154	0.127	1.037	3.492
1946	0.437	0.058	0.030	0.016	0.009	0.071	0.030	0.023	0.030	1.058	0.423	0.092	2.282
1947	0.106	0.051	0.023	0.009	0.002	0.065	0.044	0.016	0.085	0.251	0.127	0.113	0.897
1948	1.541	0.541	0.037	0.016	0.002	0.002	0.120	0.065	0.044	0.092	0.327	0.203	2.995
1949	0.085	0.423	0.134	0.009	0.002	0.014	0.168	0.051	0.009	0.147	0.071	0.209	1.327
1950	0.306	0.734	0.251	0.134	0.037	0.002	0.430	0.189	2.811	2.169	1.914	4.701	13.683
1951	1.417	0.120	0.044	0.030	0.030	0.023	0.023	0.037	0.134	0.492	1.265	1.320	4.940
1952	0.499	0.851	0.306	0.044	0.023	0.016	0.686	0.306	0.140	0.775	0.568	0.203	4.422
1953	0.092	0.092	0.030	0.016	0.009	0.009	0.051	1.396	0.775	2.569	3.515	1.245	9.804
1954	0.120	0.065	0.044	0.030	1.866	0.617	0.030	0.030	0.182	0.858	1.810	0.644	6.301
1955	0.444	0.189	0.044	0.023	0.016	0.016	0.016	1.072	0.906	0.548	0.899	0.368	4.546
1956	0.175	0.078	0.037	0.023	0.016	0.065	0.051	1.245	2.210	1.776	2.514	2.224	10.419
1957	2.721	0.554	0.044	0.037	0.030	0.078	0.065	1.037	0.451	0.099	0.541	0.299	5.961
1958	0.161	0.071	0.037	0.016	0.016	0.009	1.721	1.100	0.230	0.106	0.865	0.382	4.719
1959	0.313	0.134	0.037	0.016	0.009	0.030	0.009	0.058	0.299	0.175	0.085	0.078	1.248
1960	0.058	0.030	0.030	0.106	0.023	0.002	0.014	0.037	0.065	0.127	0.251	0.389	1.137
1961	0.237	0.058	0.016	0.002	0.014	0.030	0.209	0.078	1.369	0.561	2.417	0.886	5.882
1962	1.886	0.706	0.051	0.044	0.030	0.023	0.023	0.058	0.078	0.354	0.686	0.279	4.223
1963	0.106	0.071	0.030	0.016	0.009	0.127	0.051	0.030	0.948	0.561	2.162	0.817	4.933
1964	0.140	0.175	0.051	0.023	0.016	0.051	0.092	0.113	0.071	0.189	0.168	0.106	1.200
1965	0.085	0.044	0.023	0.009	0.002	0.014	0.002	0.016	0.016	0.265	2.238	1.438	4.157
1966	0.327	0.051	0.023	0.009	0.002	0.002	0.534	0.265	0.472	0.313	0.637	0.320	2.960
1967	0.147	0.078	0.030	0.009	0.002	0.002	0.002	0.071	0.285	0.161	0.258	0.147	1.197
1968	0.099	0.037	0.016	0.002	0.002	0.014	0.058	0.016	0.071	0.044	0.044	0.037	0.445
1969	0.065	0.023	0.002	0.011	0.127	0.037	0.011	0.011	0.071	0.279	0.492	0.223	1.354
1970	0.113	0.044	0.016	0.002	0.014	0.014	0.014	0.071	0.196	0.472	1.638	0.589	3.187
1971	0.092	0.078	0.030	0.016	0.023	0.016	0.203	0.313	0.189	0.168	0.948	0.437	2.518
1972	0.113	0.044	0.023	0.009	0.002	0.014	0.014	0.009	0.023	0.113	0.085	0.092	0.545
1973	0.044	0.016	0.002	0.014	0.014	0.011	0.011	0.320	0.140	0.030	3.363	1.893	5.861
1974	0.451	0.099	0.030	0.016	0.009	0.002	0.002	0.327	0.134	0.258	0.706	0.313	2.352
1975	0.134	0.058	0.023	0.002	0.014	0.009	0.009	0.044	2.217	0.906	0.582	0.430	4.433
1976	0.216	0.182	0.058	0.023	0.237	0.071	0.078	0.451	0.403	2.093	2.487	0.720	7.024
1977	0.120	0.065	0.078	0.030	0.023	0.016	0.051	0.023	0.030	0.955	0.858	0.554	2.808
1978	0.230	0.065	0.037	0.023	0.755	0.244	0.009	0.341	0.223	0.147	0.161	0.120	2.360
1979	0.209	0.078	0.023	0.009	0.002	0.014	0.014	0.037	0.437	0.175	0.065	0.051	1.118
1980	0.071	0.313	0.099	0.396	0.354	0.099	0.437	0.168	0.037	0.755	0.582	0.692	4.008
1981	0.279	0.058	0.030	0.016	0.009	0.002	0.479	0.168	0.251	0.140	0.203	0.134	1.774
1982	0.065	0.037	0.016	0.002	0.265	0.078	0.009	1.341	1.044	1.058	1.258	0.520	5.698
1983	0.147	0.058	0.030	0.023	0.016	0.009	0.023	1.258	0.465	0.209	0.140	0.203	2.586
1984	0.458	0.168	0.168	0.127	0.030	0.044	0.265	0.092	0.030	1.803	0.713	0.134	4.037
1985	0.354	0.147	0.037	0.016	0.009	0.058	0.037	0.016	0.120	0.175	4.094	1.665	6.733
1986	0.258	0.113	0.044	0.030	0.023	0.016	0.134	0.099	0.244	0.168	1.493	1.265	3.892
1987	0.348	0.058	0.030	0.016	0.009	0.002	0.071	0.051	0.147	0.134	0.568	0.292	1.731
1988	0.099	0.044	0.016	0.002	0.002	0.610	1.921	0.617	0.610	2.141	2.535	2.666	11.268
1989	1.348	0.230	0.044	0.030	0.154	0.051	0.382	0.472	1.169	1.583	0.541	0.147	6.156
1990	0.099	0.058	0.037	0.023	0.009	0.009	0.009	0.030	0.258	1.189	0.451	0.113	2.290
1991	1.893	0.672	0.037	0.023	0.016	0.009	0.037	0.154	0.906	0.410	0.623	0.844	5.629
1992	1.134	0.368	0.044	0.023	0.023	0.016	1.507	0.582	0.279	2.838	2.245	0.548	9.612
1993	0.085	0.051	0.058	0.030	0.023	0.016	0.023	0.078	2.783	1.017	0.416	0.223	4.808
1994	0.140	0.065	0.099	0.037	0.016	0.030	0.037	0.361	0.265	0.741	1.127	0.403	3.326
1995	0.161	0.078	0.416	0.120	0.016	0.016	0.009	0.009	0.196	0.396	0.209	0.168	1.799
1996	0.637	0.479	0.120	0.023	0.009	0.002	0.002	0.837	0.589	0.168	0.223	0.140	3.234
1997	0.071	0.127	0.037	0.009	0.002	0.002	0.092	1.210	0.458	0.251	0.575	0.258	3.097
1998	0.078	0.554	0.927	0.258	0.016	0.009	0.120	0.071	0.044	0.044	0.499	1.658	4.283
1999	0.582	0.051	0.030	0.016	0.009	0.099	0.030	0.016	0.058	0.382	0.223	0.410	1.911
2000	0.189	0.044	0.016	0.009	0.002	0.014	0.030	0.058	0.016	1.389	1.182	0.582	3.536
2001	0.244	0.071	0.030	0.237	0.071	0.009	0.127	0.209	0.396	0.941	1.389	0.499	4.228
2002	0.120	0.058	0.030	0.016	0.009	0.341	0.113	0.437	0.175	0.044	2.445	0.927	4.720
2003	0.140	0.058	0.037	0.023	0.009	0.009	0.023	0.009	0.078	0.327	0.161	0.092	0.971
2004	1.734	0.610	0.044	0.078	0.016	0.009	4.439	1.617	1.645	0.699	1.148	0.368	12.412
2005	0.113	0.058	0.037	0.030	0.023	0.016	0.030	0.334	0.147	1.245	1.320	0.416	3.774
2006	0.175	0.092	0.037	0.016	0.009	0.009	0.078	0.085	0.665	1.251	1.403	0.472	4.297
2007	0.154	1.700	0.589	0.037	0.023	0.023	0.016	0.016	0.168	1.017	0.899	1.417	6.064
2008	0.499	2.624	0.886	0.037	0.030	0.023	0.016	0.044	0.348	0.672	0.630	0.548	6.362
2009	0.375	0.134	0.037	0.016	0.009	0.009	0.009	0.071	0.292	0.230	0.106	0.071	1.364

Monthly flows for EWR Scenario 2

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.034	0.089	0.027	0.014	0.016	0.011	0.018	0.014	3.925	2.228	3.145	3.208	12.728
1921	0.517	0.040	0.013	0.406	0.103	0.021	0.021	0.013	2.656	0.924	3.967	1.365	10.044
1922	0.109	3.139	0.758	0.013	0.006	0.021	0.834	2.083	1.351	6.830	5.968	1.082	22.192
1923	0.123	1.186	0.392	0.013	0.006	0.006	0.021	0.020	1.786	0.634	0.544	0.220	4.949
1924	0.096	0.096	0.020	0.021	0.016	0.014	0.014	0.014	2.276	1.082	0.206	0.165	4.018
1925	0.551	0.206	0.013	0.018	0.016	0.014	0.014	0.013	0.068	1.131	0.510	0.116	2.669
1926	1.779	0.627	0.013	0.018	0.016	0.014	0.014	0.082	0.089	0.027	0.799	0.323	3.800
1927	0.027	0.034	0.021	0.014	0.011	0.011	0.011	0.009	0.220	0.061	0.034	0.199	0.652
1928	0.068	0.006	0.014	0.009	0.007	0.007	0.021	0.021	0.021	0.634	0.268	0.047	1.121
1929	0.013	0.018	0.006	0.014	0.009	0.006	0.014	0.021	0.021	0.006	0.248	0.303	0.678
1930	0.123	0.027	0.016	0.011	0.009	0.009	0.399	0.130	0.018	0.358	0.882	0.358	2.341
1931	0.724	0.261	0.006	0.016	0.021	0.014	0.011	0.158	0.158	0.096	0.047	0.793	2.304
1932	0.317	0.013	0.016	0.014	0.011	0.009	0.009	0.021	0.682	0.385	0.862	0.344	2.683
1933	0.047	0.006	0.016	0.011	0.009	0.009	0.009	0.009	0.016	0.282	0.406	0.572	1.393
1934	0.289	0.047	0.018	0.014	0.009	0.009	0.027	0.351	0.227	0.213	0.123	0.172	1.499
1935	0.089	0.020	0.018	0.123	0.013	0.011	0.011	0.021	0.137	0.234	0.144	0.130	0.951
1936	0.075	0.068	0.040	0.016	0.011	0.011	0.014	0.014	0.254	1.241	0.441	0.206	2.390
1937	0.116	0.020	0.018	0.014	0.011	0.047	0.054	0.185	0.103	0.151	0.241	1.151	2.110
1938	0.510	0.075	0.006	0.016	0.013	0.006	0.018	0.061	0.013	0.317	0.958	0.379	2.371
1939	0.075	0.020	0.018	0.014	0.965	0.317	0.103	0.034	0.330	0.227	0.096	0.123	2.321
1940	0.068	0.192	0.034	0.014	0.011	0.011	0.827	1.103	0.944	1.214	0.661	2.166	7.244
1941	0.793	0.054	0.013	0.006	0.018	0.016	0.016	0.558	0.627	0.199	0.172	0.144	2.615
1942	0.089	0.020	0.020	1.241	0.392	0.021	0.020	0.047	0.034	0.116	0.330	0.503	2.831
1943	0.192	0.034	0.021	0.014	0.011	0.009	0.009	0.261	1.220	0.406	1.627	3.346	7.150
1944	0.979	0.034	0.006	0.021	0.018	0.014	0.034	2.697	1.510	1.752	3.711	1.034	11.809
1945	1.165	0.303	0.020	0.006	0.006	0.248	0.068	0.006	0.068	0.123	0.096	1.006	3.114
1946	0.406	0.027	0.021	0.016	0.014	0.040	0.021	0.018	0.021	1.027	0.392	0.061	2.062
1947	0.075	0.020	0.018	0.014	0.011	0.034	0.013	0.016	0.054	0.220	0.096	0.082	0.652
1948	1.510	0.510	0.006	0.016	0.011	0.011	0.089	0.034	0.013	0.061	0.296	0.172	2.729
1949	0.054	0.392	0.103	0.014	0.011	0.009	0.137	0.020	0.014	0.116	0.040	0.178	1.087
1950	0.275	0.703	0.220	0.103	0.006	0.011	0.399	0.158	2.780	2.138	1.883	4.670	13.345
1951	1.386	0.089	0.013	0.021	0.021	0.018	0.018	0.006	0.103	0.461	1.234	1.289	4.658
1952	0.468	0.820	0.275	0.013	0.018	0.016	0.655	0.275	0.109	0.744	0.537	0.172	4.101
1953	0.061	0.061	0.021	0.016	0.014	0.014	0.020	1.365	0.744	2.538	3.484	1.214	9.550
1954	0.089	0.034	0.013	0.021	1.835	0.586	0.021	0.021	0.151	0.827	1.779	0.613	5.988
1955	0.413	0.158	0.013	0.018	0.016	0.016	0.016	1.041	0.875	0.517	0.868	0.337	4.287
1956	0.144	0.047	0.006	0.018	0.016	0.034	0.020	1.214	2.179	1.745	2.483	2.193	10.098
1957	2.690	0.523	0.013	0.006	0.021	0.047	0.034	1.006	0.420	0.068	0.510	0.268	5.604
1958	0.130	0.040	0.006	0.016	0.016	0.014	1.690	1.069	0.199	0.075	0.834	0.351	4.439
1959	0.282	0.103	0.006	0.016	0.014	0.021	0.014	0.027	0.268	0.144	0.054	0.047	0.994
1960	0.027	0.021	0.021	0.075	0.018	0.011	0.009	0.006	0.034	0.096	0.220	0.358	0.896
1961	0.206	0.027	0.016	0.011	0.009	0.021	0.178	0.047	1.338	0.530	2.386	0.855	5.623
1962	1.855	0.675	0.020	0.013	0.021	0.018	0.018	0.027	0.047	0.323	0.655	0.248	3.919
1963	0.075	0.040	0.021	0.016	0.014	0.096	0.020	0.021	0.917	0.530	2.131	0.786	4.665
1964	0.109	0.144	0.020	0.018	0.016	0.020	0.061	0.082	0.040	0.158	0.137	0.075	0.879
1965	0.054	0.013	0.018	0.014	0.011	0.009	0.011	0.016	0.016	0.234	2.207	1.407	4.010
1966	0.296	0.020	0.018	0.014	0.011	0.011	0.503	0.234	0.441	0.282	0.606	0.289	2.725
1967	0.116	0.047	0.021	0.014	0.011	0.011	0.011	0.040	0.254	0.130	0.227	0.116	0.998
1968	0.068	0.006	0.016	0.011	0.011	0.009	0.027	0.016	0.040	0.013	0.013	0.006	0.236
1969	0.034	0.018	0.011	0.007	0.096	0.006	0.007	0.007	0.040	0.248	0.461	0.192	1.127
1970	0.082	0.013	0.016	0.011	0.009	0.009	0.009	0.040	0.165	0.441	1.607	0.558	2.961
1971	0.061	0.047	0.021	0.016	0.018	0.016	0.172	0.282	0.158	0.137	0.917	0.406	2.250
1972	0.082	0.013	0.018	0.014	0.011	0.009	0.009	0.014	0.018	0.082	0.054	0.061	0.385
1973	0.013	0.016	0.011	0.009	0.009	0.007	0.007	0.289	0.109	0.021	3.332	1.862	5.685
1974	0.420	0.068	0.021	0.016	0.014	0.011	0.011	0.296	0.103	0.227	0.675	0.282	2.143
1975	0.103	0.027	0.018	0.011	0.009	0.014	0.014	0.013	2.186	0.875	0.551	0.399	4.220
1976	0.185	0.151	0.027	0.018	0.206	0.040	0.047	0.420	0.372	2.062	2.456	0.689	6.672
1977	0.089	0.034	0.047	0.021	0.018	0.016	0.020	0.018	0.021	0.924	0.827	0.523	2.557
1978	0.199	0.034	0.006	0.018	0.724	0.213	0.014	0.310	0.192	0.116	0.130	0.089	2.044
1979	0.178	0.047	0.018	0.014	0.011	0.009	0.009	0.006	0.406	0.144	0.034	0.020	0.896
1980	0.040	0.282	0.068	0.365	0.323	0.068	0.406	0.137	0.006	0.724	0.551	0.661	3.630
1981	0.248	0.027	0.021	0.016	0.014	0.011	0.448	0.137	0.220	0.109	0.172	0.103	1.525
1982	0.034	0.006	0.016	0.011	0.234	0.047	0.014	1.310	1.013	1.027	1.227	0.489	5.427
1983	0.116	0.027	0.021	0.018	0.016	0.014	0.018	1.227	0.434	0.178	0.109	0.172	2.349
1984	0.427	0.137	0.137	0.096	0.021	0.013	0.234	0.061	0.021	1.772	0.682	0.103	3.702
1985	0.323	0.116	0.006	0.016	0.014	0.027	0.006	0.016	0.089	0.144	4.063	1.634	6.453
1986	0.227	0.082	0.013	0.021	0.018	0.016	0.103	0.068	0.213	0.137	1.462	1.234	3.593
1987	0.317	0.027	0.021	0.016	0.014	0.011	0.040	0.020	0.116	0.103	0.537	0.261	1.482
1988	0.068	0.013	0.016	0.011	0.011	0.579	1.890	0.586	0.579	2.110	2.504	2.635	11.002
1989	1.317	0.199	0.013	0.021	0.123	0.020	0.351	0.441	1.138	1.552	0.510	0.116	5.799
1990	0.068	0.027	0.006	0.018	0.014	0.014	0.014	0.021	0.227	1.158	0.420	0.082	2.067
1991	1.862	0.641	0.006	0.018	0.016	0.014	0.006	0.123	0.875	0.379	0.592	0.813	5.344
1992	1.103	0.337	0.013	0.018	0.018	0.016	1.476	0.551	0.248	2.807	2.214	0.517	9.318
1993	0.054	0.020	0.027	0.021	0.018	0.016	0.018	0.047	2.752	0.986	0.385	0.192	4.535
1994	0.109	0.034	0.068	0.006	0.016	0.021	0.006	0.330	0.234	0.710	1.096	0.372	3.001
1995	0.130	0.047	0.385	0.089	0.016	0.016	0.014	0.014	0.165	0.365	0.178	0.137	1.554
1996	0.606	0.448	0.089	0.018	0.014	0.011	0.011	0.806	0.558	0.137	0.192	0.109	2.999
1997	0.040	0.096	0.006	0.014	0.011	0.011	0.061	1.179	0.427	0.220	0.544	0.227	2.835
1998	0.047	0.523	0.896	0.227	0.016	0.014	0.089	0.040	0.013	0.013	0.468	1.627	3.972
1999	0.551	0.020	0.021	0.016	0.014	0.068	0.021	0.016	0.027	0.351	0.192	0.379	1.674
2000	0.158	0.013	0.016	0.014	0.011	0.009	0.021	0.027	0.016	1.358	1.151	0.551	3.344
2001	0.213	0.040	0.021	0.206	0.040	0.014	0.096	0.178	0.365	0.910	1.358	0.468	3.907
2002	0.089	0.027	0.021	0.016	0.014	0.310	0.082	0.406	0.144	0.013	2.414	0.896	4.430
2003	0.109	0.027	0.006	0.018	0.014	0.014	0.018	0.014	0.047	0.296	0.130	0.061	0.753
2004	1.703	0.579	0.013	0.047	0.016	0.014	4.408	1.586	1.614	0.668	1.117	0.337	12.101
2005	0.082	0.027	0.006	0.021	0.018	0.016	0.021	0.303	0.116	1.214	1.289	0.385	3.497
2006	0.144	0.061	0.006	0.016	0.014	0.014	0.047	0.054	0.634	1.220	1.372	0.441	4.021
2007	0.123	1.669	0.558	0.006	0.018	0.018	0.016	0.016	0.137	0.986	0.868	1.386	5.801
2008	0.468	2.593	0.855	0.006	0.021	0.018	0.016	0.013	0.317	0.641	0.599	0.517	6.063
2009	0.344	0.103	0.006	0.016	0.014	0.014	0.014	0.040	0.261	0.199	0.075	0.040	1.124

Monthly flows for EWR Scenario 3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.138	0.242	0.128	0.048	0.059	0.034	0.079	0.048	5.599	3.399	4.154	3.533	17.459
1921	0.770	0.141	0.100	0.745	0.263	0.076	0.073	0.100	3.913	1.411	5.665	1.987	15.242
1922	0.207	3.844	1.194	0.093	0.083	0.076	1.384	3.195	2.063	8.187	6.255	1.287	27.866
1923	0.238	1.887	0.673	0.100	0.086	0.083	0.080	0.104	2.739	1.015	0.832	0.404	8.238
1924	0.207	0.228	0.104	0.080	0.069	0.059	0.055	0.059	3.412	1.711	0.397	0.328	6.707
1925	0.973	0.407	0.100	0.073	0.062	0.055	0.055	0.121	0.211	1.829	0.870	0.245	4.999
1926	2.802	1.039	0.100	0.073	0.062	0.059	0.055	0.235	0.238	0.118	1.335	0.573	6.686
1927	0.135	0.149	0.086	0.055	0.045	0.045	0.041	0.038	0.452	0.190	0.149	0.421	1.803
1928	0.193	0.100	0.052	0.035	0.028	0.028	0.097	0.093	0.090	1.094	0.511	0.155	2.472
1929	0.111	0.073	0.107	0.055	0.035	0.107	0.059	0.086	0.093	0.097	0.490	0.573	1.884
1930	0.273	0.128	0.069	0.045	0.038	0.035	0.749	0.300	0.073	0.666	1.525	0.645	4.543
1931	1.239	0.487	0.090	0.062	0.093	0.055	0.048	0.359	0.349	0.245	0.148	1.318	4.491
1932	0.563	0.104	0.069	0.055	0.045	0.038	0.038	0.093	1.170	0.697	1.553	0.638	5.060
1933	0.155	0.097	0.062	0.045	0.042	0.038	0.038	0.042	0.073	0.552	0.742	1.042	2.925
1934	0.545	0.155	0.073	0.055	0.042	0.038	0.152	0.666	0.456	0.421	0.266	0.352	3.219
1935	0.211	0.121	0.073	0.321	0.121	0.045	0.045	0.097	0.321	0.466	0.314	0.287	2.419
1936	0.193	0.200	0.159	0.059	0.045	0.045	0.052	0.048	0.504	1.994	0.752	0.400	4.448
1937	0.245	0.114	0.073	0.055	0.045	0.186	0.197	0.397	0.249	0.325	0.473	2.060	4.416
1938	0.925	0.180	0.090	0.062	0.121	0.104	0.083	0.197	0.111	0.590	1.673	0.677	4.810
1939	0.187	0.114	0.073	0.055	1.604	0.601	0.266	0.138	0.614	0.435	0.207	0.255	4.548
1940	0.173	0.393	0.149	0.059	0.048	0.045	1.391	1.808	1.559	2.074	1.107	2.995	11.798
1941	1.163	0.159	0.104	0.086	0.073	0.062	0.062	0.973	1.080	0.380	0.339	0.283	4.762
1942	0.204	0.121	0.125	2.001	0.700	0.086	0.121	0.166	0.138	0.273	0.614	0.928	5.475
1943	0.383	0.132	0.086	0.059	0.052	0.042	0.042	0.528	1.967	0.707	2.660	4.810	11.464
1944	1.435	0.138	0.090	0.076	0.066	0.055	0.159	3.985	2.339	2.874	4.609	1.356	17.181
1945	1.497	0.521	0.107	0.083	0.080	0.501	0.193	0.090	0.190	0.273	0.218	1.687	5.437
1946	0.697	0.125	0.080	0.062	0.055	0.172	0.086	0.076	0.093	1.670	0.690	0.180	3.984
1947	0.197	0.118	0.073	0.055	0.045	0.159	0.118	0.062	0.176	0.442	0.232	0.207	1.881
1948	2.363	0.853	0.086	0.062	0.045	0.045	0.256	0.149	0.118	0.190	0.563	0.345	5.071
1949	0.162	0.728	0.266	0.055	0.045	0.038	0.335	0.131	0.059	0.280	0.152	0.383	2.631
1950	0.535	1.201	0.442	0.273	0.100	0.045	0.742	0.345	4.089	3.471	2.753	5.172	19.164
1951	1.698	0.194	0.104	0.080	0.076	0.066	0.073	0.097	0.256	0.818	2.156	2.174	7.787
1952	0.800	1.342	0.497	0.093	0.073	0.062	1.132	0.525	0.262	1.256	0.963	0.328	7.331
1953	0.176	0.186	0.086	0.066	0.059	0.055	0.131	2.167	1.232	4.064	4.855	1.477	14.552
1954	0.204	0.138	0.093	0.076	2.819	0.970	0.080	0.083	0.325	1.377	3.029	1.063	10.254
1955	0.690	0.301	0.100	0.073	0.062	0.069	0.062	1.694	1.449	0.935	1.594	0.618	7.645
1956	0.280	0.138	0.090	0.073	0.062	0.149	0.125	1.946	3.364	2.747	3.478	2.525	14.973
1957	2.953	0.787	0.100	0.086	0.076	0.166	0.138	1.632	0.721	0.176	0.873	0.476	8.183
1958	0.252	0.141	0.090	0.069	0.062	0.059	2.619	1.729	0.387	0.187	1.477	0.632	7.700
1959	0.507	0.228	0.090	0.069	0.059	0.100	0.059	0.145	0.531	0.314	0.166	0.159	2.425
1960	0.128	0.086	0.086	0.235	0.083	0.045	0.038	0.111	0.156	0.245	0.442	0.683	2.335
1961	0.411	0.135	0.062	0.048	0.042	0.104	0.404	0.173	2.119	0.894	3.823	1.387	9.598
1962	2.650	1.021	0.107	0.100	0.076	0.066	0.073	0.135	0.162	0.604	1.177	0.466	6.634
1963	0.183	0.148	0.083	0.062	0.055	0.270	0.125	0.086	1.508	0.911	3.474	1.304	8.207
1964	0.214	0.294	0.114	0.069	0.062	0.125	0.207	0.225	0.145	0.335	0.297	0.190	2.273
1965	0.162	0.107	0.073	0.055	0.045	0.042	0.045	0.069	0.062	0.466	3.405	2.360	6.889
1966	0.559	0.107	0.073	0.055	0.045	0.045	0.908	0.476	0.797	0.518	1.149	0.552	5.281
1967	0.242	0.148	0.083	0.059	0.052	0.048	0.045	0.172	0.504	0.297	0.452	0.255	2.354
1968	0.186	0.100	0.062	0.045	0.045	0.042	0.145	0.069	0.162	0.114	0.111	0.100	1.179
1969	0.149	0.076	0.041	0.028	0.283	0.107	0.028	0.028	0.169	0.497	0.828	0.376	2.608
1970	0.211	0.107	0.062	0.045	0.035	0.035	0.035	0.172	0.370	0.797	2.784	0.983	5.633
1971	0.166	0.155	0.083	0.062	0.083	0.069	0.383	0.545	0.335	0.293	1.681	0.752	4.605
1972	0.190	0.107	0.073	0.055	0.045	0.042	0.042	0.059	0.083	0.228	0.179	0.190	1.290
1973	0.111	0.069	0.045	0.035	0.031	0.028	0.028	0.566	0.269	0.086	4.823	2.978	9.066
1974	0.776	0.176	0.080	0.062	0.052	0.045	0.045	0.570	0.252	0.456	1.170	0.511	4.191
1975	0.228	0.125	0.073	0.048	0.042	0.059	0.062	0.121	3.295	1.387	1.042	0.749	7.228
1976	0.355	0.314	0.128	0.073	0.442	0.169	0.176	0.766	0.673	3.450	3.568	1.008	11.120
1977	0.197	0.132	0.159	0.076	0.066	0.062	0.125	0.073	0.080	1.511	1.380	0.945	4.803
1978	0.383	0.132	0.086	0.069	1.246	0.438	0.059	0.597	0.400	0.273	0.287	0.204	4.171
1979	0.362	0.162	0.073	0.055	0.045	0.042	0.038	0.114	0.752	0.314	0.138	0.125	2.218
1980	0.155	0.556	0.214	0.704	0.631	0.211	0.745	0.300	0.097	1.218	0.977	1.204	7.010
1981	0.463	0.125	0.083	0.062	0.055	0.048	0.822	0.314	0.449	0.255	0.359	0.239	3.271
1982	0.149	0.097	0.062	0.045	0.501	0.186	0.052	2.077	1.656	1.825	1.880	0.766	9.294
1983	0.217	0.125	0.080	0.066	0.062	0.055	0.083	1.960	0.746	0.366	0.238	0.345	4.340
1984	0.752	0.293	0.328	0.270	0.086	0.114	0.476	0.186	0.086	2.719	1.101	0.221	6.630
1985	0.583	0.255	0.090	0.062	0.055	0.142	0.107	0.062	0.242	0.318	5.958	2.519	10.391
1986	0.428	0.197	0.093	0.073	0.062	0.059	0.266	0.200	0.428	0.297	2.495	2.053	6.648
1987	0.546	0.118	0.080	0.062	0.055	0.048	0.169	0.125	0.280	0.249	0.963	0.490	3.181
1988	0.183	0.107	0.066	0.052	0.045	1.028	2.936	0.970	0.994	3.274	3.543	3.029	16.225
1989	1.615	0.359	0.104	0.083	0.307	0.121	0.656	0.797	1.836	2.612	0.877	0.238	9.602
1990	0.183	0.125	0.090	0.073	0.059	0.059	0.055	0.097	0.463	1.873	0.725	0.200	3.998
1991	2.843	1.035	0.093	0.073	0.062	0.059	0.104	0.300	1.456	0.673	1.111	1.490	9.297
1992	1.663	0.528	0.100	0.076	0.073	0.066	2.322	0.935	0.483	4.409	3.243	0.759	14.656
1993	0.162	0.114	0.128	0.076	0.069	0.062	0.079	0.169	4.057	1.515	0.731	0.366	7.527
1994	0.228	0.128	0.200	0.097	0.062	0.093	0.097	0.625	0.459	1.249	1.987	0.687	5.910
1995	0.259	0.145	0.707	0.242	0.069	0.062	0.055	0.055	0.359	0.673	0.362	0.297	3.283
1996	1.042	0.790	0.232	0.076	0.059	0.052	0.048	1.356	0.973	0.290	0.383	0.235	5.533
1997	0.145	0.252	0.100	0.059	0.052	0.045	0.207	1.898	0.745	0.425	1.021	0.442	5.388
1998	0.155	0.918	1.504	0.449	0.069	0.059	0.256	0.162	0.104	0.107	0.832	2.708	7.320
1999	0.946	0.114	0.080	0.062	0.055	0.224	0.093	0.062	0.135	0.649	0.383	0.711	3.512
2000	0.328	0.104	0.069	0.055	0.045	0.042	0.104	0.145	0.069	2.146	1.922	1.004	6.030
2001	0.411	0.135	0.080	0.452	0.169	0.055	0.263	0.376	0.677	1.611	2.294	0.800	7.321
2002	0.197	0.125	0.083	0.062	0.055	0.615	0.228	0.745	0.311	0.111	3.592	1.387	7.508
2003	0.231	0.128	0.086	0.069	0.055	0.055	0.079	0.055	0.169	0.570	0.290	0.173	1.959
2004	2.632	0.949	0.107	0.173	0.066	0.055	6.241	2.339	2.526	1.011	1.460	0.576	18.133
2005	0.190	0.128	0.090	0.076	0.066	0.059	0.086	0.583	0.269	1.936	2.253	0.711	6.444
2006	0.276	0.162	0.090	0.066	0.059	0.059	0.176	0.179	1.087	2.111	2.298	0.742	7.302
2007	0.245	2.571	0.911	0.090	0.073	0.073	0.066	0.066	0.318	1.615	1.494	2.357	9.874
2008	0.818	3.826	1.329	0.090	0.076	0.073	0.066	0.114	0.597	1.097	1.083	0.963	10.129
2009	0.621	0.225	0.097	0.069	0.059	0.055	0.055	0.169	0.518	0.407	0.193	0.155	2.621