NAMWATER

Namibia Water Corporation Ltd

Update to the report:

A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer

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EXECUTIVE SUMMARY

1. BACKGROUND

The findings of the report *"A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer"* was presented to NamWater and the Ministry of Agriculture and Forestry on the 21st of June 2010 and then again presented to the Ministry of Agriculture and Forestry on the 4th of April 2011. The Ministry of Agriculture and Forestry requested to:

- model with the present data over a 5 year period with a silt load of 10% and to present these results to the Omdel Technical Committee.
- Update the hydrological models with rainfall and runoff figures up to 2010 and to calculate the average water available for recharge over a 5 year period with a silt load of 10%.

This work was carried out and the report was to be presented to the Omdel Technical Steering Committee during 2012.

During July 2012 Hydrology finalised a new water balance model for the Omdel Dam and aquifer system as has rerun the input data using the refined model that was programed by Dorsch Gruppe Dorsch International Consultants.

2. HYDROLOGICAL DATA

The data from the Namibia Meteorological Services' rainfall stations in the catchment area, as well as the rainfall data obtained from the farmers were utilized to convert point rainfall to areal rainfall using the Multiquadric Surface Fit Model.

Reference was made to the Namibia National Map of Annual Evaporation and Precipitation. Using this map an A-Pan evaporation figure of 2 800 mm/a was calculated, which when converted to open lake evaporation results in 2 100 mm/a.

For the purpose of the rainfall/runoff modelling the runoff records at Henties Monument and Omdel Dam were combined to produce a runoff record for the period 1966/67 to 2012/13.

3. DATA SETS CALIBRATED WITH THE RAINFALL / RUNOFF MODEL

For this study a relationship between rainfall and runoff was determined to be able to extend the runoff record of Omdel Dam. The results of the Multiquadric Surface Fit analyses were utilised in the Namibia Rainfall Runoff Model, NAMROM to determine a regression equation between rainfall and runoff. The Multiquadric Surface Fit rainfall data was calibrated against the combined Henties Monument and Omdel Dam runoff records. Using the regression equation, which had an extremely poor correlation coefficient of 37.42%, the Omdel Dam runoff record was extended to 1926/27.

Due to the extremely poor correlation coefficient obtained the Omdel Dam runoff record was evaluated and amended. The Henties Monument observed runoff record indicated that for the 1984/85 season a volume of 114.936 Mm^3 was recorded in the month of February 1985. When comparing the Multiquadric Surface Fit rainfall of this month with similar rainfall for February it was noted that the runoff for these months was only between 0 and 27.771 Mm^3. It was then opted to change the February 1985 runoff value in an attempt to obtain a better correlation coefficient. One could argue that this should not be done or that the figure could be more or less, however by amending this flood volume the correlation coefficient increased to 52.45%, which is still a poor fit. Using this regression equation with the improved correlation coefficient, the Omdel Dam runoff record was extended to 1926/27.

4. METHODOLOGY ADOPTED FOR THE OMDEL DEPLETION ANALYSES

The combined synthesised and observed runoff record for the period 1926/27 to 2009/2010 was used as input data to generate a stochastic runoff record. Every sequence of 5 years of data was utilised as input data to set up a sample of data for 100 5-year sequences. A depletion model was used to calculate average releases from the Omdel Dam at various abstraction rates and by incorporating evaporation, infiltration, 10% siltation, the routing of the releases to the two infiltration sites and infiltration at the two sites.

The 2012 analyses were based on modelling rainfall and runoff to be able to extend the runoff record of Omdel Dam. Due to the poor correlation coefficient between the

synthesised and observed runoff records and taking into account the improved hydrological water balance model developed it was opted to rerun the models with the updated Omdel Dam inflow record to 2013, with special emphases on the observed runoff records of Henties Monument and Omdel Dam.

5. RECOMMENDED VOLUMES AVAILABLE FOR RECHARGE

The average volumes that infiltrate at the two sites and are recommended to be used for planning purposes are presented in **Table E1.**

Table E.1: Recommended average infiltration volume of the total system and the ponds for infiltration Site 1 and 2, which are based on the combined observed runoff record of Omdel Dam and Henties Monument runoff records 1966/67 - 2012/13.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1966/67 – 2012/13 Omdel Dam observed runoff combined with Henties Monument. Site 1 to 2 initial loss = 0.05 Mm^3	19.200	2.262	1.487	Yes

** *Infiltration up to and including infiltration Site 1*

Based on an silt content of 10% and at an abstraction rate of 19.2 Mm^3/a, the average volume of infiltration is calculated at 1.487 Mm^3/a to infiltrate at the two infiltration sites and to use as the average Aquifer recharge until further studies have been undertaken to calculate the actual recharge that is available from the total system infiltration.

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ACKNOWLEDGEMENTS

I would like to acknowledge the:

- Ministry of Agriculture Water and Forestry, Department Hydrology for the hydrological data supplied.
- Namibia metrological Services for the rainfall data supplied.
- Farmers for supplying rainfall data.
- G van Langenhove for assisting with the Multiquadric Surface fitting program and for hydrological input for this study.

1. INTRODUCTION

1.1 GENERAL

The cost of supplying water to the Namibian coast from the interior of the country was determined to be very costly and hence in 1988 a research project was initiated with the aim to investigate making better use of the floods passing over the Omdel Aquifer and subsequently lost to the Atlantic Ocean. From this research it was suggested that it would be feasible to capture these floods and then artificially recharge the aquifer by means of infiltration ponds. **(Reference 20.1).**

Hence during 1989 a project to artificially recharge the Omdel Aquifer, called the Omdel Dam Project, was introduced with the aim to contain the flood waters in a dam, let the silt settle and then release the water via a canal into infiltration ponds to recharge the Omdel aquifer. In this way the yields from Omdel Aquifer would be increased thereby improving the water supply situation at the central coast.

At the time it was considered that the western flowing rivers of Namibia sustain sensitive environments and that the establishment of a major impoundment may have adverse effects on these systems. An Environmental Impact Study was conducted for the then Department of Fisheries and Water **(Reference 20.2)** for the proposed Omdel Dam. The steering committee of the Environmental Impact Study consisted of members of the Department of Fisheries and Water, the Environmental Evaluation Unit of the University of Cape Town as technical advisors, the Directorate of Conservation and Research, Shell Namibia and the State Museum of Namibia.

The Omdel Dam was subsequently constructed during the period 1991 to 1995 and when completed had a full storage capacity of 41.300 Mm^3. The main purpose of the dam is to store water during rare flood events for a limited period and prevent it from flowing to the Atlantic Ocean. Once the silt has settled and the turbidity is low enough, the water can be released and utilised for recharge of the Omdel Aquifer by means of infiltration basins. Originally only Site 1 existed for artificial enhancement, however in 2004/05 Site 2 was developed to create additional infiltration capacity. The first release to Site 2 took place during March 2009 and information pertaining to this is

available in the report “Water Balance for Omdel Dam during Release for Artificial Recharge during the 2008/2009 Hydrological Season”.

With limited hydrological studies done in the past and the sensitivity of the Omdel Aquifer, the need was identified by the Ministry of Agriculture Water and Forestry to re-asses the hydrology of Omdel Dam. The aim of this report is hence to re-evaluate the hydrology of the Omdel Dam and to determine the amount of water available for artificial recharge from Omdel Dam for the Omdel Aquifer. The work was undertaken and the report *“A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer” was* presented to the Ministry of Agriculture Water and Forestry. **(Reference 20.3)**

1.2 BACKGROUND

The findings of the above mentioned study was presented to NamWater and the Ministry of Agriculture and Forestry on the 21st of June 2010 and then again presented to the Ministry of Agriculture and Forestry on the 4th of April 2011. The Ministry of Agriculture and Forestry requested to:

- Run the model with the present data over a 5 year period with a silt load of 10% and to present these results to the Omdel Technical Committee that was re-established at the presentation. This modelling was completed and presented in 2011 **(Appendix 1).**
- Update the hydrological models with rainfall and runoff figures up to 2010 and to calculate the average water available for recharge over a 5 year period with a silt load of 10%.

During July 2012 Hydrology finalised a new water balance model for the Omdel Dam and aquifer system as has rerun the input data using the refined model that was programed by Dorsch Gruppe Dorsch International Consultants. It was opted to update the report *“A Comprehensive Assessment of the Hydrology of the Omaruru*

Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer" **to include the information of the updated rainfall and latest refined water balance model results.** This report is an update to the report *"A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer".*

2. PREVIOUS STUDIES

Following is a brief summary of previous studies in chronological order.

2.1 Research into Possible Enhancement of Recharge at the Omaruru Delta

Recharge of the aquifer only occurred during flood events which are characterised by heavy laden silt which clogs the river bed and hampers free infiltration into the aquifer. During 1988 the Department of Water Affairs, Namibia initiated means of increasing fresh water availability in the Central Namib Area. These investigations were deemed necessary as the demand on the Omdel aquifer of between 4 and 6 Mm^3/a of fresh water was increasing and the rates of recharge from flood waters to alluvial aquifers were found to be lower than expected. **(Reference 20.1).** This was resulting in insufficient replenishment of the aquifer of which the reserves were rapidly becoming exhausted.

2.2 Omdel Infiltration Enhancement Action Planned and Funds Required

During 1989, a preliminary assessment of the hydrology of the Omdel Dam site was conducted. **(Reference 20.4).** The flow records of Henties Monument, dating back to 1966, the flow records of Nei-Neis dating back to 1975 and the flow records of Etemba, which incorporated a synthesised runoff record dating back to 1943 were evaluated. The monthly runoff volumes of Etemba were routed down to Nei-Neis taking into account transmission losses as well as rainfall intervention over the catchment. It was further assumed that negligible additional flow occurs downstream of Nei-Neis and hence the monthly volumes were routed down to Henties Monument, taking only

transmission losses into account. Following some minor adjustments this resulted in a 45 year runoff record for Henties Monument starting at 1943. The MAR (Mean Annul Runoff) was calculated to be 15.670 Mm^3/a and the median was 0 Mm^3/a due to the fact that in only 20 out of the 45 year's record, flow occurred. The potential mean annual recharge of 6.66 Mm^3/a, was calculated for a dam with a storage volume of 20 Mm^3. The storage draft analyses indicated a 95% safe yield of 0.4 Mm^3/a and an 80% safe yield of 2.4 Mm^3/a. The results of the pre-feasibility study indicated that artificial recharge through infiltration enhancement was a realistic option for Omdel. Further work recommended included topographical surveys, infiltration studies, soil analyses, attempts to refinement of the Henties Monument runoff data, determination of the settling time required after a flood before releases can take place and identification of the infiltration areas likely to be most suitable.

2.3 A Re-examination of the Geohydrology and a Re-evaluation of the Potential of the Omaruru Delta (OMDEL) Aquifer

A summary of reports compiled on the geohydrology of Omdel prior to September 1990 is presented in the report: "A re-examination of the Geohydrology and a re-evaluation of the potential of the Omaruru Delta (OMDEL) aquifer". **(Reference 20.5).** Of interest to note are the following findings referred to in the report:

- A study of the Water Resources of the Omaruru River Delta in S.W.A. CSIR, 1965. Synopsis: Results of seismic refraction survey, drilling and pump testing. Includes potential of the OMDEL aquifer of 7 Mm^3.
- Groundwater Resources of the Omaruru River Delta in S.W.A. Bechtel USA, 1972. Synopsis: Comprehensive geohydrological report to date. Includes usable potential of the OMDEL aquifer of 60 Mm^3 and a stored reserve of 120 Mm^3.
- Hydrological report on the groundwater potential of the Omaruru Delta. Report No 2972. J Schumman, 1976. Synopsis: Report reassessing the potential in the light of the latest geophysical, drilling and pump testing results. Includes the potential of the Omaruru aquifer of 138 Mm^3.

- “Sommige aspekte van wateronttrekking uit die Omaruru Delta akwifer aan die Weskus van Suid-wes-Afrika/Namibia. JS van Vuuren, 1980.” Synopsis: An academic study on the methodology of groundwater balance simulation on a computer based model. Includes the potential of the Omaruru aquifer of 259.9 Mm^3 and a mean annual recharge of 1.8 Mm^3/a was estimated.
- “Voorlopige evaluering van die grondwater potensiaal en die versoutingsbedreiging in die Omaruru Delta deur die gebruik van modelleringstegnieke.” OFS Institute of Groundwater Studies, 1981. Comprehensive geohydrological study involving development of model to simulate behaviour of the aquifer under different parameters and abstraction rates. Includes the potential of the Omaruru aquifer of 464 Mm^3. The abstract able volume of water was calculated to be 291 Mm^3. At an abstraction rate of 11 Mm^3/a it gives the aquifer a lifespan of 26 years considering hardly any recharge. Fresh water flow to the sea was calculated to be between 2.84 and 3.06 Mm^3/a, and artificial recharge would seem a definite possibility.
- Investigation by SWA Geological Survey. Reports of 1973 to 1976. The total stored reserve of Omdel was calculated to be 250 $Mm^3$of which 50% was considered to be readily abstract able. The annual recharge was estimated to be 2.3 Mm^3/a.
- The report “A re-examination of the Geohydrology and a re-evaluation of the potential of the Omaruru Delta (OMDEL) aquifer” found that based on the sample of data used for the period 1979-1989 the safe yield of the aquifer, without artificial recharge, was 4.5 Mm^3/a and was made up of an average of 1 Mm^3/a from the periodic floods and 3.5 Mm^3/a from other sources. Considering an infiltration enhancement dam with storage volume of 25 Mm^3, it was expected to add another 3.5 Mm^3/a from artificial recharge and hence increase the safe yield of the Omdel aquifer to 8 Mm^3/a.

2.4 Final Environmental Impact Report for the Proposed Omdel Dam on the Omaruru River

The "Final Environmental impact report for the proposed Omdel Dam on the Omaruru River" **(Reference 20.6)** reports that Water Affairs had estimated that after making allowance for siltation, a reservoir with an estimated capacity of 30 Mm^3 would effect a mean annual recharge of 4.6 Mm^3/a for a transfer efficiency of 70% over a period of 20 years. The dam is further likely to be empty for periods of up to 10 years, but on most occasions for only 1 – 3 years. The aquifer recharge scheme is likely to be a medium term solution to maintain water availability. More capital intensive schemes may ultimately have to be installed. This is an accepted fact.

2.5 Report on Investigation of Artificial Recharge Experiments, Recharge Basin Design and Operational Rules in Recharge Basins at Site 1, Omdel Dam

This 1993 report of Nawrowski, **(Reference 20.7)** stated that an average flood of 14 Mm^3 would give a 1 Mm^3 recharge. However, with the development of the infiltration ponds at Site 1 the recharge potential was determined to be 7.4 Mm^3/a, based on the 1991 flood events.

2.6 The Impact and Evaluation on Enhanced Recharge on the Omdel Aquifer during 1997/98

The report on "The impact and evaluation on enhanced recharge on the Omdel aquifer during 1997/98" **(Reference 20.8)** evaluated the enhanced recharge of the Omdel Aquifer. The findings were that for the flood season 1996 – 1998 a total of 18.027 Mm^3 inflow was received in the Omdel Dam and of this 53% was added to the aquifer, 29% evaporated and 11% was left in the dam.

2.7 Re-Assessment of the Hydrology and Yield of Omdel Dam

During January 2000 the hydrology of Omdel Dam was re-assessed **(Reference 20.9)**. The study used the generated synthesised runoff record of 1998 and incorporated the latest flood information in the report. The average storable run-off with peak flows reduced to the maximum dam capacity of 41.3 Mm amounted to 6.9 Mm³/a. The yield of the dam utilising the then existing infiltration basins with infiltration capacity of 4 Mm³/a amounted to approximately 2.4 Mm³/a, this excluded additional losses during releases, which amends this figure to 1.8 Mm³/a. With extended basins to infiltrate 7.4 Mm³/a, the yield of the dam is 3.5 Mm³/a without losses and 2.6 Mm³/a taking losses of 25% into account. Up to this date the Omdel aquifer yield was deemed to be 4.7 Mm³/a, and an additional yield of 3.5 Mm³/a was added for artificial recharge (instead of the 2.6 Mm³/a) giving a total yield of 8.2 Mm³/a.

2.8 A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be available for Recharge of the Omdel Aquifer

During 2010 the hydrology of the Omdel Dam was assessed for the volumes of water available for recharge **(Reference 20.10**). The runoff volumes were considered to have a 10% silt load as determined through silt surveys and inflow records since the completion of the Omdel Dam. Depletion analyses for floods with a 10% silt load indicate a shorter life span of the dam which results in a more pessimistic volume available from the dam over the long term. It was hence decided to also determine the short-term average volumes that could be statistically obtained from the dam if the floods had only a 2% silt load. The average volume obtained through this set of data is considered the appropriate figures to be considered for short-term permit allocations. Based on this rationale the recommended volumes available from Omdel Dam for release rates of 9.500 Mm³/a and 20.000 Mm³/a are presented in **Table 2.8.1.**

Table 2.8.1: Recommended Short to Medium Term Volumes Available from Omdel Dam

Release Rate (Mm³/a)	Full supply capacity (Mm³)	Dead storage capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)		Average Volume Infiltrated from the dam, river system and the infiltration sites (Mm³/a)		Sites 1&2: Average Volume Infiltrated (Mm³/a)	
			10% Silt	2% Silt	10% Silt	2% Silt	10% Silt	2% Silt
9.500	41.300	0.200	2.575	3.350	2.564	3.935	1.301	2.325
20.000	41.300	0.200	3.453	4.413	3.068	4.549	1.584	2.840

Shortcomings in this study were the reliability of the rainfall data and a poor correlation between rainfall and runoff. Following the presentation of the report the Ministry of Agriculture requested that the rainfall data be updated and that a 5 year recharge figure is calculated using the stochastic runoff record.

2.9 Memorandum: Omdel Aquifer Recharger (Appendix 1)

Based on the request from the Ministry of Agriculture Water and Forestry the potential infiltration to the Omdel Aquifer for the next 5 years were calculated using a stochastic runoff record.

The 10th year stochastic runoff data for the 500 5-year sequences with the initial dry river channel losses of 1.000 Mm^3/a for the channel up to Site 1 and an initial loss of 0.050 Mm^3 for the river section from Site 1 to Site 2 was used as input data. For this data set release rates of 9.500 Mm^3/a, 19.200 Mm^3/a and 20.000 Mm^3/a were modelled. The adding of the 19.200 Mm^3/a releases rate was considered to be more relevant as fewer losses occurred to Site 2 and hence a lower release rate was adopted to prevent spilling of the infiltration basins. The initial infiltration for Omdel Dam basin was set to 1.000 Mm^3 as the dam already has had 5 flood events that have resulted in a “large” silt load into the dam.

The results obtained from the water balance model were then averaged and the most relevant values are presented in **Table 2.9.1**.

Table 2.9.1: Average Volumes Released from Omdel Dam and Infiltrated at the Sites Based on 2008/2009 Channel Losses

Release Rate (Mm^3/a)	Full Supply Capacity (Mm^3)	Dead Storage Capacity (Mm^3)	Average Volume Released from Omdel Dam (Mm^3/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm^3/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm^3/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.379	3.376	1.957
19.200	37.389	0.200	3.142	3.899	2.648
20.000	37.389	0.200	3.184	3.930	2.693

3. PHYSICAL CHARACTERISTICS OF THE OMDEL DAM CATCHMENT

3.1 TOPOGRAPHY

The Omaruru River, which feeds the Omdel Dam, flows in a westerly direction through a broad regional depression between the Brandberg Mountain in the north and the Erongo and Spitzkoppe mountains in the south. The river has generated extensive alluvial deposits, which extend approximately 120 km eastward from the river mouth with only the lower 35 km of the river flowing over alluvial deposits that provide recharge to the Omdel Aquifer. Over this 35 km stretch the river has cut a shallow channel into the generally flat Namib plain, which rises from sea level to 230 m AMSL. Further upstream, tectonic activity has resulted in a shifting of the river away from its original course.

3.2 LOCATION

Refer to **Figure 3.2.1** for orientation of the Omdel Dam on the Central Namib Map. The Omdel Dam situated in the Omaruru River is located just north east of Henties Bay along the Namibian coast. The mouth of the Omaruru River enters the Atlantic Ocean approximately 2 km north of Henties Bay. The dam is approximately 40 km inland from the Omaruru River mouth.

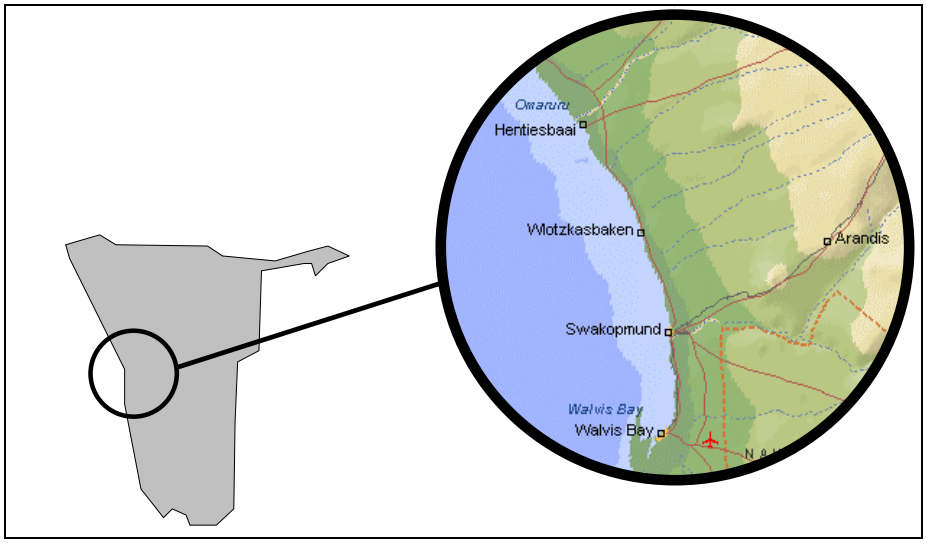

Figure 3.2.1: Locality Map of Central Namib Area

The catchment includes the following features:

(I) It is located in the Erongo administrative region.

(II) The main towns in the catchment are Omaruru, Okombahe and Henties Bay, with Walvis Bay and Swakopmund also in the vicinity. The coastal town of Walvisbay is supplied with water from the Kuiseb aquifers at Rooibank and Swartbank, whereas Swakopmund, Henties Bay and Arandis are largely supplied from the Omdel Aquifer and recently also from desalinated water.

(III) In the east the catchment is used for commercial stock farming up to the Namib plains, whereas the west of the catchment is defined as the Namib Desert.

(IV) The Omdel Dam site is near to the Atlantic Ocean where hardly any rainfall occurs.

(V) Just about all runoff originates in the central and eastern part of the Omdel catchment during the months of December to middle April and this only after intense rainfalls of fairly long duration of 2 to 3 days.

3.3 DRAINAGE

The Omaruru catchment has well-developed drainage systems with the river flowing in a south westerly/westerly direction through a regional depression between the Brandberg Mountain in the north and the Erongo and Spitzkoppe mountains in the south. The river has generated alluvial deposits over the last 120 km, although only the last 35km is considered to provide recharge to these alluvial deposits. The channel systems are well pronounced throughout the catchment up to the Atlantic Ocean. On average, flows that reach the Atlantic Ocean or now the Omdel Dam can be seen as an exception and not the norm with the historic runoff indicating an average of one in every four years. There have however been periods of up to 6 consecutive years for the period 1976/77 to 1981/82 and 4 consecutive years for the period 2002/03 to 2004/05 where no flow had reached the Omdel Dam location.

3.4 VEGETATION

The upper catchment of the Omaruru River is part of the Savannah Biome. The vegetation type is Thornbush Savannah. Woody trees and shrubs share dominance with perennial grasses. Vegetation is dominated by a mixture of *Acacia* species, like *A.* erioloba, *A. hereroensis* and *A. mellifera,* while other species like *Combretum apiculatum, C. imberbe, Faidherbia albida. Ziziphus mucronata, Euclea pseudebenus and Ficus spp.* are frequently found. The Omaruru River forms a linear oasis, which supports tall woodland species. The diversity and density of tree species decrease from the upper catchment reaches to the mouth of the Omaruru River.

The lower reaches of the Omaruru River drain across the Namib Desert which has a unique flora. A diverse array of succulents, adapted to the small amounts of water provided by fog, is found. Lichen fields on gypsum and gravel flats are a prominent feature between the Omaruru and Kuiseb rivers.

Several alien species like *Prosopis* spp,, *Nicotiana glauca, Tamarix usneiodes, Datura innoxia*, *Ricinus communis* and *Argemone ochroleuca* occur in the catchment of the Omaruru River. All of these species are easily dispersed via floodwaters.

3.5 CLIMATE

The Omdel Dam is located within the Namib Desert, which is influenced by the Cold Benguela current of the Atlantic Ocean, which cools the south westerly winds and reduces their ability to absorb moisture. The westerly winds warm up over the land and as a result the relative humidity of the air decreases. This phenomenon brings about the formation of fog for approximately 102 days per annum producing precipitation of approximately 31 mm per annum. This precipitation does not result in any runoff and has a high salt content with Total Dissolved Solids of 795 to 9 860 ppm. This fog can extend approximately 70 km inland.

As with most deserts, temperature are cool to cold during the nights and very hot during the days. Temperatures range between 15 Cº and 32 Cº. The inland desert temperatures are more extreme than the coastal temperatures.

4. HYDROLOGICAL FEATURES

For the location of the hydrological stations refer to **Figure 4.1**.

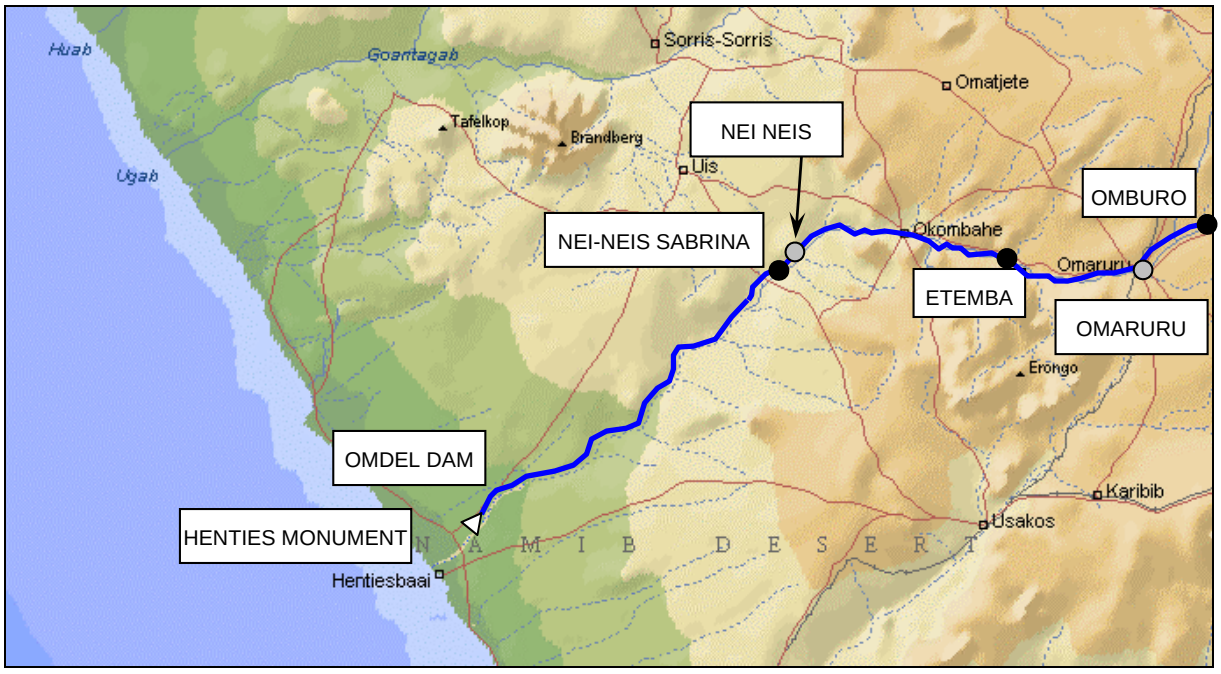

Figure 4.1: Location of the Hydrological Stations in the Omaruru Catchment

Following is a description of each hydrological station in the Omdel Dam catchment.

4.1 OMBURO HYDROLOGICAL STATION

Omburo hydrological station is situated approximately 30 km east of the town of Omaruru. The gauging structure is a weir and water level data has been recorded at this site from 1973/74. The catchment area upstream is 1 314 km² and the main river has a length of approximately 60 km.

4.2 OMARURU HYDROLOGICAL STATION

The Omaruru hydrological gauging station is an unstable open section and has recorded data for the period 1964/65 to 1996/97. The record of the Omaruru station is not very reliable. The catchment upstream is 2520 km² and the main river has a length of approximately 101 km.

4.3 ETEMBA HYDROLOGICAL STATION

Etemba hydrological station is situated approximately 30 km west of the town of Omaruru. The gauging structure is a weir and water level data has been recorded at this site from 1967/68. The catchment upstream is 3 676 km² and the main river has a length of approximately 125 km. Based on the present gauging structure's flood information, this station produces the highest volumes of flows in the Omaruru River.

4.4 NEI-NEIS HYDROLOGICAL STATION

The hydrological station Nei-Neis is situated in the Omaruru River and has a water level record for the period 1974/75 to 1989/90. The catchment upstream of the station covers an area of 8 188 km². The main stream has a length of approximately 208 km. Downstream of Nei-Neis hardly any additional runoff is contributed to the Omaruru River.

4.5 NEI-NEIS SABRINA HYDROLOGICAL STATION

The hydrological station Nei-Neis Sabrina is situated in the Omaruru River and has a water level record for the period 1985/86 to 1997/8. The catchment upstream of the station covers an area of 8 188 km². The main stream has a length of approximately 208 km. Downstream of Nei-Neis Sabrina hardly any additional runoff is contributed to the Omaruru River.

4.6 HENTIES MONUMENT AND OMDEL DAM

The hydrological station Henties Monument had a water level record dating back to 1966/67. It used to be a weir, but during the 1984/85 flood events the weir was washed away. The Omdel Dam was constructed approximately 7 km upstream of the station and inflows into the dam have been recorded since 1992/93. The catchment area of the dam is 11 453 km² and the main stream length is approximately 297 km.

5. HYDROLOGICAL DATA

5.1 RAINFALL

Rainfall data up to 2010 was requested from the Namibia Meteorological Services for the 73 stations used in the previous study. Data for 20 stations were received of which 12 extended to 2010. The farmers that supplied data for the previous study was contacted again and data for 15 stations were received of which 4 extended to 2010. The rainfall data used in the study is documented in "*Rainfall data report for the Omdel Dam recharge study March 2014*". (**Reference 20.11**)

The Multiquadric Surface Fit program, which was developed for modelling the topography of irregular surfaces and whereby point rainfall is converted to areal rainfall for each of the sub-catchments, was used for the rainfall analyses.

Utilising the Multiquadric Surface Fitting model areal rainfall figures were calculated for each of the sub catchments. Lost record was recorded as "L" and "-1" in the rainfall data sets. The results were not found to be satisfactory as extreme high rainfall figures were calculated for the upper catchment. Due to these high figures additional rainfall

station data was requested from the Namibia Meteorological Services extending further north, south and east of the Omaruru Catchment as well as using rainfall stations data of NamWater. This resulted in 89 rainfall stations been used in the model.

Due to a lack of sufficient rainfall data prior to 1923 the rainfall data sets could not be extended further back than 1923/24 with the use of the Multiquadric Surface Fit program. Refer to **Appendix 2** for the results of the Multiquadric Surface Fit for each sub-catchment. The rainfall data is summarised in **Table 5.1.1** below for each of the 4 sub catchments.

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Table 5.1.1: **Summary of the rainfall data of the 4 sub catchments calculated with the use of the Multiquadric Surface Fit rainfall model.**

Rainfall (mm)													
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**

Average Sub-Catchment 4	10.5	26.3	39.4	88.8	90.4	73.9	31.6	3.8	0.7	0.1	0.4	1.3	367.3
Median Sub-Catchment 4	5.7	17.8	25.9	67.6	70.0	62.7	18.2	0.5	0.0	0.0	0.0	0.1	340.4
Average Sub-Catchment 3	7.8	20.4	30.9	71.9	81.9	67.0	28.5	2.8	0.8	0.1	0.4	1.2	313.8
Median Sub-Catchment 3	4.5	10.8	21.3	53.3	68.8	55.1	18.8	0.3	0.0	0.0	0.0	0.1	284.8
Average Sub-Catchment 2	6.7	17.9	28.3	63.9	71.1	66.9	26.1	2.1	0.6	0.1	0.3	0.8	284.6
Median Sub-Catchment 2	3.3	10.5	17.8	46.7	55.5	53.6	16.8	0.0	0.0	0.0	0.0	0.0	255.0
Average Sub-Catchment 1	6.2	16.2	26.7	59.6	63.7	66.7	23.6	2.1	2.1	0.1	0.4	0.8	266.4
Median Sub-Catchment 1	1.2	7.8	7.5	35.3	35.1	47.9	9.6	0.0	0.0.	0.0	0.0	0.0	199.5

The average annual rainfall for the Omdel Dam catchment varies from approximately 367.3 mm in the eastern area to 199.5 mm in the south-west. The rainfall figure of 199.5 mm is considered to be too high. This could be due to insufficient rainfall information in the western part of the catchment and insufficient rainfall data west of the catchment. (Data obtained from the Multiquadric Surface Fit results for the period 1923/24 to 2009/10). However since the dam site is located in the area of the catchment where the lowest rainfall occurs and taking into account that rainfall figures decline from east to west, it was decided to be conservative and to consider no rainfall at the dam site for the water balance of Omdel Dam.

Refer to **Annexure 1** for the graphical representation of the areal rainfall distribution obtained from the Multiquadric Surface Fit for the sub-catchments as identified for the

study. The five-year moving mean rainfall is also presented as a time series for the period 1923/24 to 2009/10 and is graphically presented in the same annexure.

Presented in **Table 5.1.2** are the durations of wet and dry periods detected from the graphs as per the Sub-catchments 4 to 1. Sub-catchment 4 is upstream of Omburo, Sub-catchment 3 is between Etemba and Omburo, Sub-catchment 2 is between Nei – Neis Sabrina and Etemba and Sub-catchment 1 is from the Omdel Dam to Nei – Neis Sabrina.

Wet and dry periods were determined form the five year moving mean graph as a deviation from the mean figures obtained.

Table 5.1.2: Identified Wet and Dry Rainfall Periods for the 1927/28 to 2009/10 Hydrological Years

Wet Rainfall Periods for		Dry Rainfall Periods for	
Omdel Area	**Nei-Neis Sabrina**	**Omdel Area**	**Nei-Neis Sabrina**
1927/28 to 1928/29 (2 years)	1927/28 to 1928/29 (2 years)	1929/30 to 1932/33 (4 years)	1929/30 to 1932/33 (4 years)
1934/35 to 1937/38 (5 years)	1934/35 to 1937/38 (5 years)	1938/39 to 1942/43 (5 years)	1938/39 to 1945/46 (8 years)
1943/44 to 1947/48 (5 years)	1946/47 (1 year)	1948/49 (1year)	1947/48 to 1948/49 (2 years)
1949/50 to 1950/51 (2 years)	1949/50 to 1953/54 (5 years)	1951/52 to 2000/01 (50 years)	1954/55 to 1965/66 (12 years)
2001/02 to2009/10 (9 years)	1966/67 (1 year)	-	1967/68 (1 year)
-	1968/69 (1 year)	-	1969/70 to 1973/74 (5 years)
-	1974/74 to 1979/80 (6 years)	-	1980/81 to 1992/93 (13 years)
-	1993/94 (1 year)	-	1994/95 to 2002/03 (9 years)
-	2003/04 to 2009/10 (7 years)	-	-

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Wet Rainfall Periods for		Dry Rainfall Periods for	
Etemba	**Omburo**	**Etemba**	**Omburo**
1927/28 to 1928/29 (2 years)		1929/30 to 1933/34 (5 years)	1927/28 to 1933/34 **(7 years)**
1934/35 to 1937/38 (4 years)	1934/35 to 1943/44 **(10 years)**	1938/39 to 1948/49 (11 years)	1944/45 (1 year)
1949/50 to 1958/59 (10 years)	1945/46 to 1946/47 (2 years)	1959/60 to 1964/65 (6 years)	1947/48 to 1948/49 (2 years)
1965/66 to 1971/72 (7 years)	1949/50 to 1959/60 **(11 years)**	1972/73 (1 year)	1960/61 to 1964/65 (5 years)
1973/74 to 1979/80 (7 years)	1965/66 to 1971/72 (7 years)	1980/81 to 2004/05 (25 years)	1972/73 (1 year)
1965/66 to 2009/10 (5 years)	1973/74 to 1979/80 (7 years)	-	1980/81 to 2006/07 **(27 years)**
-	2007/08 to2009/10 (3 years)	-	-

The results of the Multiquadric Surface Fit program indicate that for the upper part of the Omdel catchment the area has experienced below mean rainfall for two extensive periods, with the latter being from 1980/81 to 2006/07.

5.2 EVAPORATION

As input for the water balance and yield analyses of the Omdel Dam, the gross and net evaporation is required for the dam site. Evaporation data for the Omdel Dam site is available for the period when the Omdel Dam was under construction. Due to this record being too short, reference was rather made to the Namibia National Map of Annual Evaporation and Precipitation. **(Reference 20.12)**

The Namibia National Map of Annual Evaporation and Precipitation was used to calculate the monthly evaporation figures. This resulted in an A-Pan evaporation figure of 2 800 mm/a, which when converted to open lake evaporation, results in 2 100 mm/a. For the months January to June a pan to lake conversion factor of 0.8 and for the rest of the year a pan to lake conversion factor of 0.7 was used as recommended by the Namibia National Map of Annual Evaporation and Precipitation. For the water balance of Omdel Dam the rainfall needs to be deducted from the gross evaporation to obtain the annual net evaporation, which was considered to be zero.

Using this information from the map the following figures were derived and adopted for Omdel Dam as presented in **Table 5.2.1.**

Table 5.2.1: Evaporation Figures Adopted for Omdel Dam as Determined with the Use of the Namibia National Map of Annual Evaporation and Precipitation

	Months											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Gross evaporation (mm)	172	188	198	226	193	206	179	168	148	135	137	151
% Allocated	8.8	9.6	10.1	10.1	8.6	9.2	8.0	7.5	6.6	6.8	7.0	7.7
Conversion Factor	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7
Net evaporation (mm)	172	188	198	226	193	206	179	168	148	135	137	151

5.3 RUNOFF

Runoff records are available for Omburo, Omaruru, Etemba, Nei-Neis Sabrina, Nei-Neis, Henties Monument and Omdel Dam. The reliability of the data measured at the hydrological stations is not very high as clay, silt and debris clog the inlets of the water level recorders at the stations resulting in the requirement to estimate data and at times levels were not recorded resulting in lost data. For the purpose of the rainfall/runoff modelling the runoff records at Henties Monument and Omdel Dam were combined to produce a runoff record for the period 1966/67 to 2012/13. Refer to **Appendix 3** for the observed runoff records of the hydrological stations used in this study. This data is presented graphically in **Annexure 2**. River station runoff data used in this study was obtained from the Ministry of Agriculture, Water and Forestry which is deemed to be the best available data. For the period 2006 to 2013 the inflow data for Omdel Dam was obtained from the NamWater hydrological water balance for Omdel Dam. For comparison purposes the data of the annual flood volumes was

plotted comparing runoff data of an upstream hydrological station with that of a downstream station. The results of this comparison are shown and discussed below.

5.3.1 Omburo vs. Omaruru Runoff

Runoff records are available for Omburo from 1974/1975 to 2010/11 (station is still operational) and for Omaruru from 1964/65 to 1996/97 (station is closed). The runoff record at Omburo weir has several months of doubtful and estimated data on record. The runoff record at Omaruru open section is poor with doubtful, estimated and lost data reflected in the runoff record. As a result of this station's unreliable recordings the station has been closed. **Figure 5.3.1** presents the annual runoff records of Omburo and Omaruru. From the figure it can be seen that on average Omaruru records much larger floods than Omburo.

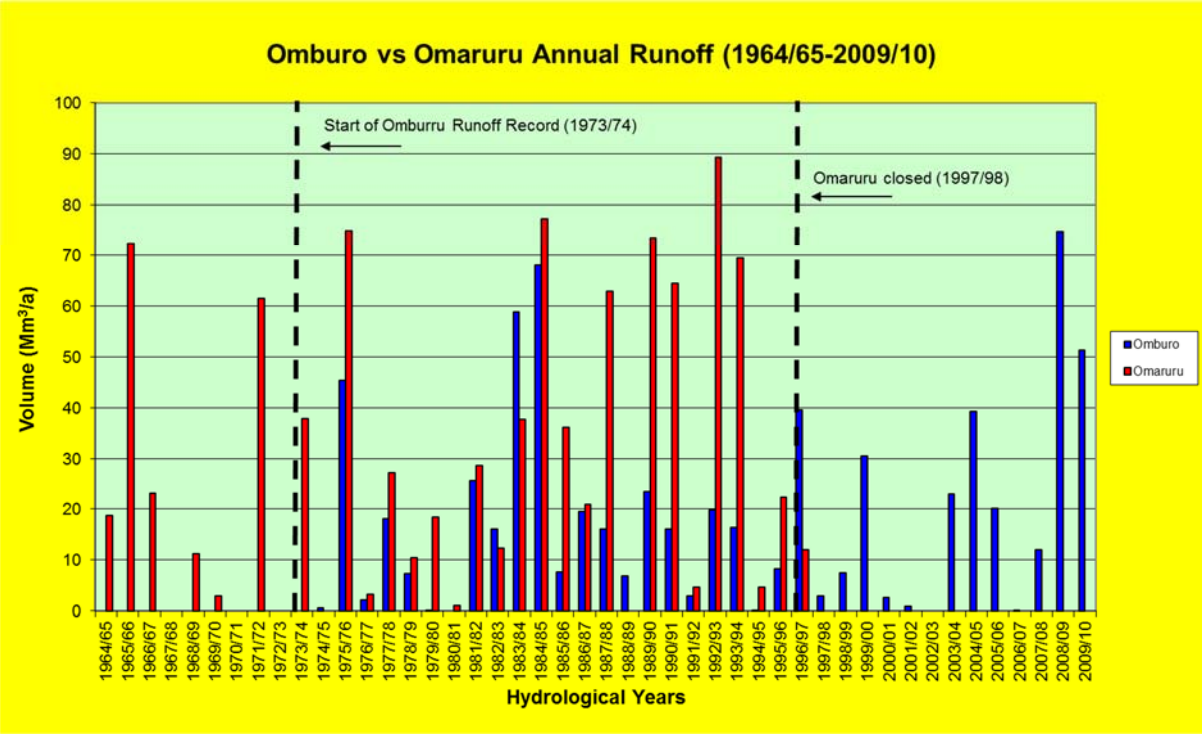

Figure 5.3.1: Omburo vs. Omaruru Annual Recorded Runoff

5.3.2 Omaruru vs Etemba Runoff

Runoff records are available for Omaruru from 1964/65 to 1996/97 and for Etemba weir from 1967/68 to 2011/12 (station still operational). The runoff record at Etemba weir is not very reliable with doubtful, estimated and lost data reflected in the runoff

record. **Figure 5.3.2** presents the annual runoff records of Omaruru and Etemba. It is difficult to detect any trend in the flows between these hydrological stations.

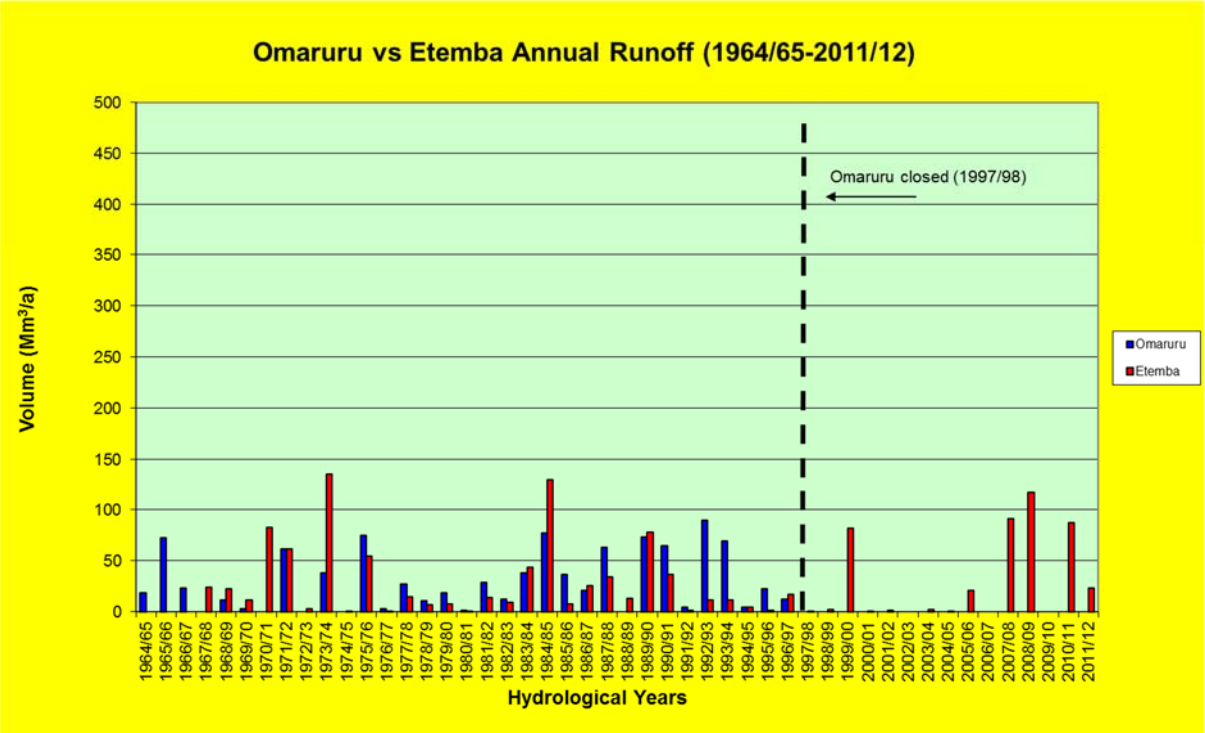

Figure 5.3.2: Omaruru vs. Etemba Annual Recorded Runoff

5.3.3 Omburo vs Etemba Runoff

The Omaruru hydrological station is an open section and the data recorded at this station is considered to be unreliable. It was therefore decided to compare Omburo's runoff with the Etemba runoff record. Runoff records are available for Omburo from 1974/75 to 2010/11 and for Etemba from 1967/68 to 2011/12. **Figure 5.3.3** presents the annual runoff records of Omburo and Etemba. From this set of data it is noted that Omburo from time to time could get more flow than Etemba in any season, however on average Etemba records more flow than Omburo. It is also seen that with larger floods events that are expected to occur when wide spread rainfall occurs for prolonged periods Etemba records much larger floods than Omburo.

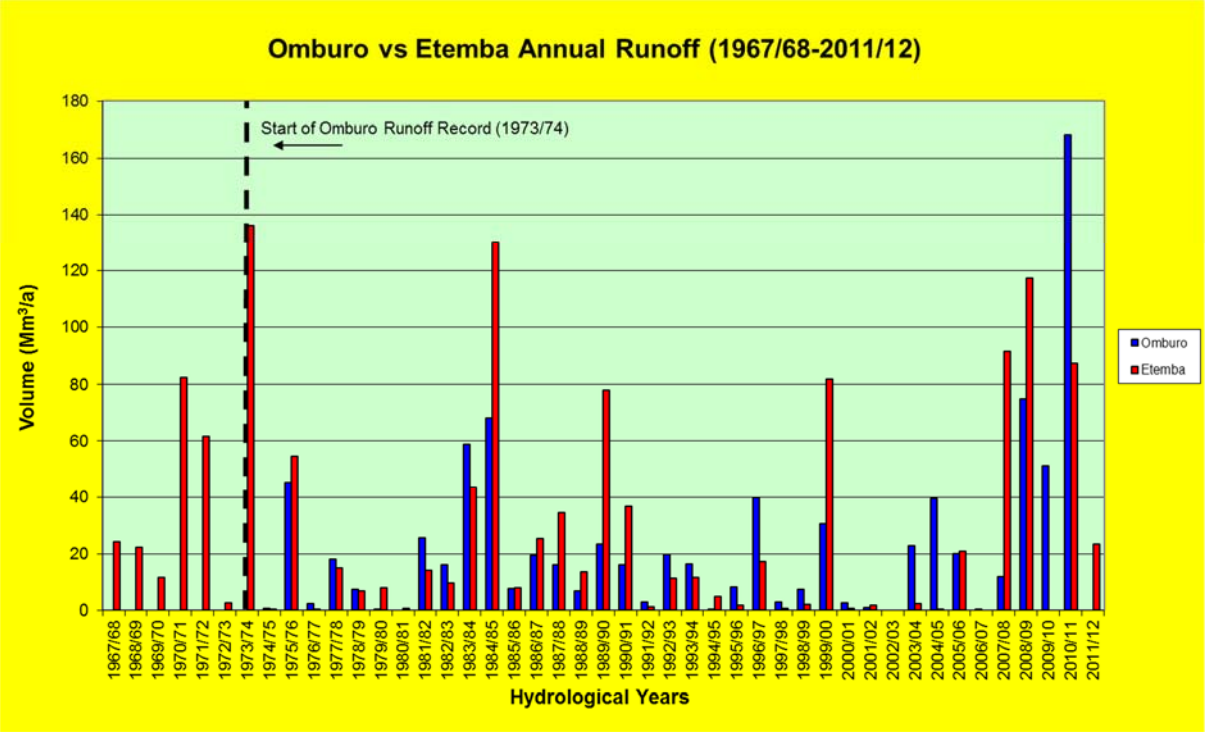

Figure 5.3.3: Omburo vs Etemba Annual Recorded Runoff

5.3.4 Otjompaue - Etemba Runoff Record

Prior to the construction of the Etemba hydrological station, flows were recorded at the Otjompaue hydrological station located 5 km upstream of Etemba. Since these two stations are very close to each other, these two sets of data have in the past been combined. During the Central Area Water Master Plan: Phase 1 Hydrological analysis, **(Reference 20.13)** a combined synthesised runoff record was generated for the Etemba / Otjompaue station. This data is a combination of the observed records of Otjompaue and Etemba, which was used in the NAMROM model to produce an extended runoff record dating back to 1923/24, where a runoff correlation coefficient of 94.6% was obtained. Refer to **Section 8.3** for a brief description of the NAMROM model. **Figure 5.3.4** presents the combined synthesised record for the Otjompaue and Etemba stations. It is noted from the record that from 2000/01 to 2004/05 Etemba has recorded very little flow, with very high flows recorded in 2007/08, 2008/09 and 2010/11. In general no trend can be detected that the runoff pattern has changed besides that three high flood events occurred between 1934 and 1962 and then the highest of 136 Mm^3 on record in 1973/74.

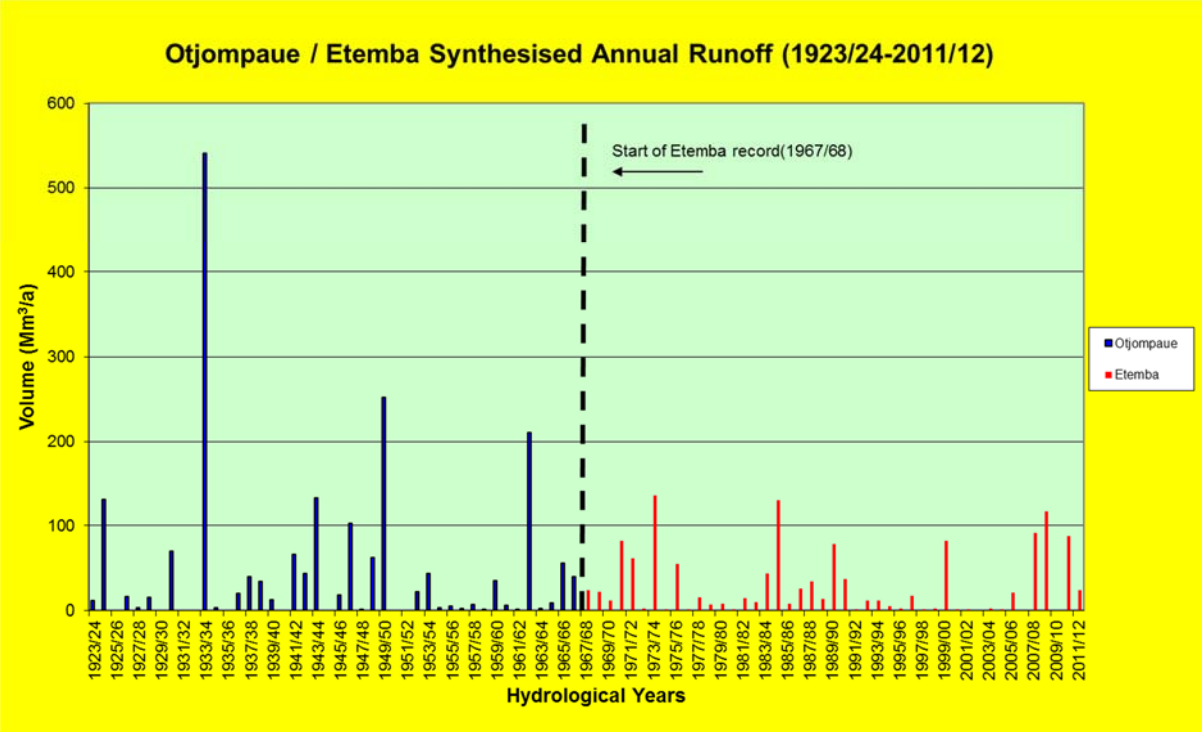

Figure 5.3.4: Otjompaue / Etemba Synthesised Annual Recorded Runoff

5.3.5 Etemba vs Nei-Neis Sabrina / Nei-Neis Runoff

Downstream of Etemba the next hydrological station is Nei-Neis Sabrina and Nei-Neis. Nei-Neis Sabrina and Nei-Neis are open sections and has recorded flows from 1986/87 to 1997/98 and 1974/75 to 1989/90 respectively. Once again the data recorded at Nei-Neis Sabrina and Nei-Neis has got estimates and lost data in the record. **Figure 5.3.5** presents the annual runoff records of Etemba and Nei-Neis Sabrina / Nei-Neis. From this set of data it is noted that for just about all years flow volumes recorded at Nei-Neis Sabrina and Nei-Neis are lower than at Etemba. It is hence clear from the data thus far presented, that Etemba shows the highest flows volumes for the Omaruru catchment. The data between Nei-Neis Sabrina and Nei-Neis further shows discrepancies that is an indication of poor quality of data.

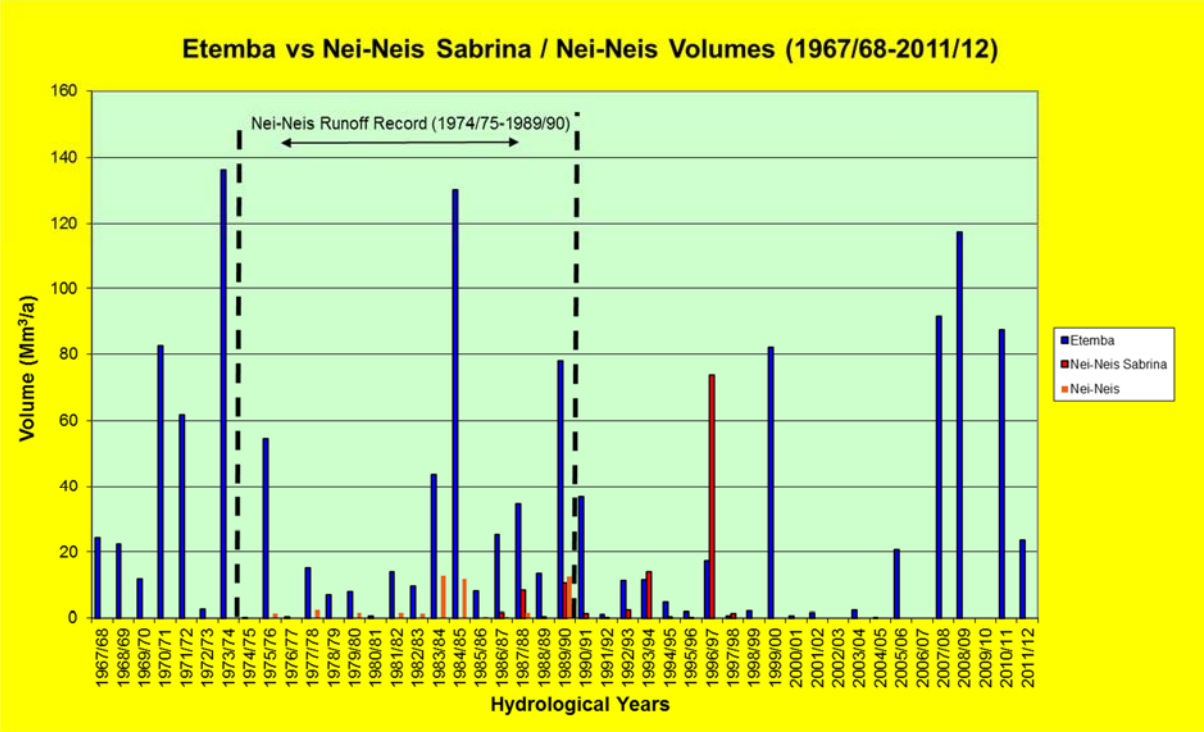

Figure 5.3.5: Etemba vs Nei-Neis Sabrina / Nei-Neis Annual Recorded Runoff

5.3.6 Nei-Neis Sabrina. / Nei-Neis vs Henties Monument / Omdel Dam Runoff

Downstream of Nei-Neis Sabrina / Nei-Neis the next hydrological station is Henties Monument and the Omdel Dam. Henties Monument recorded water levels from 1966/67 to 1995/96, with inflows recorded from 1992/93 into the Omdel Dam. **Figure 5.3.6** presents the annual runoff records of Nei-Neis Sabrina, Nei-Neis and Henties Monument / Omdel Dam. From this set of data it is noted that in just about all years flow volumes recorded at Nei-Neis Sabrina / Nei-Neis are higher than at Henties Monument / Omdel Dam. From the above data sets one detects that the eastern part of the Omaruru catchment produces the most runoff, with runoff volumes peaking at Etemba. From there westwards the flows in the Omaruru River decline to such an extent that only large prolonged floods would reach Omdel Dam.

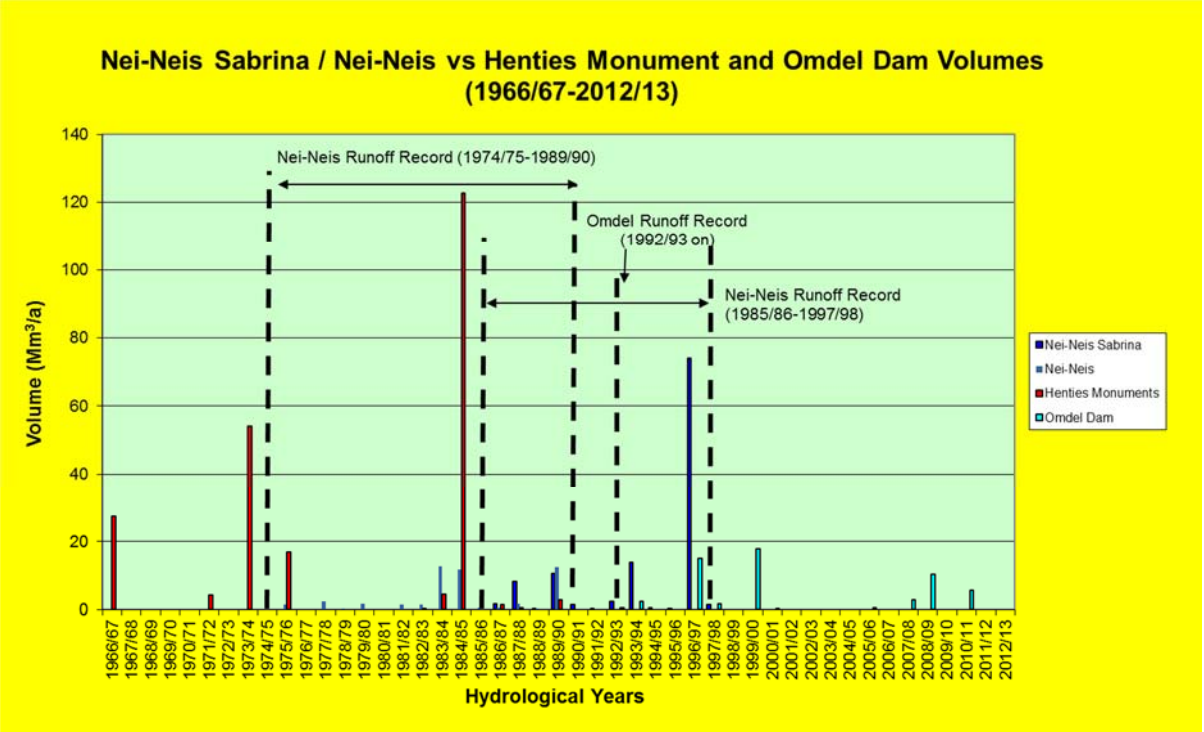

Figure 5.3.6: Nei-Neis Sabrina / Nei-Neis vs Henties Monument and Omdel Dam Annual Recorded Runoff

5.3.7 Etemba vs Henties Monument / Omdel Dam Runoff

Etemba has the most runoff record and also the highest volumes of flow of the hydrological stations in the Omaruru River catchment. Therefor the Etemba volumes were compared to the Henties Monument / Omdel Dam volumes. **Figure 5.3.7** presents the annual runoff records of Etemba vs Henties Monument / Omdel Dam.

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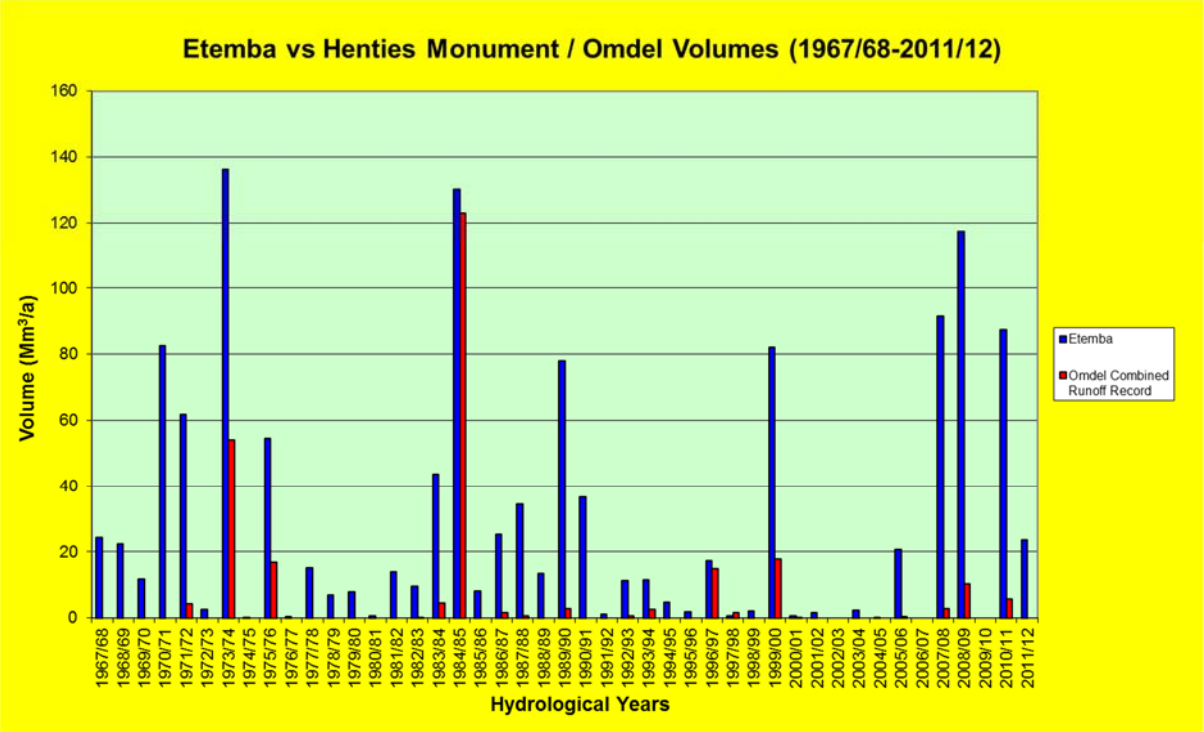

Figure 5.3.7: Etemba vs Henties Monument and Omdel Dam Annual Recorded Runoff

The 1985 flood that reached Henties Monument was very much in the same order of flood volume as that of the flood at Etemba. Often when Etemba had good floods, hardly any water reached Omdel Dam. Further based on the data presented above floods generally reduce substantially in volumes from Etemba downstream to the Omdel Dam site.

For the purpose of the rainfall/runoff modelling the runoff records at Henties Monument and Omdel Dam were combined to produce a runoff record for the period 1966/67 to 2012/13. Refer to **Appendix 3** for the observed runoff record and **Appendix 4** for the combined Henties Monument and Omdel Dam runoff records used in this study.

6. STATISTICS AND CORRELATIONS OF THE RUNOFF RECORDS

6.1. STATISTICS AND CORRELATIONS OF THE OBSERVED RUNOFF RECORDS OF THE HYDROLOGICAL STATIONS

The statistics of the runoff records of the hydrological stations were calculated and are presented in **Table 6.1.1** and **6.1.2**.

Table 6.1.1: Statistics of the Runoff Records of the Hydrological Stations

Parameter	Omburo (1974/75-2010/11)	Omaruru (1964/65-1996/97)	Etemba (1967/68-2011/12)	Otjompaue Synthesised Runoff Record (1923/24-1966/67)	Otjompaue / Etemba Synthesised Runoff Record Combined (1923/24-2011/12)
Mean (Mm^3)	23.033	29.704	28.847	45.946	37.300
Median (Mm^3)	16.060	20.887	11.749	12.300	11.850
Unbiased SD (Mm^3)	31.547	28.718	37.827	94.109	71.533
CV (Mm^3)	1.370	0.997	1.311	2.048	1.918
No of zero years	2	5	3	9	12
Length of record (Years)	37	33	45	44	89
Min (Mm^3)	0.000	0.000	0.000	0.000	0.000
Max (Mm^3)	68.141	89.400	136.164	540.740	540.740

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Table 6.1.2: Statistics of the Runoff Records of the Hydrological Stations

Parameter	Nei – Neis Sabrina (1986/87-1997/98)	Nei – Neis (1974/75-1989/90)	Henties Monument (1966/67-1991/92)	Omdel Dam (1992/93-2012/13)	Henties Monument / Omdel Dam Combined (1966/67-2012/13)
Mean (Mm^3)	9.553	3.028	9.059	2.718	6.226
Median (Mm^3)	1.554	1.403	0.000	0.000	0.000
Unbiased SD (Mm^3)	20.797	4.677	26.062	5.232	19.779
CV (Mm^3)	2.177	1.545	2.877	1.925	3.177
No of zero's years	0	3	16	11	27
Length of record (Years)	12	16	26	21	47
Min (Mm^3)	0.003	0.000	0.000	0.000	0.000
Max (Mm^3)	73.931	12.631	122.835	17.858	122.835

The statistics in **Tables 6.1.1** and **6.1.2** indicate that the mean flows (Mean), standard deviations (SD) increase up to Etemba / Otjompaue and coefficients of variance (CV) is fairly the same up to Etemba. The Etemba and Otjompaue records have a notable difference in the mean, statistical deviation and coefficient of variance indicating that the early 1900's were much wetter and with larger floods than the later 1900's. From Nei-Neis Sabrina / Nei-Neis the median is close to zero indicating that the probability of getting floods annually downstream from Nei-Neis Sabrina / Nei-Neis is slim. After Etemba the mean flows decrease, but the coefficients of variance continue to rise indicating that the variability of flood events gets higher moving westward in the catchment.

The statistical RSQ correlation coefficient was further calculated between the various hydrological stations as presented in **Section 5.3**. The RSQ returns the square of the Pearson product moment correlation coefficient through data points in known_y's and known_x's.

The equation for the Pearson product moment correlation coefficient, r, is:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

- where x and y are the sample means AVERAGE (known_x's) and AVERAGE (known_y's).
- RSQ returns r^2, which is the square of this correlation coefficient.
- The closer RSQ is to 1 the better the fit of the known data sets x and y

The results of the RSQ correlation coefficient analyses is presented in **Table 6.1.3.** For the graphical representation of the data refer to **Annexure 3.**

Table 6.1.3: RSQ Correlation Coefficient of Annual Runoff for the Hydrological Stations

RSQ Correlation with	Omaruru	Etemba	Nei-Neis Sabrina	Omdel Dam / Henties Monument combined runoff record
Omburo	0.0635	0.455	0.9637	0.182
Omaruru	1.00	0.167	NC	NC
Etemba	NA	1.00	-0.063	0.679
Nei-Neis Sabrina	NA	NA	1.00	0.976
Nei-Neis	NA	NA	NC	0.273

NA in the table indicates that the correlation in not applicable as the station is downstream and NC indicates correlations were not calculated.

The best RSQ correlation coefficient obtained for the annual runoff was between Nei-Neis Sabrina and Omdel Dam/Henties Monument, however due to the limited runoff data at Nei-Neis Sabrina this correlation is not considered to be of much value as the

station was an open section with questionable accuracy and hence was closed. The RSQ correlation coefficient obtained for the annual runoff was between Etemba and Nei-Neis Sabrina is $r^2 = -0.063$ whereas between Etemba and Omdel Dam/Henties Monument $r^2 = 0.679$. From the above analyses it is concluded that the statistical correlation of the annual runoff between the various stations is poor and this includes the Etemba and Omdel Dam / Henties Monument correlation of $r^2 = 0.679$. Presented in **Annexure 3** are the graphical comparisons between the hydrological stations' data.

A graphical presentation of the ranked runoff data at Etemba plotted against the Henties Monument / Omdel Dam ranked runoff data is presented in **Figure 6.1.1**. From the figure it can be seen that floods that occur at Etemba do not always occur at Henties Monument / Omdel Dam and that the magnitudes of the floods at Henties Monument / Omdel Dam, thou unlikely could be higher than at Etemba as in ranked year 39. It is further also clear from the graph that floods at Etemba of up to 82.5 Mm^3/a, which is in the eastern part of the catchment sometimes do not result in any runoff at Henties Monument / Omdel Dam, as in ranked year 6.

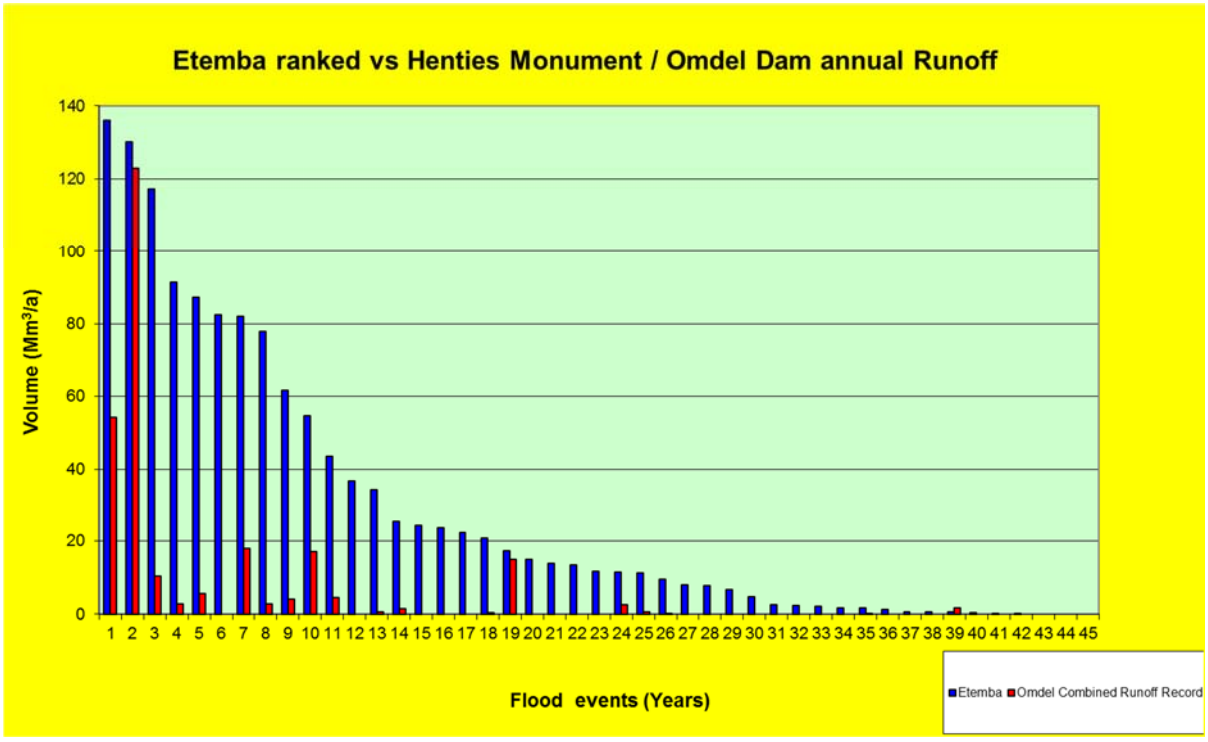

Figure 6.1.1: Etemba Ranked Runoff and Henties Monument / Omdel Dam combined Ranked Runoff

6.2. STATISTICS OF THE RUNOFF RECORDS OF OMDEL DAM AND HENTIES MONUMENT AND OMDEL DAM COMBINED

The Omdel Dam inflow record and the Henties Monument runoff record 7 km downstream of Omdel Dam was combined with the Omdel Dam inflow record to generate two observed runoff records. These records were used to determine the water available for artificial recharge of the Omdel Aquifer. The statistics of Omdel Dam are presented in **Table 6.2.1** for the period 1992/93 to 2009/10 and **Table 6.2.2** for the period 1992/93 to 2012/13. **Table 6.2.3** represents the statistics of the combined Henties Monument runoff and Omdel Dam inflow.

Table 6.2.1: Statistics of Simulated Flow Data in Mm³ from 1992/93 to 2009/10 for Omdel Dam

Statistics of Omdel Dam Observed Runoff Record from 1992/93 to 2009/10													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
MAR (Mm³)	0.00	0.00	0.09	0.73	0.47	1.51	0.05	0.00	0.00	0.00	0.00	0.00	**2.85**
Median (Mm³)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**
Unbiased SD	0.00	0.00	0.38	2.58	1.09	4.57	0.12	0.02	0.00	0.00	0.00	0.00	**5.55**
CV	#DIV/0!	#DIV/0!	4.24	3.53	2.32	3.03	2.43	3.50	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	**1.94**
Zero's	18.00	18.00	17.00	16.00	13.00	13.00	13.00	16.00	18.00	18.00	18.00	18.00	**9.00**
Years	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	**18.00**
Min (Mm³)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Max (Mm³)	0.00	0.00	1.60	10.85	3.97	17.76	0.50	0.07	0.00	0.00	0.00	0.00	**17.86**

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Table 6.2.2: Statistics of Simulated Flow Data in Mm³ from 1992/93 to 2012/13 for Omdel Dam

Statistics of Omdel Dam Observed Runoff Record from 1992/93 to 2012/13													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
MAR (Mm^3)	0.00	0.00	0.08	0.63	0.40	1.32	0.28	0.00	0.00	0.00	0.00	0.00	**2.72**
Median (Mm^3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Unbiased SD	0.00	0.00	0.35	2.40	1.02	4.24	1.09	0.01	0.00	0.00	0.00	0.00	**5.23**
CV	#DIV/0!	#DIV/0!	4.58	3.82	2.53	3.20	3.87	3.79	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	**1.92**
zero's	21.00	21.00	20.00	19.00	16.00	15.00	15.00	19.00	21.00	21.00	21.00	21.00	**11.00**
Years	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	**21.00**
Min (Mm^3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Max (Mm^3)	0.00	0.00	1.60	10.85	3.97	17.76	5.04	0.07	0.00	0.00	0.00	0.00	**17.86**

Table 6.2.3: Statistics of Simulated Flow Data in Mm^3 from 1966/67 to 2012/13 for Henties Monument and Omdel Dam combined runoff records

Statistics of Henties Monument/Omdel Dam Observed Runoff Record from 1966/67 to 2012/13													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
MAR (Mm^3)	0.00	0.00	0.04	0.98	3.86	1.13	0.22	0.00	0.00	0.00	0.00	0.00	**6.23**
Median (Mm^3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Unbiased SD	0.00	0.00	0.24	3.80	17.31	3.34	0.88	0.01	0.00	0.00	0.00	0.00	**19.78**
CV	#DIV/0!	#DIV/0!	6.13	3.89	4.48	2.95	4.05	5.70	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	**3.18**
zero's	47.00	47.00	45.00	41.00	35.00	34.00	37.00	45.00	47.00	47.00	47.00	47.00	**27.00**
Years	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	**47.00**
Min (Mm^3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Max (Mm^3)	0.00	0.00	1.60	22.87	114.94	17.76	5.04	0.07	0.00	0.00	0.00	0.00	**122.84**

7. OMDEL DAM CHARACTERISTICS

7.1 FULL SUPPLY LEVEL AND STORAGE CAPACITIES

The Omdel Dam is an earth fill embankment with a clay core and has a spillway length of 188 m at a level of 262.2 m AMSL at which the dam would presently store 37.389 Mm^3 of water and cover a surface are of 4.398 km^2. This information is obtained from the Omdel Dam silt survey which was finalised during October 2006, as updated data for this study. **(Reference 20.14)**. The dam basin was resurveyed during 2013 and the results are expected in 2014.

7.2 SILTATION

The lower part of the Omaruru River is renowned for its high silt loads during flood events. During October 2005 as part of the evaluation of the hydrology of Omdel Dam the Omdel Dam basin was surveyed and compared to the original dam basin survey. The results were finalised during October 2006.

The survey revealed that the silt deposits reached the 244 m contour level at the lowest point in the basin close to the dam wall. This indicates a 244 m to 235 m = 9 m silt deposit inside the 244 m closed contour. Silt deposits were seen as far as the 254 m contour upstream, where much of it was only a top layer of approximate 50 mm to 100 mm. It is expected that further down it is probably a mixture of sand and debris presently. Between the 254 m and 256 m contours, no definite silt deposits could be determined although there is a significant difference between the original volume and the new volume.

The difference between the total original volume and the total present volume of the dam basin amounts to 3.828 Mm^3. During the same period the total inflow recorded into Omdel Dam amounted to 37.589 Mm^3. The percentage silt load is calculated to be 10.18% of the volume of floods recorded into the dam since its completion. This is more than 3 times the 3% normally used for silt loads of floods in Namibia. **Photo 7.2.1** indicates the silt deposits in the Omdel Dam basin.

Photo 7.2.1: Silt deposits in the Omdel Dam basin.

7.3 DEAD STORAGE

It is attempted to manage Omdel Dam in such a way that the dead storage of the Omdel Dam is zero. The reason for this is that presently annually silt is removed around the abstraction tower resulting in a depression at the abstraction tower. However for the modelling a value of 0.200 Mm^3 was used. Refer to **Photo 7.3.1** for the result of the silt removal around the abstraction tower.

Photo 7.3.1: Omdel Dam after the removal of the silt around the abstraction tower.

The removal of the silt results that presently, just about all water of the dam can be drained to the abstraction tower and released from Omdel Dam as can be observed in **Photo: 7.3.2**.

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Photo 7.3.2: Dead storage water of Omdel Dam is canalled to the abstraction tower.

Silt is known to affect aquifer recharge from floods (*CRERAR ET AL., 1988*). While infiltration rates in the alluvium can reach more than 1 cm/hour in the absence of silt layers (KÜLLS ET AL., 1994), silt may reduce infiltration dramatically to 0 cm/h. **(Reference 20.15)**.

Infiltration processes are complex and are variable under different flow and storage conditions and hence accurate estimates are a challenge. During 1988 a study was conducted to investigate factors affecting groundwater recharge from ephemeral flows in SWA / Namibia. **(Reference 20.16)**. Although this study was conducted in an ephemeral river and the laboratory, the results indicated that the first flood events result in the highest infiltration rate and that silt plays a significant role in the rate at which infiltration would occur and that silt can alleviate infiltration, irrespectively of the silt load.

Hence the high silt load as experienced for Omdel Dam was expected to affect the infiltration characteristics of the dam basin in a fairly short time span, estimated at five annual flood events. It was further expected that when releases from the Omdel Dam took place, initial losses in the river bed would be high and as silt is deposited in the river bed the silt load would reduce until hardly any infiltration took

place. This information from previous studies was incorporated in the water balance of the Omdel Dam releases for the enhancement of the Omdel Aquifer.

For each flood event a water balance was carried out for Omdel Dam. The water balances included calculating the infiltration into the dam basin and following in **Figures 7.3.1** and **7.3.2** is a plot of the results obtained from the 1996/97 and 1999/2000 flood season reports when the dam received inflows of 16.272 Mm³ and 18.060 Mm³ respectively.

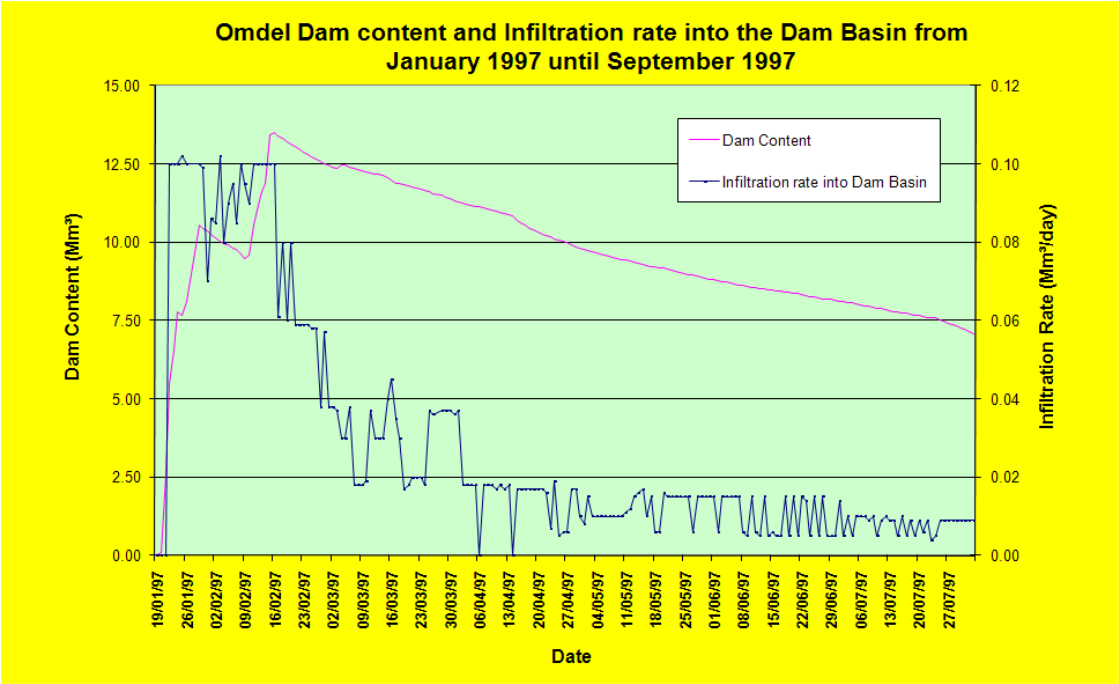

Figure 7.3.1: Content and Infiltration Rate/day at Omdel Dam for 1996/1997

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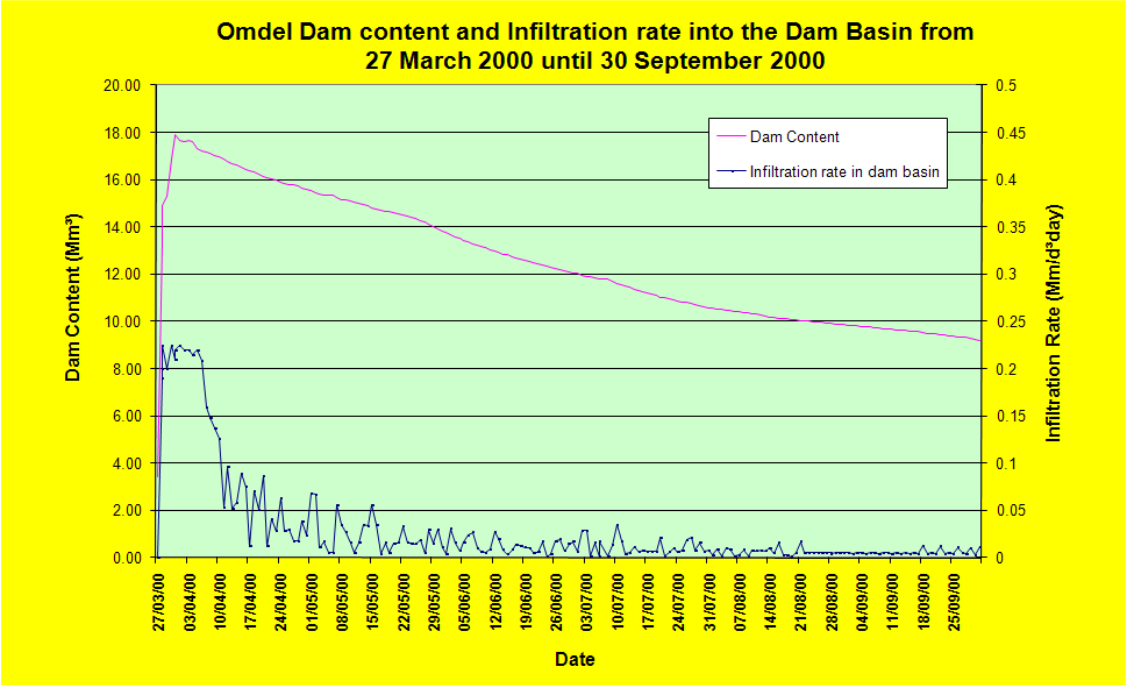

Figure 7.3.2: Content and Infiltration Rate rate/day at Omdel Dam for 1999/2000

Based on the data collected thus far, the initial infiltration losses for the first month after inflow vary between 1 and 3 Mm³/month and are linked to the magnitude of the flood volume. **Table 7.3.1** summarises the water balance data calculated thus far for Omdel Dam flood events for various hydrological years the dam had received inflow. Further reference can be made to the annual water balance reports compiled by Hydrology for these years.

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Table 7.3.1: Summary of Omdel Dam Water Balances

Hydrological Year	Total Inflow (Mm^3)	Volume Infiltrated (Mm^3)	Volume Evaporated (Mm^3)	Volume Released (Mm^3)	Storage on 30 September (Mm^3)
1996/97	16.403	5.556	3.620	2.115	5.112
1997/98	1.644	0.512	1.957	2.715	1.572
1998/99	0.000	0.000	0.000	0.000	0.000
1999/00	19.166	4.814	3.133	2.022	9.197
2000/01	0.071	0.741	2.176	2.766	3.584
2001/02	0.000	0.000	0.000	0.000	0.000
2002/03	0.000	0.000	0.000	0.000	0.000
2003/04	0.000	0.000	0.000	0.000	0.000
2004/05	0.000	0.000	0.000	0.000	0.000
2005/06	0.501	0.141	0.179	0.013	0.168
2006/07	0.000	0.000	0.000	0.000	0.000
2007/08	2.853	0.492	0.226	1.528	0.322
2008/09	10.423	2.755	0.715	6.084	0.000
2010/11	5.716	2.795	0.166	2.215	0.000
2011/12	0.000	0.000	0.000	0.000	0.000
1012/13	0.000	0.000	0.000	0.000	0.000

If water could still be released after September, then releases continued into the next hydrological year.

General note: The water balances were only calculated to the point where the dam reached the lowest level of the gauge plate or alternatively until releases were discontinued.

Based on this information and in consultation with the Deputy Director: Geohydrology, Mr G Christelis, and the Chief Geohydrologist, Dr E Tordiffe, both

from DWAF, it was agreed to assume that the infiltration losses for flood one on record will be 2 Mm^3 for the first month and that the losses will reduce by 0.2 Mm^3 for the following year's floods until the minimum of a 1 Mm^3 base loss. It was further agreed that the base monthly infiltration loss at the dam for the months following the first month of inflow would be 0.222 Mm^3/month.

7.4 OMDEL DAM BASIN CHARACTERISTICS

The physical characteristics of the dam basins are presented in **Table 7.4.1**.

Table 7.4.1: Physical Characteristics of the Omdel Dam

Elevation (m AMSL)	Capacity (Mm^3)	Surface Area (km^2)
244	0.000	0.069
245	0.195	0.322
246	0.646	0.579
247	1.368	0.865
248	2.297	0.993
249	3.349	1.111
250	4.607	1.405
252	7.695	1.683
254	11.369	1.992
256	15.980	2.619
258	21.767	3.168
260	28.591	3.655
262	36.526	4.280
264	37.389	4.348

The surface areas at different volumes are used to determine the volume of water that is evaporated, which is required as a loss in the yield analyses of the dam. The volume area relationship is given by the equation:

Area Volume Relationship: Area = 0.540739(Volume)$^{0.567936}$*

8. RAINFALL / RUNOFF RELATIONSHIP AND RUNOFF SYNTHESIS

For this study a relationship between rainfall and runoff was determined to be able to extend the runoff record of Omdel Dam.

8.1 METHODOLOGY ADOPTED FOR THE RAINFALL ANALYSES

The Multiquadric Surface Fit analysis was developed for modelling the topographic of irregular surfaces. **(Reference 20.17)**. For **n** data points with co-ordinates (x_i, y_i) to which the surface is fitted, the following equation applies:

$$Z_i = {}^{n}\sum C_j \{(x_j - x_i)^2 + (y_j - y_i)^2\}^{½}$$

Where Z_i = heights of the surface at n data points

C_j = coefficients associated with each of the cones/rectangles.

The Multiquadric Surface Fit program was subsequently run for every sub-catchment to convert point rainfall to areal rainfall for the period 1923/24 to 2009/2010.

8.2 METHODOLOGY ADOPTED FOR THE RAINFALL / RUNOFF RELATIONSHIP

The results of the Multiquadric Surface Fit analyses were utilised in the Namibian Rainfall/Runoff Model, NAMROM, to determine a regression equation between rainfall and runoff. For the evaluation of the runoffs and yields the Omdel Dam and the Henties Monument hydrological stations data was combined in the following procedure, with the assumption that Henties Monument's runoff data is representative for Omdel Dam. The procedure followed can be described as follows:

- The hydrological routing of these monthly rainfall volumes through the catchment of the Omdel Dam to calibrate the parameters of the rainfall / runoff model, NAMROM, for the period with the observed flow record.
- The application of this model to extend the observed flow record back to 1926/1927 to obtain a long synthetic monthly flow sequence.

8.3 CALIBRATION OF THE RAINFALL/RUNOFF MODEL

The area of each of the sub-catchments was determined and the average areal precipitation depth of each sub-catchment was calculated. This average areal precipitation depth was converted to a rainfall volume by multiplying it by the area of each sub-catchment. After obtaining the volumes, these were weighted according to a number of parameters as specified in the rainfall/runoff model **(Reference 20.18)**, summed for all the sub-catchments and fitted to the observed monthly runoff.

Having calibrated the model for the observed runoff data, it was then used to extend the runoff record back to 1926/27 for the Omdel Dam site stations.

8.4 DATA SETS CALIBRATED WITH THE RAINFALL / RUNOFF MODEL

The Multiquadric Surface Fit rainfall data was calibrated against the combined Henties Monument and Omdel Dam runoff records. Using the regression equation, which had an extremely poor correlation coefficient of 37.42%, the Omdel Dam runoff record was extended to 1926/27. This data is presented in **Appendix 5**.

Due to the extremely poor correlation coefficient obtained, the Omdel Dam runoff record was evaluated and amended. The Henties Monument observed runoff record indicated that for the 1983/84 season a volume of 114.936 Mm^3 was recorded in the month of February 1985. When comparing the Multiquadric Surface Fit rainfall of 1983/84 to years with similar rainfall it was noted that the runoff for these years was only between 0 and 27.771 Mm^3. It was opted to change the 1983/84 season's runoff value in an attempt to obtain a better correlation coefficient. The value adopted at the end through modelling testing was 20.936 Mm^3 for the month of February 1984. One could argue that this should not be done or that the figure could be more or less,

however by amending this flood volume the correlation coefficient increased to 52.45%, which is still very poor. Using the regression equation, which had an improved correlation coefficient the Omdel Dam runoff record was extended to 1926/27. It should be noted that 1983/84 had high flood events ant that the 114.936 Mm is the correct figure. This data is presented in **Appendix 6**.

9. RAINFALL/RUNOFF RESULTS

9.1 COMBINED HENTIES MONUMENT / OMDEL DAM RUNOFF RECORD

The Mean Annual Runoff (MAR) for the combined Henties Monument and Omdel Dam observed runoff record from 1966/67 to 2009/10 is 6.52 Mm^3. The Coefficient of Variation (CV) is 3.13 with a median annual runoff of 0.00 Mm^3 and 25 (57%) years of zero runoff having occurred in the 44 year period.

Using NAMROM a synthesised flow record was then generated for the corresponding years (1966/67 to 2009/10). A MAR of 6.53 Mm^3 with a CV of 1.23 was obtained. The median annual runoff from the synthesised record was 2.75 Mm^3, with 7 (16%) years of zero runoff.

The calculated regression equation and the correlation coefficient are presented in **Table 9.1.1**.

Table 9.1.1: Regression Results

Regression Equation :	Runoff = 0.040 * Weighted Precipitation – 0.001
Correlation Coefficient	= 37.42 %

The coefficient of correlation of 37.42% is considered to be extremely poor.

Using this regression equation, an 84 years synthesised monthly runoff record was generated for the period 1926/27 to 2009/10, which is three years shorter than the Multiquadric Surface Fit rainfall record due to the incorporation of the three years of antecedent figures. The MAR and the median annual runoff for the synthesised runoff

record are 9.32 Mm^3 and 2.27 Mm^3, respectively. The CV was 2.23 and 20 years (24%) of zero runoff occurred.

Table 9.1.2 to **Table 9.1.4** provide a summary of the runoff statistics of the rainfall / runoff calibration for the combined Henties Monument and Omdel Dam runoff record. The observed runoff record, the combined synthesised runoff record (note that the record from 1966/67 onwards is the actual observed runoff record), and information on the variables obtained for Omdel Dam are presented in full in **Appendix 7**. **Annexure 4** presents the graphical outlook of the actual synthesised annual runoff record versus the observed runoff record.

Table 9.1.2: Statistics of Observed Flow Data in Mm^3 from 1966/67 to 2009/10 for Omdel Dam

Statistics of Henties Monument / Omdel Dam Observed Runoff Record, 1966/67 to 2009/10													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm^3	0.00	0.00	0.04	1.04	4.12	1.19	0.12	0.00	0.00	0.00	0.00	0.00	6.52
SD Mm^3	0.00	0.00	0.24	3.93	17.87	3.44	0.52	0.01	0.00	0.00	0.00	0.00	20.41
CV	0.00	0.00	5.93	3.76	4.34	2.88	4.47	5.74	0.00	0.00	0.00	0.00	3.13
Median Mm^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zero's	44	44	42	38	33	33	35	42	44	44	44	44	25
Years	44	44	44	44	44	44	44	44	44	44	44	44	44

Table 9.1.3: Statistics of Simulated Flow Data in Mm^3 from 1966/67 to 2009/10 for Omdel Dam

Simulated Flow Data from 1966/67 to 2009/10 Hydrological Years													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm^3	0.00	0.13	0.14	2.40	2.42	1.10	0.345	0.00	0.00	0.00	0.00	0.00	6.53
SD Mm^3	0.00	0.66	0.60	4.44	3.86	2.05	1.24	0.00	0.00	0.00	0.00	0.00	8.04
CV	0.00	4.89	4.21	1.85	1.60	1.87	3.67	0.00	0.00	0.00	0.00	0.00	1.23
Median Mm^3	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75
Zero's	44	41	38	25	14	22	39	44	44	44	44	44	7
Years	44	44	44	44	44	44	40	44	44	44	44	44	44

Table 9.1.4: Statistics of Simulated Flow Data in Mm³ from 1926/27 to 2009/10 for Omdel Dam

Simulated Flow Data from 1926/27 to 2009/10 Hydrological Years													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm³	0.0	0.16	0.44	3.02	2.50	2.71	0.48	0.0	0.0	0.0	0.0	0.0	9.32
SD Mm³	0.00	0.82	1.65	7.08	4.80	8.00	1.75	0.00	0.00	0.00	0.00	0.00	20.73
CV	0.00	5.02	3.75	2.34	1.92	2.95	3.63	0.00	0.00	0.00	0.00	0.00	2.23
Median Mm³	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.27
Zero's	84	78	68	49	35	44	71	84	84	84	84	84	20
Years	84	84	84	84	84	84	84	84	84	84	84	84	84

9.2 AMENDED COMBINED HENTIES MONUMENT / OMDEL DAM RUNOFF RECORD

The rainfall / runoff modelling was repeated using the amended combined Henties Monument / Omdel Dam runoff record described in **Section 8.4**.

The Mean Annual Runoff (MAR) for the amended combined Henties Monument and Omdel Dam observed runoff record from 1966/67 to 2009/10 is 4.38 Mm^3. The Coefficient of Variation (CV) is 2.38 with a median annual runoff of 0.00 Mm^3 and 25 (57%) years of zero runoff occurred for the 44 year period.

A synthesised flow record was generated for the corresponding years (1966/67 to 2009/10). A MAR of 4.38 Mm^3 with a CV of 1.11 was obtained. The median runoff from the synthesised record was 2.22 Mm^3, with 4 (9%) years of zero runoff occurring for the 44 year period.

The calculated regression equation and the correlation coefficient are presented in **Table 9.2.1**.

Table 9.2.1: Regression Results

Regression Equation : Runoff = 0.022 * Weighted Precipitation + 0
Correlation Coefficient = 52.45 %

The coefficient of correlation was 52.45%, which represents a poor fit.

Using this regression equation, a 84 year synthesised monthly runoff record was generated for the period 1926/27 to 2009/10 which is three years shorter than the

Multiquadric Surface Fit rainfall record due to the incorporation of the three years of antecedent figures. The MAR and the median annual runoff for the longer synthesised runoff record are 5.81 Mm^3 and 1.92 Mm^3, respectively. The CV was 2.01 and 14 years (17 %) of zero runoff occurred.

Table 9.2.2 to **Table 9.2.4** provides a summary of the runoff statistics of the rainfall / runoff calibration for the amended combined Henties Monument and Omdel Dam runoff record and regression results. The observed runoff record, the combined synthesised runoff record (note that besides for 1983/84 the record from 1966/67 onwards is the actual observed runoff record), and information on the variables obtained for Omdel Dam are presented in full **Appendix 7**. **Annexure 4** presents the graphical outlook of the actual synthesised annual runoff record versus the amended observed runoff record.

Table 9.2.2: Statistics of Amended Observed Flow Data in Mm^3 from 1966/67 to 2009/10 for Omdel Dam

Statistics of Henties Monument / Omdel Dam Observed Runoff Record, 1966/67 to 2009/10													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm^3	0.00	0.00	0.04	1.04	1.98	1.19	0.12	0.00	0.00	0.00	0.00	0.00	4.38
SD Mm^3	0.00	0.00	0.24	3.93	5.97	3.44	0.52	0.01	0.00	0.00	0.00	0.00	10.43
CV	0.00	0.00	5.93	3.76	3.01	2.88	4.47	5.74	0.00	0.00	0.00	0.00	2.38
Median Mm^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zero's	44	44	42	38	33	33	35	42	44	44	44	44	25
Years	44	44	44	44	44	44	44	44	44	44	44	44	44

Table 9.2.3: Statistics of Simulated Flow Data in Mm^3 from 1966/67 to 2009/10 for Omdel Dam

Simulated Flow Data from 1966/67 to 2009/10 Hydrological Years													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm^3	0.00	0.10	0.12	1.50	1.61	0.82	0.23	0.00	0.00	0.00	0.00	0.00	4.38
SD Mm^3	0.00	0.46	0.43	2.62	2.27	1.29	0.79	0.00	0.00	0.00	0.00	0.00	4.86
CV	0.00	4.56	3.60	1.74	1.41	1.57	3.47	0.00	0.00	0.00	0.00	0.00	1.11
Median Mm^3	0.00	0.00	0.00	0.01	0.69	0.19	0.00	0.00	0.00	0.00	0.00	0.00	2.22
Zero's	44	41	36	19	11	13	38	44	44	44	44	44	4
Years	44	44	44	44	44	44	44	44	44	44	44	44	44

Table 9.2.4: Statistics of Simulated Flow Data in Mm³ from 1926/27 to 2009/10 for Omdel Dam

Simulated Flow Data from 1926/27 to 2009/10 Hydrological Years													
Statistics	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
MAR Mm³	0.00	0.12	0.30	1.81	1.59	1.68	0.31	0.00	0.00	0.00	0.00	0.00	5.81
SD Mm³	0.00	0.54	1.01	3.98	2.75	4.46	1.05	0.00	0.00	0.00	0.00	0.00	11.69
CV	0.00	4.58	3.32	2.20	1.73	2.66	3.36	0.00	0.00	0.00	0.00	0.00	2.01
Median Mm³	0.00	0.00	0.00	0.00	0.35	0.10	0.00	0.00	0.00	0.00	0.00	0.00	1.92
Zero's	84	76	63	42	28	32	67	84	84	84	84	84	14
Years	84	84	84	84	84	84	84	84	84	84	84	84	84

9.3 EXTENDING HYDROLOGICAL STATIONS RUNOFF RECORDS

Due to the poor quality of the hydrological stations data, which contributes to the poor correlation coefficient obtained between the hydrological stations, no further attempts were made to extend these stations runoff records with the use of upper or lower downstream stations.

10. YIELD ANALYSES FOR OMDEL DAM

The Omdel Dam was not intended to have a safe yield of water supply, but to prevent water of small to medium floods to flow into the Atlantic Ocean. The aim of this investigation was to determine the average amount of water available from the Omdel Dam that could be utilised for enhancement of the Omdel Aquifer.

11. RELEASE RATES ADOPTED FOR THE OMDEL DEPLETION MODEL

During the 2008 releases from Omdel Dam the wetted area of the river bed between the Omdel Dam and Site 1 was surveyed and found to be 166 536 m². This information was used to calculate the evaporation losses from the wetted river area.

Once the water enters the ponds, the water either evaporates or infiltrates. Once again the evaporation volumes were calculated taking into account the areas of the ponds, which are presented in **Table 11.1.**

Table 11.1: Dimensions and Areas of Omdel Infiltration Ponds

	Dimensions (m)	Area (m²)
Site 1 Pond A	427 x 213 x 4	15 603
Site 1 Pond B	427 x 213 x 4	20 500
Site 1 Pond C	230 x 140 x 2	26 378
Site 1 Pond D	230 x 140 x 2	26 378
Site 2 Pond 1	275 x 110 x 3	30 478
Site 2 Pond 2	275 x 110 x 3	30 478

Based in this information the input data was evaluated with the Omdel Hydrological Model expressed in **Figure 11.1** to refine the optimal release rates

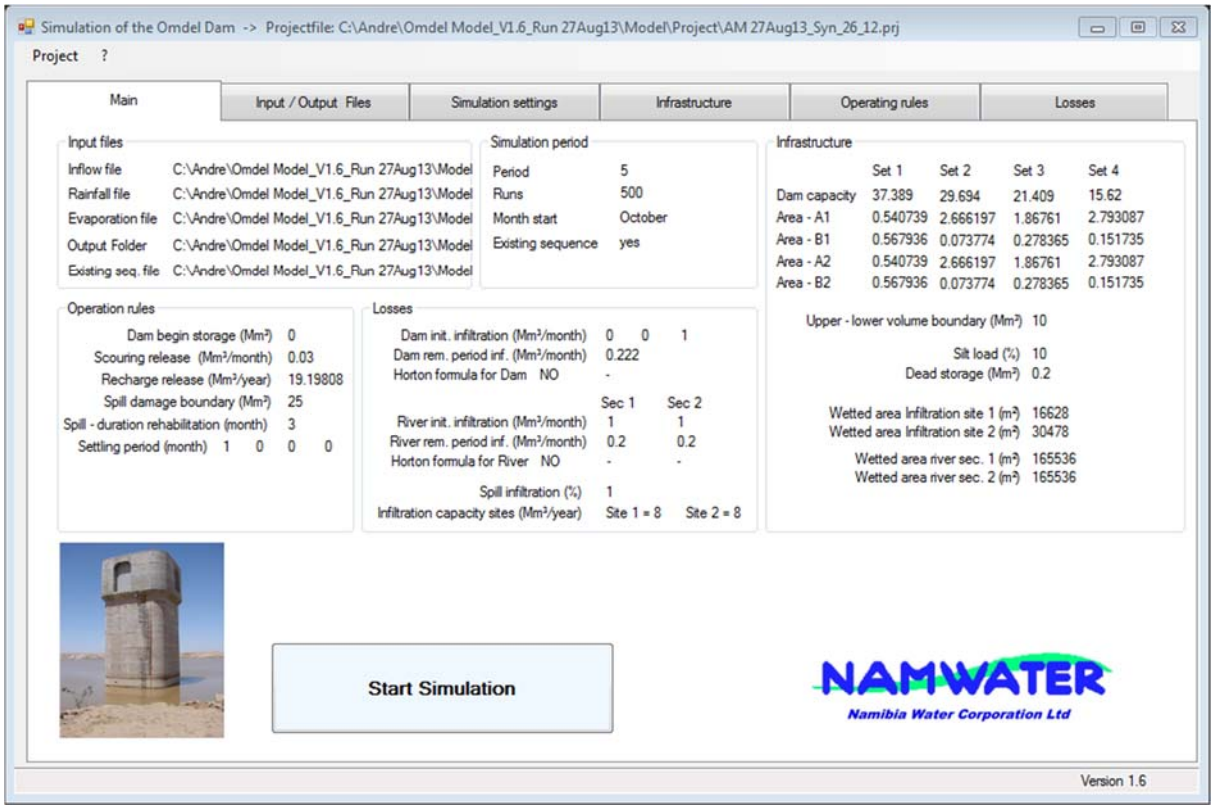

Figure 11.1: Input mask for the Omdel Hydrological Model

The release rate required for the operation of the Omdel artificial recharge basins should be at least 19.2 Mm³/a. The reason for this is that the infiltration ability for Site 1 is documented to be 8.0 Mm³/a, further due to insufficient information for the infiltration potential of Site 2, the assumption is that Site 2 will also be able to infiltrate at a rate of 8.0 Mm³/a. These two volumes along with the evaporation losses and the infiltration losses along the way to the infiltration sites amount to approximately the release rate of 19.2 Mm³/a. For comparison the modelling was also run with a 20.0 Mm³/a release rate.

If only Site 1 is operated then the release rate should be 9.5 Mm³/a, of which 1.5 Mm³/a is deemed to be for the losses in the river bed and evaporation from the wetted area during releases. These losses need to be monitored in the future to refine the losses through metering and observations.

12. HYDROLOGICAL MODELLING

12.1 HYDROLOGICAL MODELLING 2010

Following the 2011 presentation the Ministry of Agriculture and Forestry requested that the model be rerun with the present rainfall/runoff (up to 2010) data over a 5 year period with a silt load of 10% and to present these results to the Omdel Technical Committee that was re-established at the presentation. This modelling was completed and presented in 2011 **(Appendix 1).**

Following the report's discussion held on 4 April 2011, NamWater Hydrology was requested to:

- Determine the potential inflow for the next 5 years into Omdel Dam and to use this data to determine the amount of water available from the dam for artificial recharge of the Omdel Aquifer based on a flood silt load of 10%.
- To re-assess the hydrology with the most up to date rainfall and runoff data and then determine for the amount of water available from the dam for artificial recharge of the Omdel Aquifer.

This section addresses the first bullet only.

12.1.1 Methodology Adopted for the Hydrological Analysis

In consultation with the members of the Omdel Technical Committee the following methodology was adopted to determine the potential average amount of water available for infiltration at the infiltration sites over the next 5 years.

The combined synthesised and observed runoff record for the period 1916/17 to 2002/03 was used as input data to generate stochastic runoff records. The first 5 years of data was utilised from each run to set up a sample of data for 500 5-year sequences.

From the 500 ranked 5-year sequences each 10th sequences' data was used to determine the amount of water available from the dam for artificial recharge of the Omdel Aquifer. The methodology of the Omdel Dam depletion model used for this procedure is documented in the report "*A Comprehensive Assessment of the Hydrology of the Omaruru Delta (OMDEL) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer"* **(Reference 20.3)**. The analyses were done based on a 10% flood silt load and based on the latest storage volume of 37.389 Mm^3 for Omdel Dam.

Release rates of 9.500 Mm^3/a and 20.000 Mm^3/a as documented in the hydrological report were used as release rates for Site 1 and Site 2 respectively. Following the first release of water for Site 2 new information was forthcoming indicating that the channel between Site 1 and Site 2 has much lower losses than the channel from the dam to Site 1 and hence a release rate of 19.200 Mm^3/a, but with lower losses was also modelled. These lower losses were documented in the report "*Water Balance for Omdel Dam during Releases for Artificial Recharge during the 2008/2009 Hydrological Season*" **(Reference 20.19).**

12.1.2 Modelling results obtained from the stochastic runoff record derived from the amended Omdel runoff record combined with the Henties Monument runoff record (1916/17 to 2002/03, lost rainfall used as zero rainfall)

Two data sets were considered:

The first data set was the every 10th year stochastic runoff data for the 500, 5-year sequences and with initial dry river channel losses of **1.000 Mm³** each between the dam and Site 1 and Site 1 and Site 2. For this data set release rates of 9.500 Mm³/a and 20.000 Mm³/a were used. A release rate of 19.200 Mm³/a was included for reasons explained. The initial infiltration for the dry Omdel Dam basin was set to 1.000 Mm³ as the dam already has had 5 flood events that have resulted in a "large" silt load into the dam.

The data obtained from the water balance model was then averaged and is presented in **Table 12.1.2.1**.

Table 12.1.2.1: Average Volumes Released from Omdel Dam and Infiltrated at the Infiltration Sites (1916/17-2002/03 used for stochastic runs, lost rainfall =zero)

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.379	3.376	1.957
19.200	37.389	0.200	3.139	3.973	2.412
20.000	37.389	0.200	3.185	4.005	2.466

The second data set was the every 10th year stochastic runoff data for the 500, 5-year sequences with the initial dry river channel losses of 1.000 Mm³/a for the channel up to Site 1 and an initial loss of **0.050 Mm³** for the river section from Site 1 to Site 2. For this data set release rates of 9.500 Mm³/a, 19.200 Mm³/a and 20.000 Mm³/a were modelled. The adding of the 19.200 Mm³/a releases rate is considered to be more relevant as fewer losses occurred to Site 2 and hence a lower release rate was adopted to prevent spilling of the infiltration basins. The initial infiltration for Omdel Dam basin was set to1.000 Mm³ as the dam already has had 5 flood events that have resulted in a "large" silt load into the dam.

The results obtained from the water balance model were then averaged and the most relevant values are presented in **Table 12.1.2.2.**

Table 12.1.2.2: Average Volumes Released from Omdel Dam and Infiltrated at the Sites Based on 2008/2009 Channel Losses (1916/17-2002/03 used for stochastic runs, lost rainfall =zero)

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.379	3.376	1.957
19.200	37.389	0.200	3.142	3.899	2.648
20.000	37.389	0.200	3.184	3.930	2.693

12.1.3 Comparison with April 2010 Results

The recommendations from the hydrological report (**Reference 20.3**) for the short to medium term average volumes available for Omdel Dam for abstraction rates of 9.500 Mm³/a and 20.000 Mm³/a are presented in **Table 12.1.3.1**. These results were based on initial dry channel losses of 1.000 Mm³ per section and the original dam basin storage capacity. Furthermore the initial infiltration into the dry dam basin was set to 2.000 Mm³ and reduced to 1.000 Mm³ over the first 5 flood events.

Table 12.1.3.1: Recommended Short to Medium Term Average Volumes Available for Omdel Dam for Abstraction Rates of 9.5 Mm³/a and 20.0 Mm³/a

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)		Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)		Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)	
			10% Silt	2% Silt	10% Silt	2% Silt	10% Silt	2% Silt
9.500	41.300	0.200	2.575	3.350	2.564	3.935	1.301	2.325
20.000	41.300	0.200	3.453	4.413	3.068	4.549	1.584	2.840

The data from **Table 12.1.2.1** and **Table 12.1.2.2** is based on a 5-year model whereas the data from **Table 12.1.3.1** is based on the synthesised runoff record with silt loads of 10% and 2% respectively for the total duration of the synthesised runoff data.

As one would expect due to reducing capacity of the dam due to a 10% siltation load on average per flood, the long term potential of artificial recharge from the dam is lower than the 5 year potential artificial recharge. The results obtained from the different input data are summarised in **Table 12.1.3.2**, with an explanation of the data sets below the table.

Table 12.1.3.2: Summary of Results

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)		Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)		Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)	
			10% Silt	2% Silt	10% Silt	2% Silt	10% Silt	2% Silt
(1) 20.000	41.300	0.200	3.453	4.413	3.068	4.549	1.584	2.840
(2) 20.000	37.389	0.200	3.185	-	4.005	-	2.466	-
(3) 20.000	37.389	0.200	3.184	-	3.930	-	2.693	-
(4) 19.200	37.389	0.200	3.142	-	3.899	-	2.648	-

(1) Results based on the initial dry river channel losses of 1.000 Mm³ for each section and the original dam basin storage capacity. Further the initial infiltration into the dry dam basin was set to 2.000 Mm³ and reduced to 1.000 Mm³ over the first 5 flood events.

(2) Results based on the stochastic runoff data for the 500, 5-year sequences and with initial dry river channel losses of 1.000 Mm^3 along each section.

(3) Results based on the stochastic runoff data for the 500, 5-year sequences with initial dry river channel losses of 1.000 Mm^3 for the channel up to Site 1 and an initial loss of 0.050 Mm^3 for the river section from Site 1 to Site 2.

(4) Results based on the stochastic runoff data for the 500, 5-year sequences with the initial dry channel losses of 1.000 Mm^3 for the channel up to Site 1 and an initial loss of 0.050 Mm^3 for the river section from Site 1 to Site 2.

The average infiltration that can expected at the infiltration sites were calculated using the first 5 years of runoff data obtained from 500 stochastic runoff records. Utilising these stochastic runoff records and considering different input data the average infiltration that can be expected at the infiltration sites vary between 2.466 Mm^3/a and 2.693 Mm^3/a for the next 5 years. Based on the runoff records up to 2003 and the data available on the dry channel losses the average infiltration that is expected at the infiltration sites is 2.648 Mm^3/a with a release rate of 19.200 Mm^3/a. It was recommended that the combined average infiltration of 2.648 Mm^3/a at the two infiltration sites be adopted in further geohydrological studies.

12.2 UPDATED HYDROLOGY 2012

During 2012 the second request from the Ministry of Agriculture Water and Forestry was addressed, which was:

- Update the hydrological models with rainfall, including lost data and runoff figures up to 2010 and to calculate the average water available for recharge over a 5 year period with a silt load of 10%.

12.2.1 Methodology adopted for the Omdel Hydrological Model - 2012

Rainfall data up to 2010 was used to generate rainfall records for the sub-catchments, lost rainfall data is recorded as lost data. These rainfall records were used to extend runoff/inflow records with the used of calibration of rainfall with runoff. For this purposes a synthesised runoff record was generated for Omdel Dam for the period 1926/27 to 2009/10. The difference is stating years between the rainfall record and synthesised runoff record is related to the 3 years antecedent factors that are taken into account in the NAMROM model. As discussed in **Section 9.2** , the rainfall/runoff correlation of 52.45% obtained was unsatisfactory.

Every sequence of 5 years of data was utilised as input data to set up a sample of data for 500 5-year sequences. Included in the data series were the 2006 dam

capacity and the new information on the lower losses between infiltration Site 1 and Site 2.

12.2.2 Modelling results obtained from the synthesised/stochastic runoff record derived from the amended Omdel runoff record combined with the Henties Monument runoff record (1926/27 to 2009/10, rainfall data lost = lost data)

This data was used to determine the average infiltration to the Omdel Dam, two river sections and the two infiltration sites. The average volumes that infiltrate at the two sites are presented in **Table 12.2.2.1.**

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Table 12.2.2.1: Average Volumes Available from Omdel Dam based on Abstraction Rates of 9.5 Mm³/a, 19.200 and 20.000 Mm³/a (1926/27-2009/10 stochastic runs)

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.339	3.531	1.839*
19.200	37.389	0.200	3.074	4.030	2.496
20.00	37.389	0.200	3.113	4.058	2.541

** Infiltration at Site 1 only*

12.2.3 Modelling results obtained from the observed Omdel Dam runoff record derived and the observed Omdel Dam runoff combined with the Henties Monument runoff record (1923/24 to 2012/13, rainfall data lost = lost data)

The 2012 analyses were based on modelling rainfall and runoff to be able to extend the runoff record of Omdel Dam. Due to the poor correlation coefficient between the synthesised and observed runoff records and taking into account the improved hydrological water balance model developed it was opted to rerun the models with the updated Omdel Dam inflow record to 2013, with special emphases on the observed runoff records. No further modelling was undertaken on the rainfall / runoff modelling as this would require several weeks of data collection; however for comparativeness the synthesised runoff record developed in 2012 was used in this analysis as well as a stochastic analyses.

Table 12.2.3.1 presents the modelled results of the water available from the Omdel observed inflow record for 1992/93 to 2012/13. Based on the Omdel Dam water balance model optimum release rate to only utilise Site one was calculated to be 8.2 Mm^3/a (950m^3/h).

Table 12.2.3.1: Average Volumes Available from Omdel Dam based on Abstraction Rates of 8.208 Mm^3/a, 19.200 Mm^3/a

Release Rate (Mm^3/a)	Full Supply Capacity (Mm^3)	Dead Storage Capacity (Mm^3)	Average Volume Released from Omdel Dam (Mm^3/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm^3/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm^3/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	1.262	1.815	0.980*
19.200	37.389	0.200	1.611	1.865	1.101

** Infiltration at Site 1 only*

Table 12.2.3.2 presents the modelled results of the water available from the Omdel observed inflow record for 1966/67 to 2012/13.

Table 12.2.3.2: Average Volumes Available from Omdel Dam based on Abstraction Rates of 8.208 Mm³/a, 19.200 Mm³/a

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	1.457	2.100	1.220*
19.200	37.389	0.200	2.004	2.262	1.487

** Infiltration at Site 1 only*

No stochastic runs were undertaken on the two sets of observed runoff records.

Table 12.2.3.3 presents the results of the Omdel synthesised runoff from 1926/27 to 1965/66 combined with the observed inflow record for 1966/67 to 2012/13.

Table 12.2.3.3: Average Volumes Available from Omdel Dam based on Abstraction Rates of 8.208 Mm³/a, 19.2 Mm³/a

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	1.221	1.898	0.932*
19.200	37.389	0.200	1.741	2.128	1.203

** Infiltration at Site 1 only*

Table 12.2.3.4 presents the results of the Omdel stochastic runoff record based on the synthesised runoff from 1926/27 to 1965/66 combined with the observed inflow record for 1966/67 to 2012/13.

Table 12.2.3.4: Average Volumes Available from Omdel Dam based on Abstraction Rates of 8.208 Mm³/a, 19.2 Mm³/a

Release Rate (Mm^3/a)	Full Supply Capacity (Mm^3)	Dead Storage Capacity (Mm^3)	Average Volume Released from Omdel Dam (Mm^3/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm^3/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm^3/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	1.946	2.770	1.545
19.200	37.389	0.200	2.825	3.180	2.015

** Infiltration at Site 1 only*

13 RECHARGE FROM SPILLS

During the 2010 study the potential additional recharge from the Omdel Dam spilling was calculated as 1% of the spills, which amounted to an omissible amount of below 0.100 Mm^3 per year on average. For the 2013 study a similar result was obtained and hence recharge from spills is not deemed relevant for adding to the recommended recharge figures.

14 SUMMARY OF MODELLING RESULTS SINCE 2010

Following in the **tables 14.1** to **14.3** below is the results of the hydrological modelling since 2011. The full supply capacity was taken as 37.389 Mm^3 and the dead storage volume as 0.200 Mm^3.

Table 14.1: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the rainfall (lost rainfall data was used as zero rainfall) and synthesised runoff records of 1016/17 to 2002/03 used to generate a stochastic runoff record.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1916/17 – 2002/03 synthesized runoff used for generating stochastic runoff (Rainfall lost data = zero's) Site 1 to 2 initial loss = 1 Mm^3	9.500	3.376 **	1.957 **	No
	19.200	3.973	2.412	No
	20.000	4.005	2.466	No
1916/17 – 2002/03 synthesized runoff used for generating stochastic runoff (Rainfall lost	9.500	3.376 **	1.957 *	No
	19.200	3.899	2.648	No

data = zero's) Site 1 to 2 initial loss = 0.05 Mm^3	20.000	3.930	2.693	No

** *Infiltration up to and including infiltration Site 1*

* *Infiltration at Site 1 only*

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Table 14.2: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the rainfall (lost rainfall data was used as lost rainfall) and synthesised runoff records of 1016/17 to 2002/03 used to generate a stochastic runoff record.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1926/27 – 2009/10 synthesized runoff used for generating stochastic runoff (Rainfall lost data = lost data) Site 1 to 2 initial loss = 0.05 Mm^3	9.500	3.531 **	1.839 *	No
	19.200	4.030	2.496	No
	20.000	4.058	2.541	No

** *Infiltration up to and including infiltration Site 1*

* *Infiltration at Site 1 only*

Table 14.3: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the observed runoff record of Omdel Dam (1992/93 - 20012/13) and the combine Omdel Dam Henties Monument runoff records 1966/67 - 2012/13.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1992/93 – 2012/13 Omdel Dam observed runoff. Site 1 to 2 initial loss = 0.05 Mm^3	9.500	1.815 **	0.980 *	No
	19.200	1.865	1.101	No
1966/67 – 2012/13 Omdel Dam observed runoff combined with Henties Monument. Site 1 to 2 initial loss = 0.05 Mm^3	9.500	2.100 **	1.200 *	No
	19.200	2.262	1.487	Yes

** *Infiltration up to and including infiltration Site 1*

* *Infiltration at Site 1 only*

Table 14.4: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the rainfall (lost rainfall data was used as lost rainfall) and synthesised runoff records of 1926/27 to 20012/13.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1926/27 – 2012/13 Synthesized Omdel Dam runoff. Site 1 to 2 initial loss = 0.05 Mm^3	9.500	1.898 **	0.932 *	No
	19.200	2.128	1.203	No
	19.200	3.180	2.015	No

** *Infiltration up to and including infiltration Site 1*

* *Infiltration at Site 1 only*

Table 14.5: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the rainfall (lost rainfall data was used as lost rainfall) and synthesised runoff records of 1926/27 to 20012/13, which was used to generate a stochastic runoff record.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	

1926/27 – 2012/13 Synthesized Omdel Dam runoff used for stochastic runoff record. Site 1 to 2 initial loss = 0.05 Mm^3	9.500	2.770 **	1.545 *	No
	19.200	3.180	2.015	No

*** Infiltration up to and including infiltration Site 1*

** Infiltration at Site 1 only*

16. COMPARISON WITH PREVIOUS STUDIES

Several studies have been undertaken for the Omdel Aquifer, however no detail studies have been undertaken since 2006 to analyse the hydrology of the Omdel Dam. Following the presentation of the 2006 study further modelling was identified, which was undertaken and reported in this report. **Table 16.1** summarises previous studies' results for Omdel Dam.

Table 16.1: Summary of Previous Studies' Yield Results for Omdel Dam

During 1989 a preliminary assessment of the hydrology of the Omdel Dam site was conducted. **(Reference 20.4).** The potential **mean annual recharge of 6.660 Mm^3/a**, was calculated for a dam with a storage volume of 20 Mm^3.
Water Affairs had estimated that after making allowance for siltation, a reservoir with an estimated capacity of 30 Mm^3 would effect a **mean annual recharge of 4.600 Mm^3/a** for a transfer efficiency of 70% over a period of 20 years.
Thomas Winter: With extended basins to infiltrate 7.400 Mm^3/a, the **yield of the dam is 3.500 Mm^3/a without losses and 2.600 Mm^3/a taking losses of 25% into account**. Up to this date the yield of the Omdel Aquifer was deemed to be 4.700 Mm^3/a, and an additional yield of 3.500 Mm^3/a was added for artificial recharge (instead of the 2.600 Mm^3/a) giving a total yield of 8.200 Mm^3/a. **(Reference 20.9).**

A C Mostert calculated the average water to infiltrate at Site 1 and 2 to be 1.301 Mm^3/a and 1.584 Mm^3/a respectively with a silt load of 10% and 2.325 Mm^3/a and 2.840 Mm^3/a respectively with a silt load of 2%, based on the synthesised runoff record of 87 years. It should however be noted that all lost rainfall was recorded as zero's during the running of the Multiquadric program in this study. April 2010. **(Reference 20.10).**

17. SUMMARY AND CONCLUSION

17.1 RAINFALL/RUNOFF ANALYSIS

Rainfall data for the last 10 years was requested from the Namibia Meteorological Services for the 73 stations used in the previous study. Data for 20 stations were received of which 12 extended to 2010. The farmers that supplied data for the previous study was contacted again and data for 15 stations were received of which 4 extended to 2010. After running the Multiquadric Surface Fit the results were not found to be satisfactory as extreme high rainfall figures were calculated for the upper catchment. Due to these high figures additional rainfall station data was requested from the Namibia Meteorological Services extending further north, south and east of the Omaruru Catchment as well as using rainfall stations data of NamWater. This resulted in 89 rainfall stations been used in the model.

An assessment of the Omdel Dam hydrology was undertaken using the Henties Monument runoff data from 1966/67 and the Omdel Dam inflow data from 1993 to 2009/10. The NAMROM model has been used with various degrees of success in Namibia. For the Omdel Dam a correlation coefficient of 37.42% was obtained. By amending the February 1985 data an improved, but still poor correlation coefficient of 52.45% was obtained.

Using latter regression equation, a 84 year synthesised monthly runoff record was generated for the period 1926/27 to 2009/10 which is three years shorter than the Multiquadric Surface Fit rainfall record due to the incorporation of the three years of antecedent figures. The MAR and the median annual runoff for the longer synthesised

runoff record are 5.81 Mm^3 and 1.92 Mm^3, respectively. The CV was 2.01 and 14 out of 84 years (17 %) had zero runoff.

This data set was further used in generation a stochastic runoff record of 500 years.

17.2 WATER BALANCE ANALYSIS

Using the actual runoff data from Omdel Dam and the combined runoff data from Henties Monument and Omdel Dam the water available for artificial recharge as calculated. As these records are relatively short a rainfall/runoff analyses was done to extend the runoff records length and to use this data in a stochastic analyses to calculate the water available for artificial recharge. Every sequence of 5 years of data was utilised as input data to set up a sample of data for 500 5-year sequences. This data was used to determine the average infiltration to the Omdel Dam, two river sections and the two infiltration sites.

Evaluation of the rainfall/runoff study concluded that correlation obtained from the data was poor and hence the results of the synthesised and stochastic analyses are not to be used for planning purposes. As a result of this it is recommended to only consider the results based on the combined Omdel Dam and Henties Monument observed runoff record of for the average volume that infiltrate at the two sites for planning purposes. The recommended figure is presented in **Table 17.2.1.**

Table 17.2.1: Infiltration of the total system and the ponds for infiltration Site 1 and 2, which are based on the combined observed runoff record of Omdel Dam Henties Monument runoff records 1966/67 - 2012/13.

Data Series	Release Rate (Mm^3/a)	Sum of infiltration at the dam, river section and pond(s)	Average volumes infiltrated at Site 1 and 2	Recommended hydrological infiltration
		10% Silt	10% Silt	
1966/67 – 2012/13 Omdel Dam observed runoff combined with Henties Monument. Site 1 to 2 initial loss = 0.05 Mm^3	19.200	2.262	1.487	Yes

** *Infiltration up to and including infiltration Site 1*

** Infiltration at Site 1 only*

18. RECOMMENDATIONS

It is recommended that:

18.1 The utilised data, the assumptions made and the methodology applied be accepted as the best presently available.

MANAGEMENT

18.2 A 95% assured yield of 0 Mm^3/a be adopted for the Omdel Dam.

PLANNING

18.3 Based on a silt content of 10% and at an abstraction rate of 19.2 Mm^3/a, the total system average volume of infiltration is 2.262 Mm^3/a from surface water.

PLANNING

18.4 Based on an silt content of 10% and at an abstraction rate of 19.2 Mm^3/a, the average volume of infiltration at the two infiltration sites are 1.487 Mm^3/a and are to be used as the average aquifer recharge from Omdel Dam until further studies have been undertaken to calculate the actual recharge that is available from the total system infiltration.

PLANNING

18.5 The infiltration volumes of 2.262 Mm^3/a and 1.487 Mm^3/a be incorporated in future geohydrological studies.

GEOHYDROLOGY

18.6 This study should be re-assessed every 10 years, or as inflow dictates to take into account additional runoff data and the reduction of the dam capacity.

REPORT COMPILED BY: A C MOSTERT (Pr.Sci.Nat)

MANAGER: HYDROLOGY

19. APPROVAL OF RECOMMENDATIONS

19.1 This report is submitted to the Senior Manager: Water Supply South.

_____

_____

_____

SENIOR MANAGER: PLANNING AND WATER RESOURCES

DATE:

19.2 This report has been completed to the satisfaction of Water Supply South and I support the recommendations in this report.

_____

_____

_____

SENIOR MANAGER: WATER SUPPLY SOUTH

DATE:

19.3 This report has been discussed by interested parties within NamWater and the recommendations in the report are approved by NamWater.

_____

_____

_____

GENERAL MANAGER: ENGINEERING & SCIENTIFIC SERVICES

DATE:

20. REFERENCES

20.1 Research into the possible enhancement of recharge at the Omaruru Delta. Report No: 2972/1/H1. Hydrology Division, August 1988.

20.2 Final Environmental impact report for the proposed Omdel Dam on the Omaruru River. Report No WR/90/7, Environmental Evaluation Unit of the University of Cape Town, May 1991.

20.3 A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer. NWC-HYD-OMDEL HYD. April 2010.

20.4 Omdel infiltration enhancement action planned and funds required. Report No: 2972/1/H2. Hydrology Division, January 1989.

20.5 A re-examination of the geohydrology and a re-evaluation of the potential of the Omaruru Delta (OMDEL) aquifer. Report No: 12/7/G15. Geohydrology Division, September 1990.

20.6 Final environmental impact report for the proposed Omdel Dam on the Omaruru River. Report No: WR/90/7. Environmental Evaluation Unit, University of Cape Town, May 1991.

20.7 Report on the investigation of Artificial Recharge experiments, recharging basin design and operational rules in recharge basins at site 1. Report No 12/7/G17 by Geohydrology Division, October 1993.

20.8 The impact and evaluation of enhanced recharge on the Omdel aquifer during 1997/98. Ref: NWC-WR-7/1/6/4-10-98 by Geohydrology Division, October 1998.

20.9 Re-assessment of the hydrology and yield of Omdel Dam. Ref: NWC-IP-OMDUT98-01 by Infrastructure Planning Division, January 2000

20.10 Comprehensive assessment of the hydrology of the Omaruru Delta (Omdel) Dam to determine the volume of water expected to be available for recharge into the Omdel Dam – Rainfall data collection progress report, May 2007, Hydrology Division NamWater.

20.11 Rainfall data collection report for the ”Updated report: A Comprehensive Assessment of the Hydrology of the Omaruru Delta (Omdel) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer

20.12 Department of Water Affairs Namibia, The comparison of A-Pan Evaporation with Dam Evaporation, Hydrology Division, Report No: 11/1/8/1/H4, September 1991.

20.13 Ministry of Agriculture, Water and Rural Development, Department of Water Affairs. Central Area Water Master Plan: Phase 1, Volume 4, Hydrology, July 1993.

20.14 NamWater: Omdel Dam Silt Survey, Hydrology Division, October 2006.

20.15 Application of Couple Surface Water Groundwater Model for Estimating Groundwater Recharge from Flash Floods, Dr Christoph Kuells and Ingo Heidbüchel, 2006.

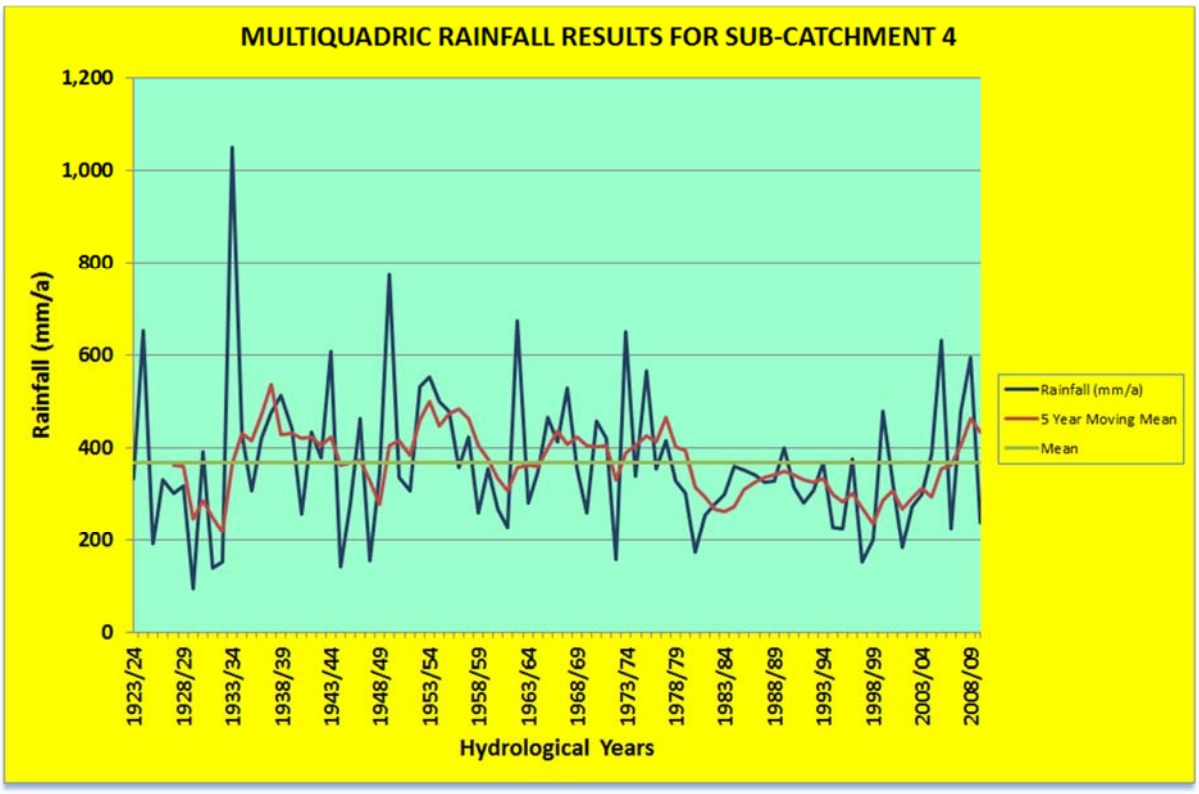
20.16 An unexpected factor affecting recharge from ephemeral river flows in SWA/Namibia. S Crerar, R G Fry, P M Slater, G van Langenhove and D Wheeler. Department of Water Affairs, 1988.

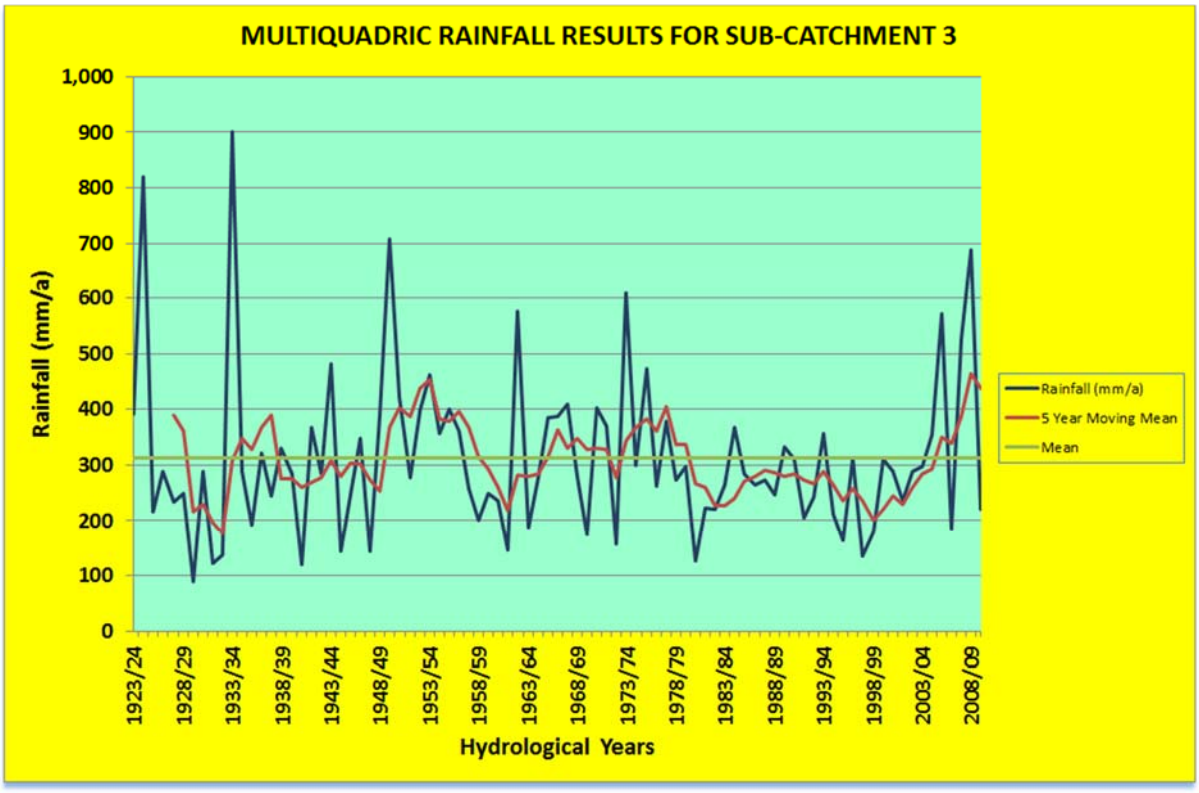
20.17 Comparison of a Polynomial Trend Surface and a Multiquadric Surface Fitting Technique applied to storms in South West Africa. Unpublished MSc Thesis, Imperial College, London, August 1974, D J R Plathe.

20.18 Rainfall/Runoff modelling in large catchments is SWA/Namibia, State of the Art, Department of Water Affairs, Report No. 11/1/5/1/H1, August 1983, P Webster

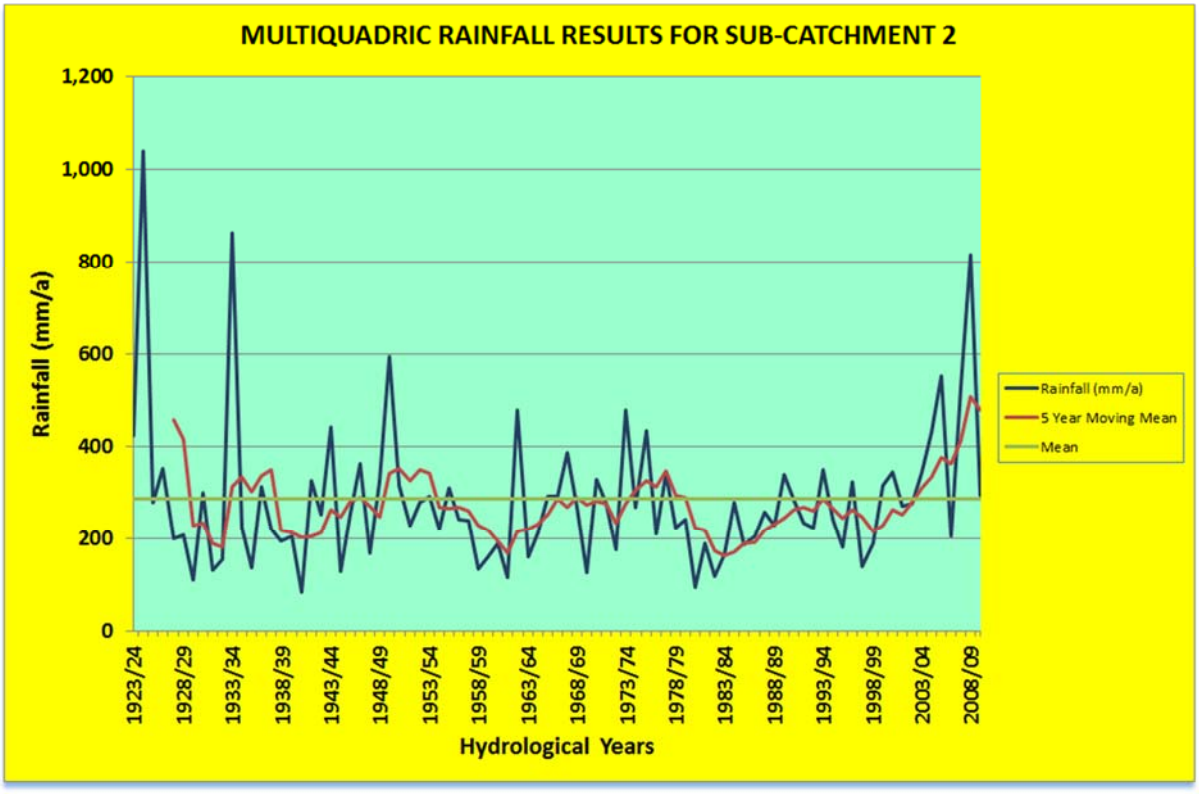
20.19 Water Balance for Omdel Dam during Releases for Artificial Recharge during the 2008/2009 Hydrological Season.

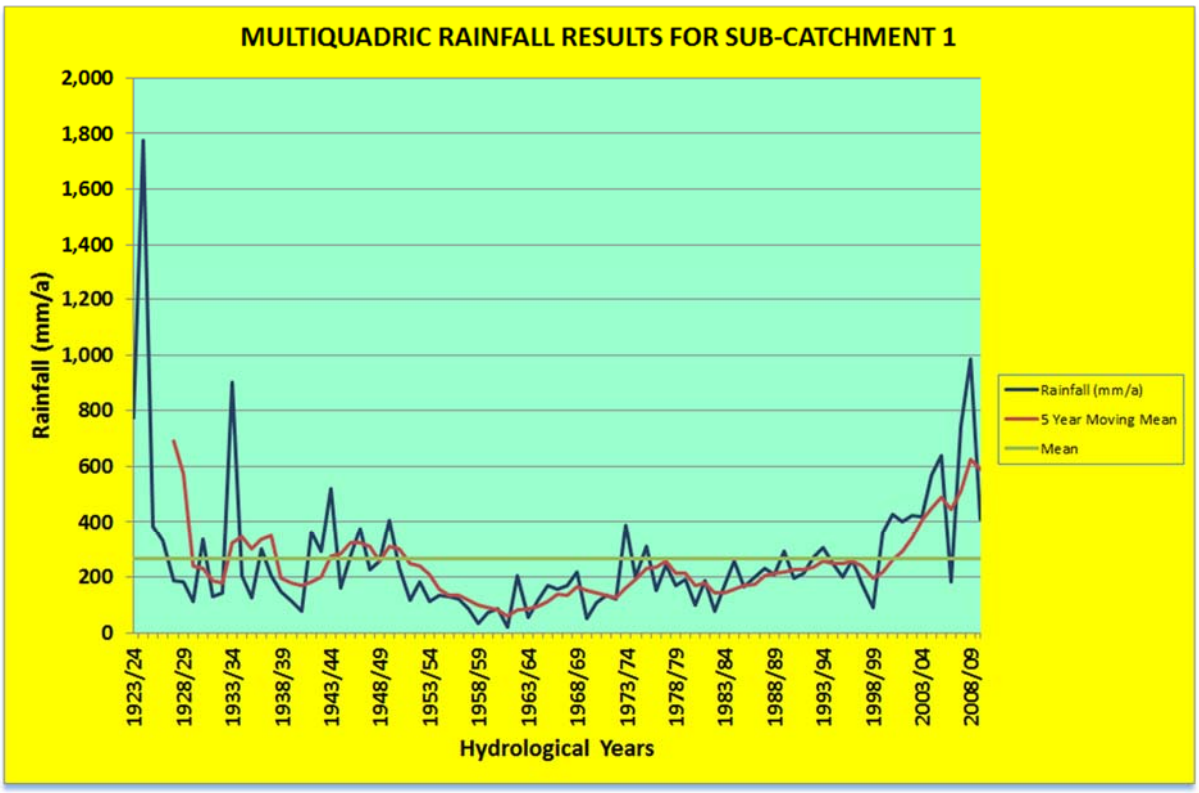
MULTIQUADRIC ANNUAL RAINFALL RESULTS PLOTTED





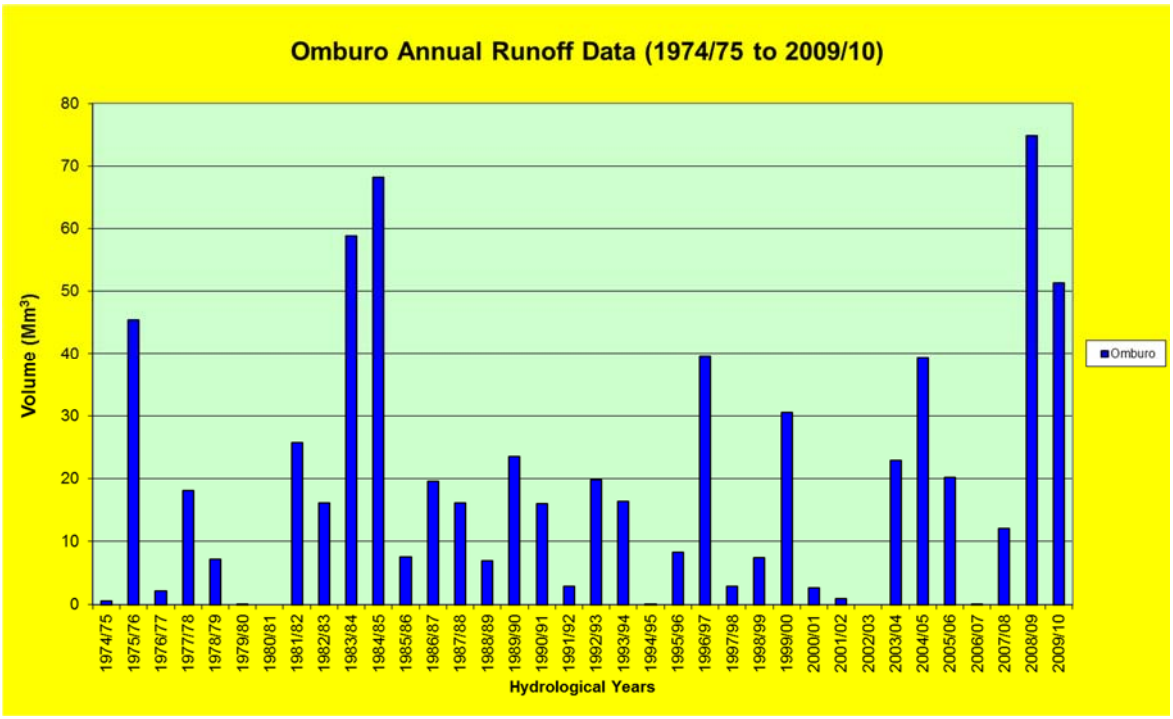
Annexure 1

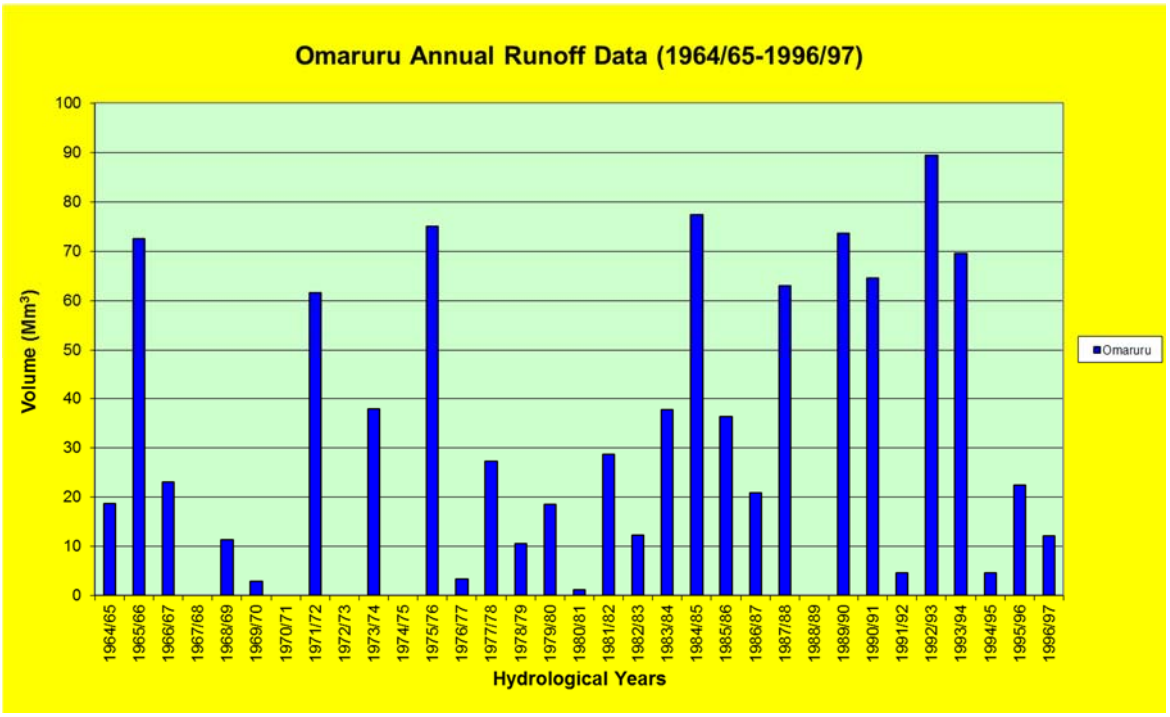

MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 2
Rainfall (mm/a)
1,200
1,000
800
600
400
200
0
1923/24
1928/29
1933/34
1938/39
1943/44
1948/49
1953/54
1958/59
1963/64
1968/69
1973/74
1978/79
1983/84
1988/89
1993/94
1998/99
2003/04
2008/09
Hydrological Years
Rainfall (mm/a)
5 Year Moving Mean
Mean


MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 1
Rainfall (mm/a)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1923/24
1928/29
1933/34
1938/39
1943/44
1948/49
1953/54
1958/59
1963/64
1968/69
1973/74
1978/79
1983/84
1988/89
1993/94
1998/99
2003/04
2008/09
Hydrological Years
Rainfall (mm/a)
5 Year Moving Mean
Mean

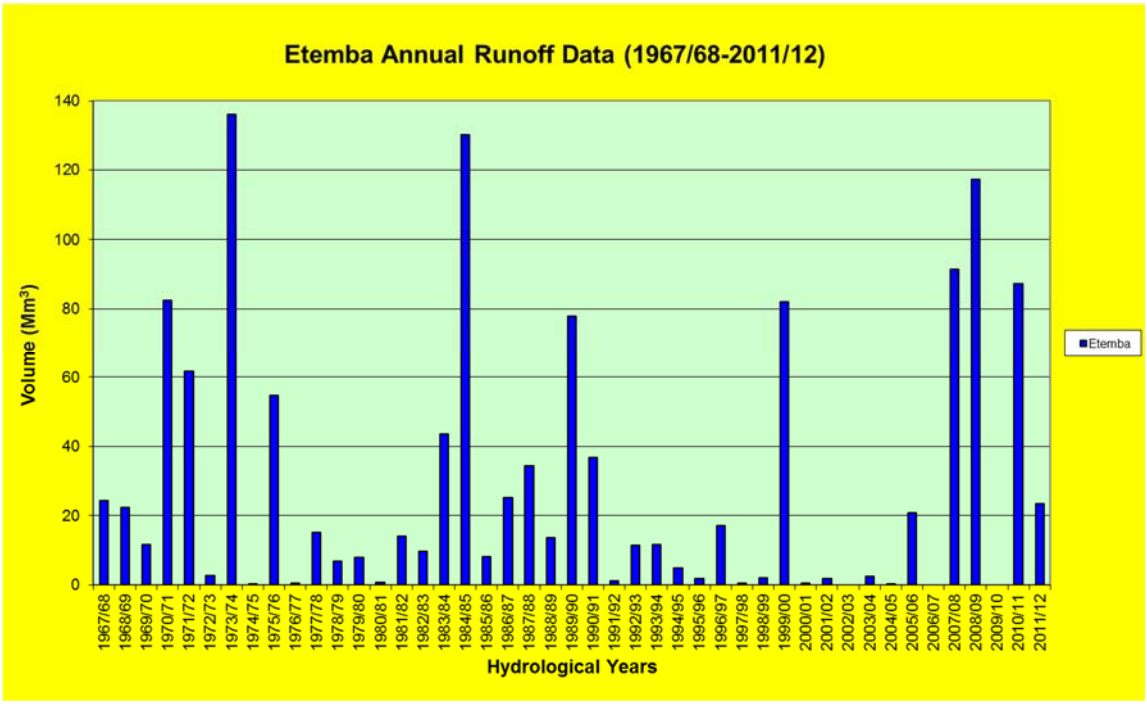
Annexure 1

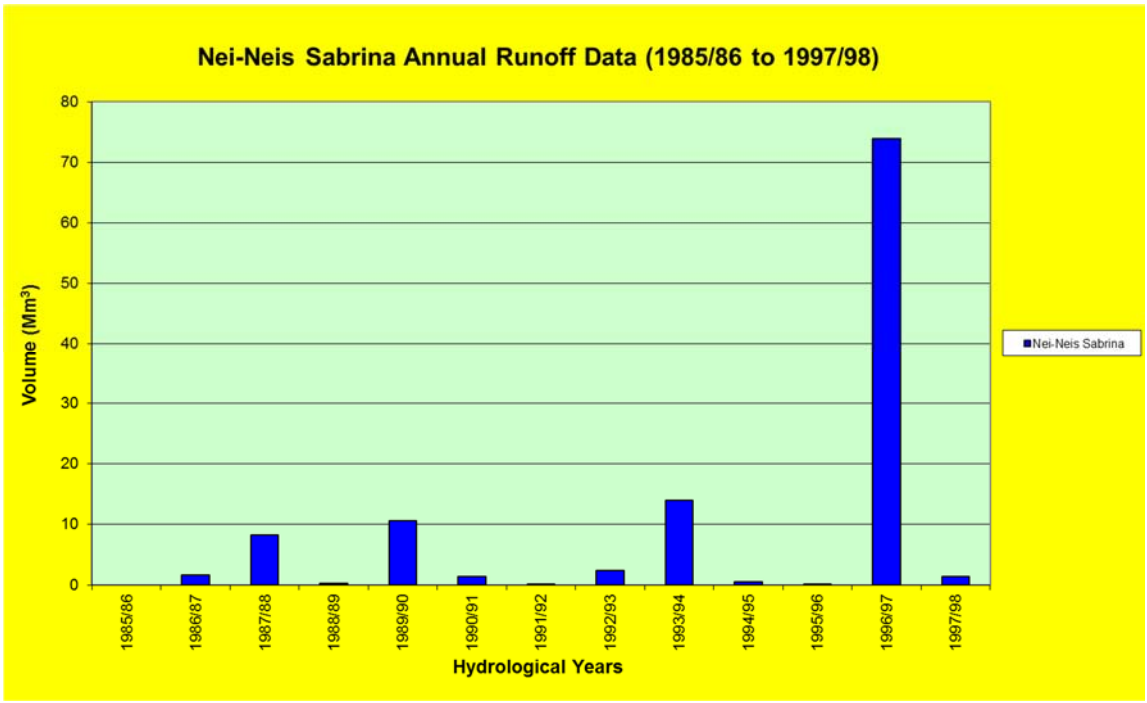
OBSERVED RUNOFF RECORDS FOR THE OMARURU HYDROLOGICAL STATIONS



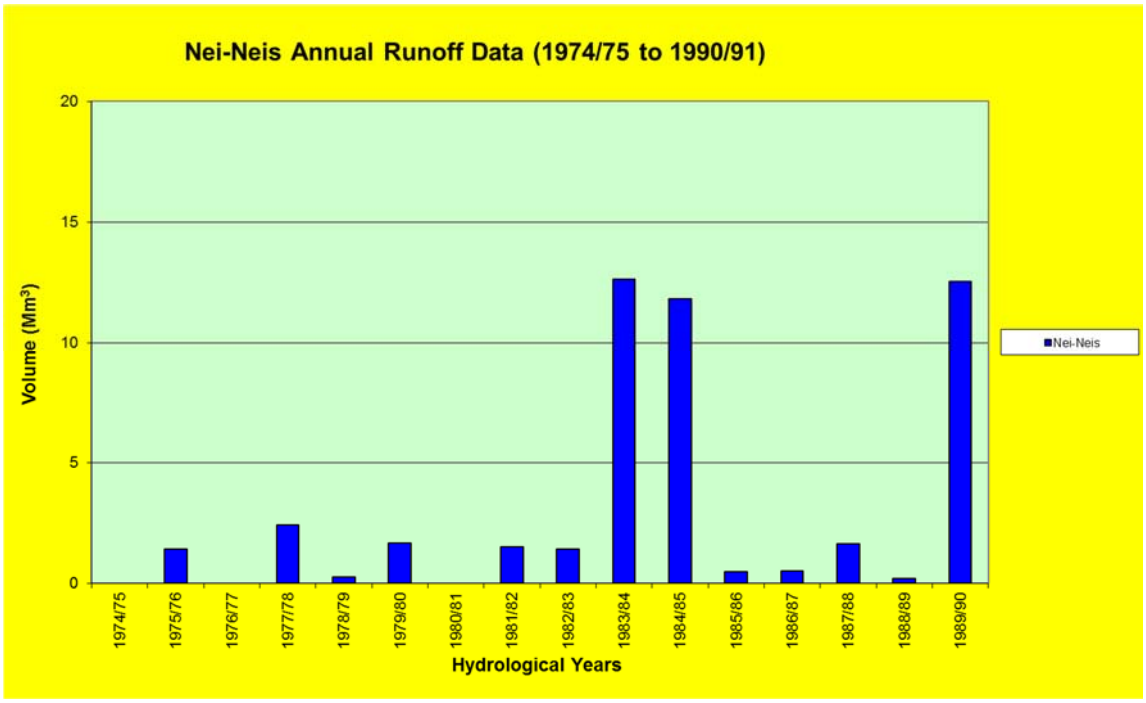


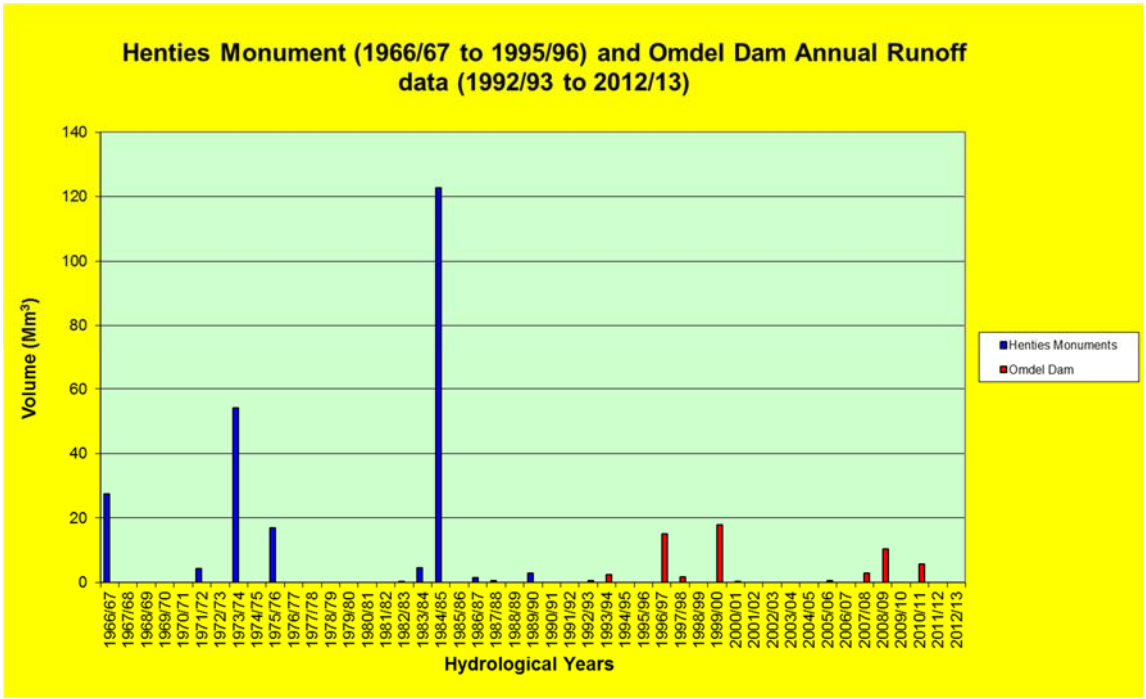
Annexure 2


Etemba Annual Runoff Data (1967/68-2011/12)
Volume (Mm³)
140
120
100
80
60
40
20
0
1967/68
1968/69
1969/70
1970/71
1971/72
1972/73
1973/74
1974/75
1975/76
1976/77
1977/78
1978/79
1979/80
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1988/89
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
2003/04
2004/05
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
Hydrological Years
Etemba


Nei-Neis Sabrina Annual Runoff Data (1985/86 to 1997/98)
Volume (Mm³)
80
70
60
50
40
30
20
10
0
1985/86
1986/87
1987/88
1988/89
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
Hydrological Years
Nei-Neis Sabrina

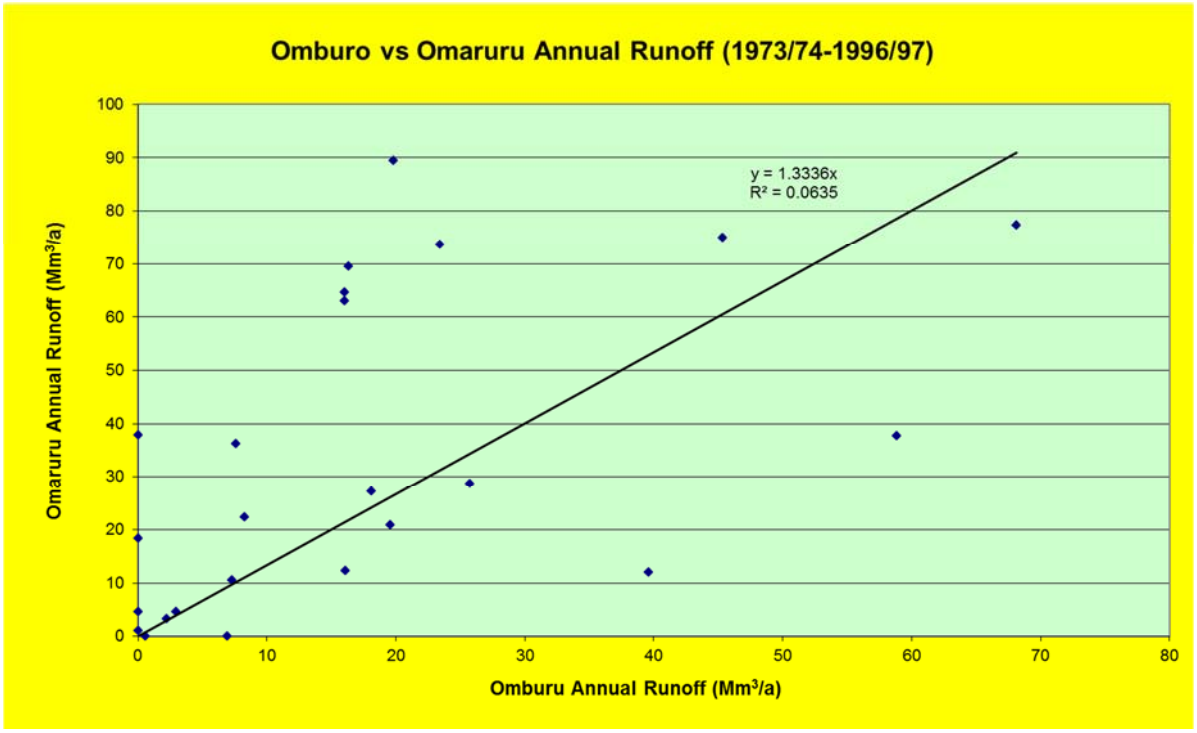
Annexure 2

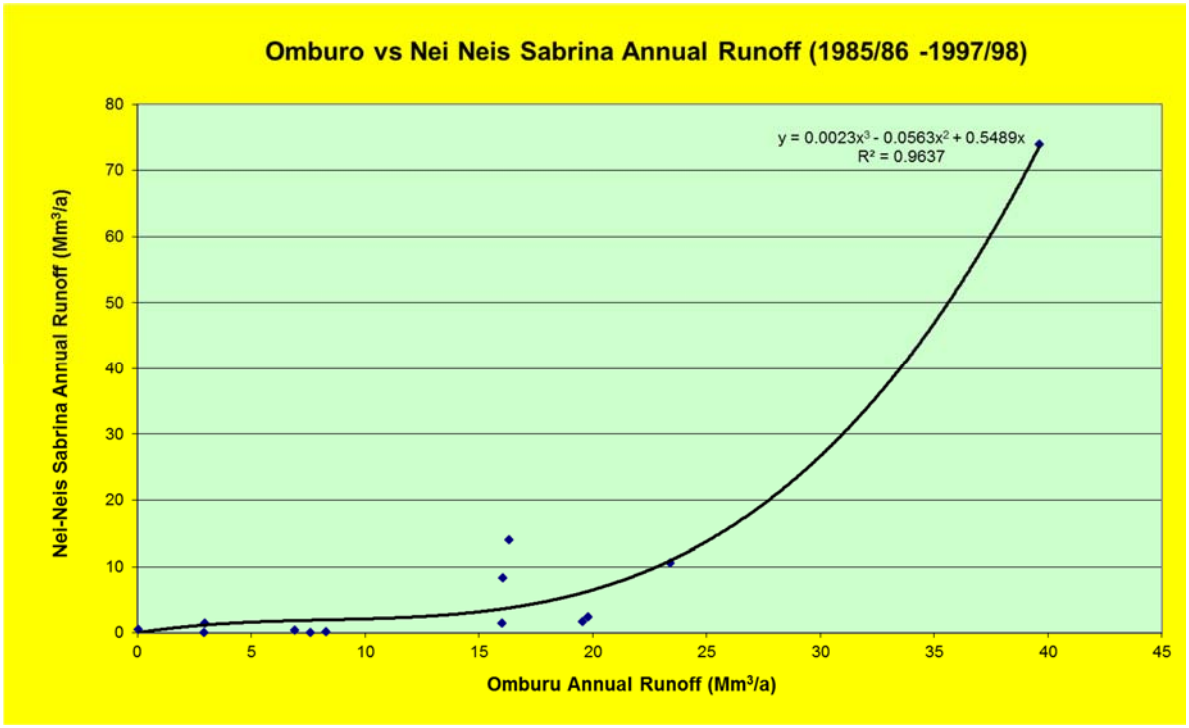

Nei-Neis Annual Runoff Data (1974/75 to 1990/91)
Volume (Mm³)
20
15
10
5
0
1974/75
1975/76
1976/77
1977/78
1978/79
1979/80
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1988/89
1989/90
Hydrological Years
Nei-Neis


Henties Monument (1966/67 to 1995/96) and Omdel Dam Annual Runoff data (1992/93 to 2012/13)
Volume (Mm³)
140
120
100
80
60
40
20
0
1966/67
1967/68
1968/69
1969/70
1970/71
1971/72
1972/73
1973/74
1974/75
1975/76
1976/77
1977/78
1978/79
1979/80
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1988/89
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
2003/04
2004/05
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
Hydrological Years
Henties Monuments
Omdel Dam

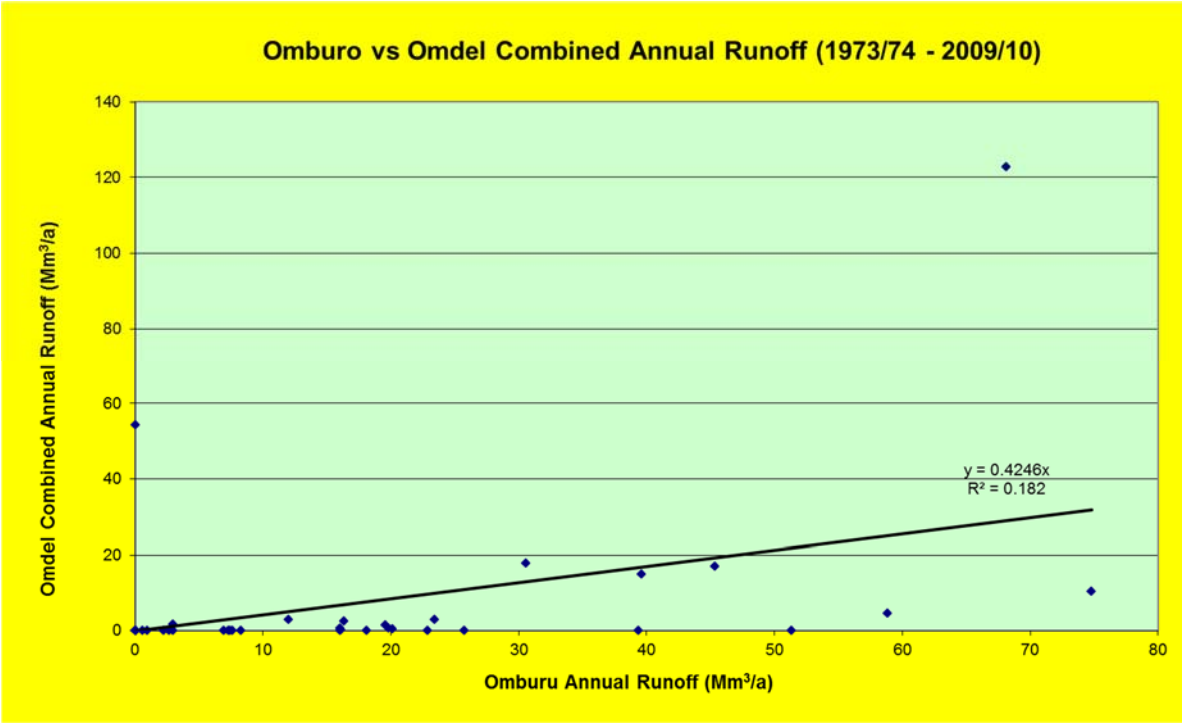
Annexure 2

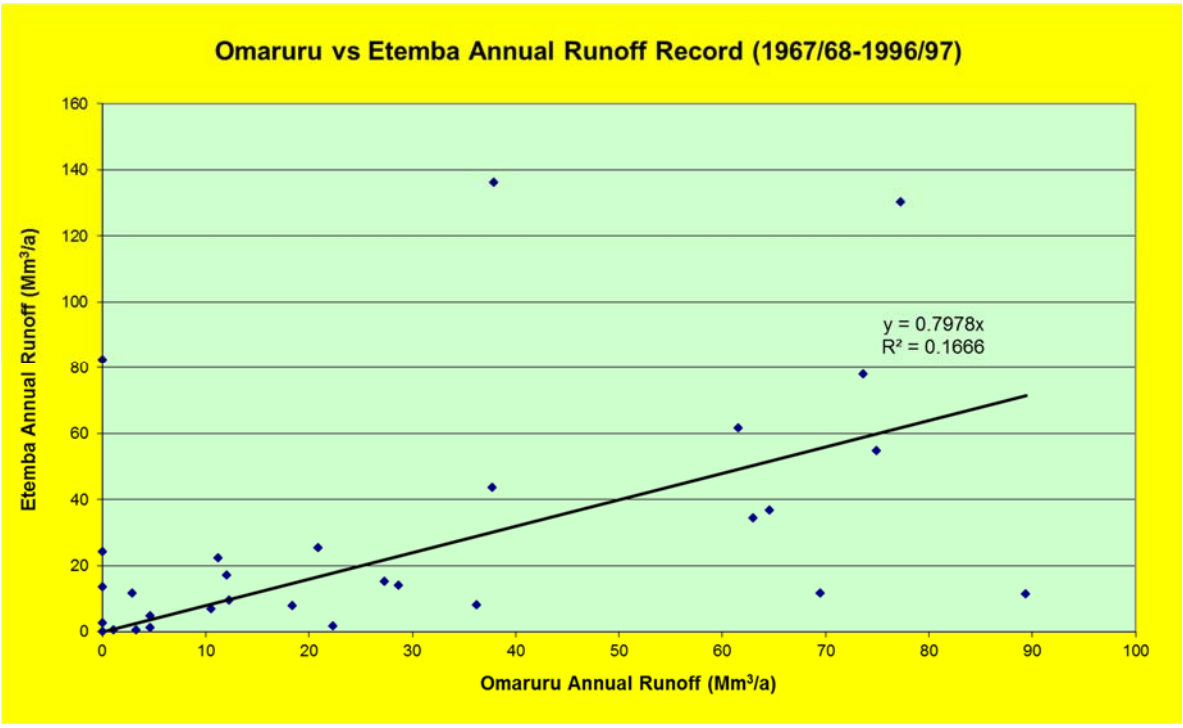
RSQ CORRELATION COEFFICIENTS BETWEEN HYDROLOGICAL STATIONS



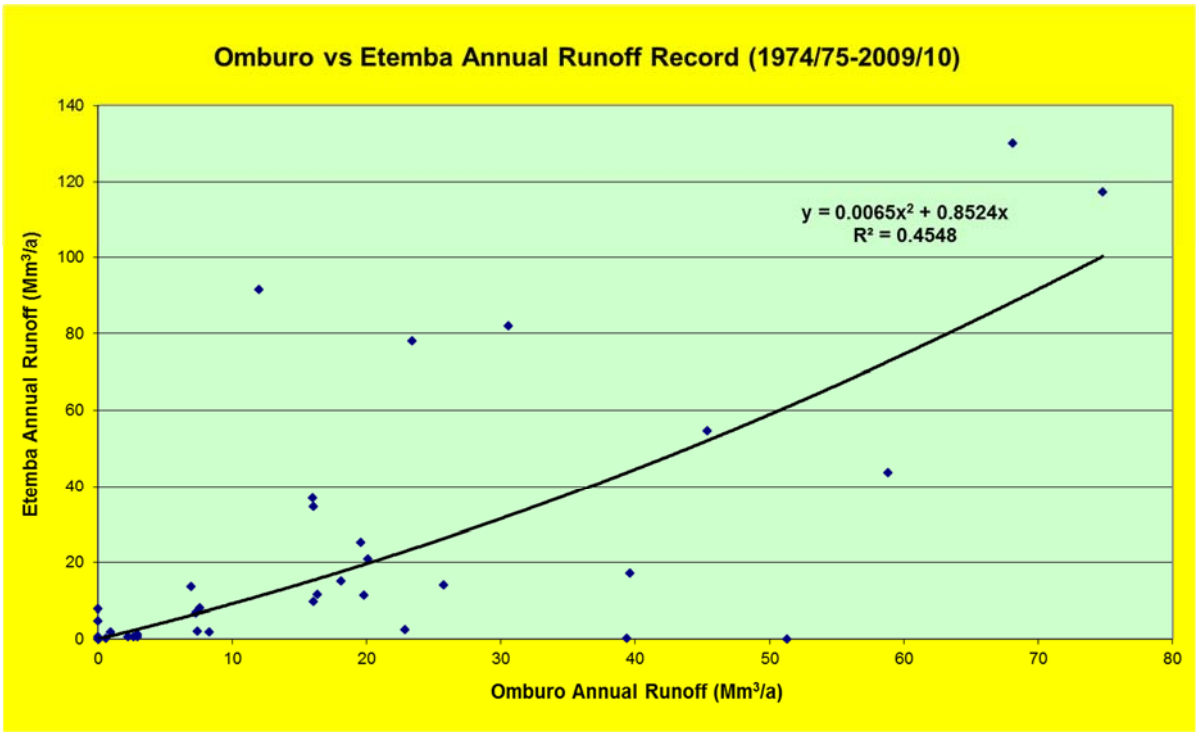


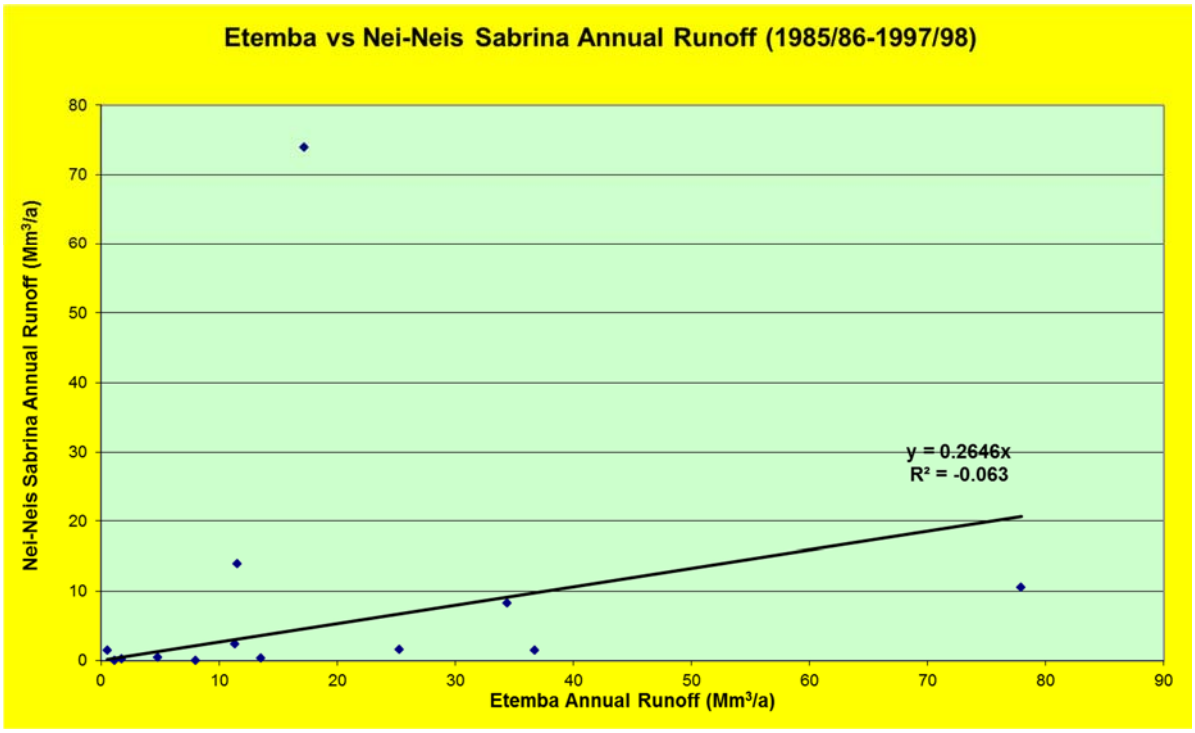
Annexure 3


Omburo vs Omdel Combined Annual Runoff (1973/74 - 2009/10)
Omdel Combined Annual Runoff (Mm³/a)
Omburu Annual Runoff (Mm³/a)
y = 0.4246x
R² = 0.182
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80

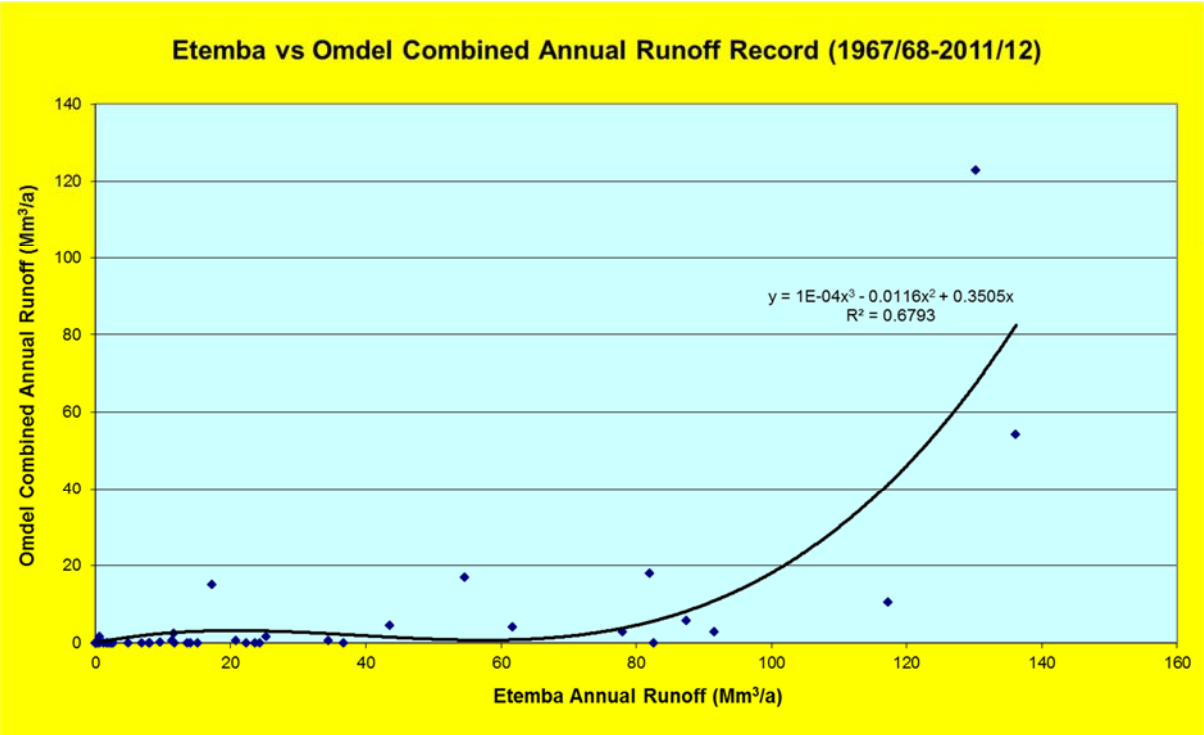

Omaruru vs Etemba Annual Runoff Record (1967/68-1996/97)
Etemba Annual Runoff (Mm³/a)
Omaruru Annual Runoff (Mm³/a)
y = 0.7978x
R² = 0.1666
0
20
40
60
80
100
120
140
160
0
10
20
30
40
50
60
70
80
90
100

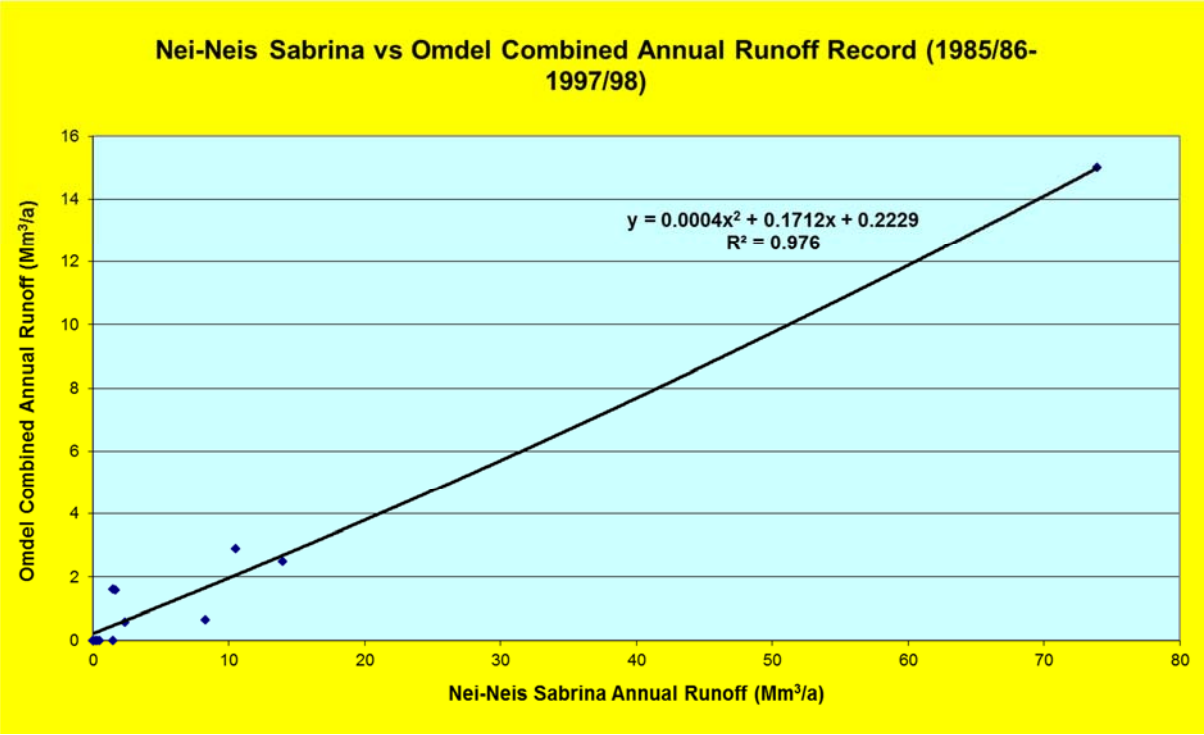
Annexure 3


Omburo vs Etemba Annual Runoff Record (1974/75-2009/10)
y = 0.0065x² + 0.8524x
R² = 0.4548
Etemba Annual Runoff (Mm³/a)
Omburo Annual Runoff (Mm³/a)
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80

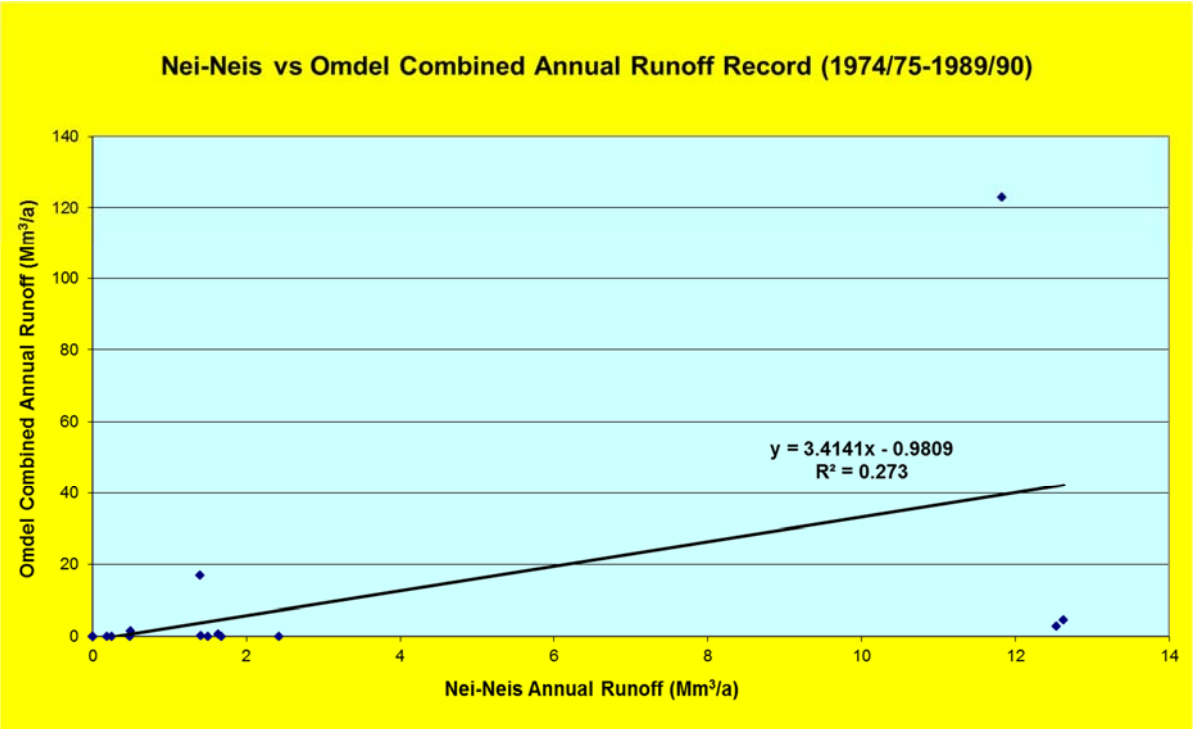

Etemba vs Nei-Neis Sabrina Annual Runoff (1985/86-1997/98)
y = 0.2646x
R² = -0.063
Nei-Neis Sabrina Annual Runoff (Mm³/a)
Etemba Annual Runoff (Mm³/a)
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90

Annexure 3


Etemba vs Omdel Combined Annual Runoff Record (1967/68-2011/12)
Omdel Combined Annual Runoff (Mm³/a)
Etemba Annual Runoff (Mm³/a)
y = 1E-04x³ - 0.0116x² + 0.3505x
R² = 0.6793
0
20
40
60
80
100
120
140
160

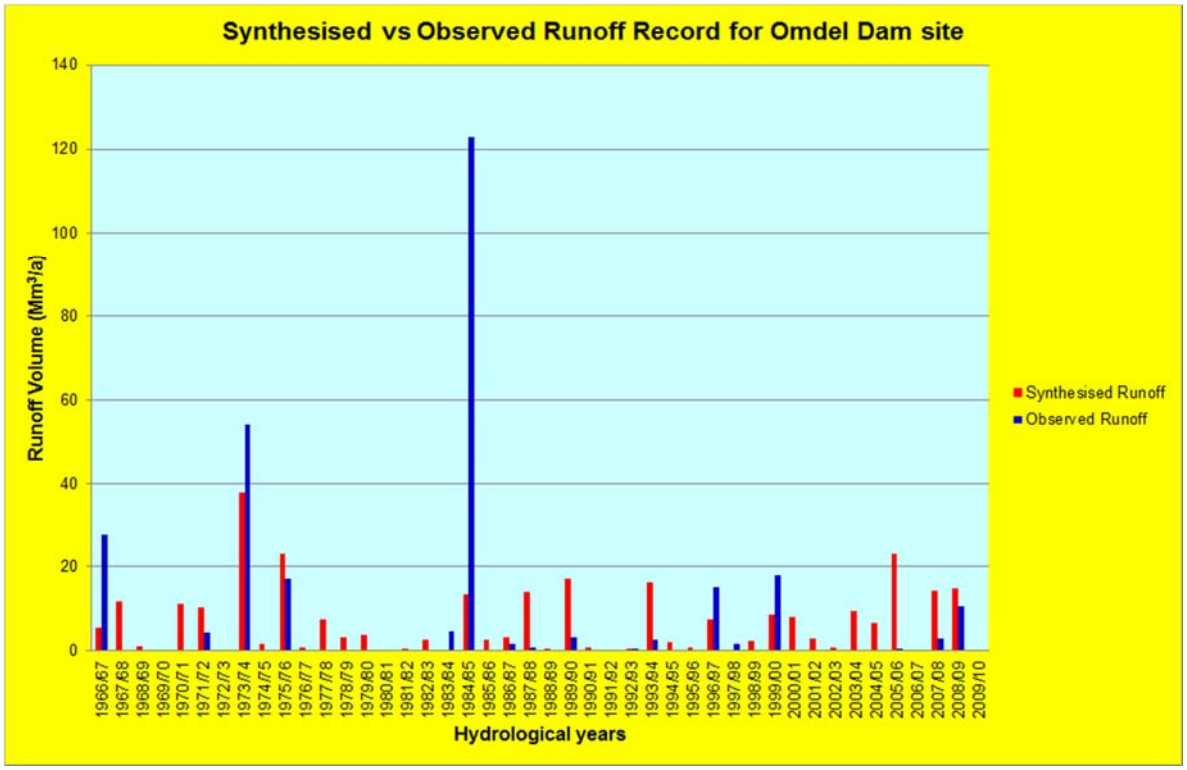

Nei-Neis Sabrina vs Omdel Combined Annual Runoff Record (1985/86-1997/98)
Omdel Combined Annual Runoff (Mm³/a)
Nei-Neis Sabrina Annual Runoff (Mm³/a)
y = 0.0004x² + 0.1712x + 0.2229
R² = 0.976
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80

Annexure 3

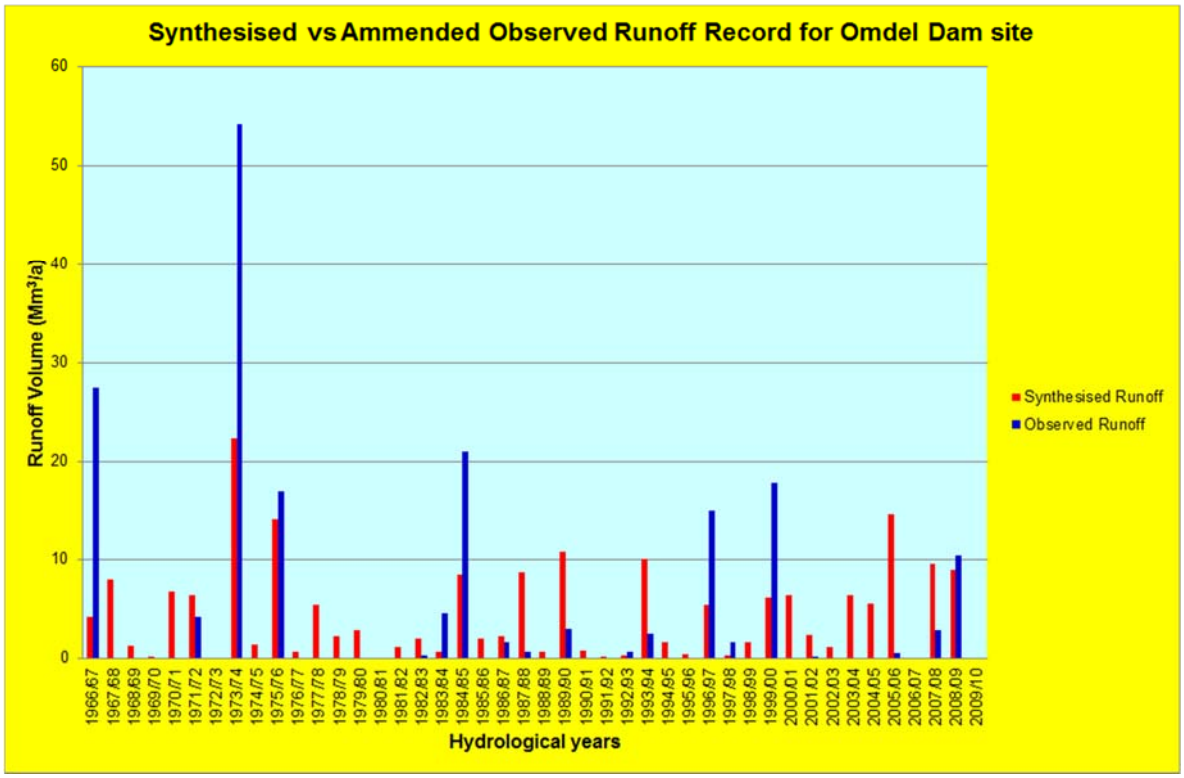

Nei-Neis vs Omdel Combined Annual Runoff Record (1974/75-1989/90)
Omdel Combined Annual Runoff (Mm³/a)
Nei-Neis Annual Runoff (Mm³/a)
y = 3.4141x - 0.9809
R² = 0.273
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14

Annexure 3

SYNTHESISED VS OMDEL SITE OBSERVED RUNOFF RECORD



SYNTHESISED VS OMDEL SITE AMENDED OBSERVED RUNOFF RECORD



Annexure 4

MEMORANDUM

To: **The Chairmen: Omdel Technical committee**
From: Manager: Hydrology NamWater
Division: Planning and Water Resources, Hydrology
Department: **Engineering & Scientific Services**
Date: 26 April 2011

SUBJECT: OMDEL AQUIFER RECHARGE

1. Background

With limited hydrological studies done in the past and the sensitivity of the Omdel Aquifer, the need to re-assess the hydrology of Omdel Dam was identified by the Ministry of Agriculture, Water and Forestry. The aim of the report "A Comprehensive Assessment of the Hydrology of the Omaruru Delta (OMDEL) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer" (Reference 7.1) was hence to re-evaluate the hydrology of the Omdel Dam and to determine the amount of water available from the dam for artificial recharge of the Omdel Aquifer.

Following the above report's discussion held on 4 April 2011, NamWater Hydrology was requested to:

1.1 Determine the potential inflow for the next 5 years into Omdel Dam and to use this data to determine the amount of water available from the dam for artificial recharge of the Omdel Aquifer based on a flood silt load of 10%.

Results expected by: 6 May 11

1.2 To re-assess the hydrology with the most up to date rainfall and runoff data and then determine for the amount of water available from the dam for artificial recharge of the Omdel Aquifer.

Results expected by: 31 October 11

This memorandum deals with point 1.1 only.

2. Methodology Adopted for the Hydrological Analysis

The following methodology was adopted to determine the potential average amount of water available for infiltration at the infiltration sites over the next 5 years.

The combined synthesised and observed runoff record for the period 1916/17 to 2002/03 was used as input data to generate stochastic runoff records. The first 5 years of data was utilised from each run to set up a sample of data for 500 5-year sequences.

From the 500 ranked 5-year sequences each 10th sequences' data was used to determine the amount of water available from the dam for artificial recharge of the Omdel Aquifer. The methodology of the model used for this procedure is documented in the report "A Comprehensive Assessment of the Hydrology of the Omaruru Delta (OMDEL) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer" (Reference 7.1). The analyses were done based on a 10% flood silt load and based on the latest storage volume of 37.389 Mm^3 for Omdel Dam.

Release rates of 9.500 Mm^3/a and 20.000 Mm^3/a as documented in the hydrological report were used as release rates for Site 1 and Site 1 plus Site 2 respectively. Following the first release of water for Site 2 new information was forthcoming indicating that the channel between Site 1 and Site 2 has much lower losses than the channel from the dam to Site 1 and hence a release rate of 19.200 Mm^3/a, but with lower losses was also modelled. These lower losses were documented in the report "Water Balance for Omdel Dam during Releases for Artificial Recharge during the 2008/2009 Hydrological Season" (Reference 7.2).

3. Results

Two data sets were considered:

The first data set was the every 10th year stochastic runoff data for the 500 5-year sequences and with initial dry river channel losses of 1.000 Mm^3 each between the dam and Site 1 and Site 1 and Site 2. For this data set release rates of 9.500 Mm^3/a and 20.000 Mm^3/a were used. A release rate of 19.200 Mm^3/a was added and is explained under the second set of data used. The initial infiltration for the dry Omdel Dam basin was set to1.000 Mm^3 as the dam already has had 5 flood events that have resulted in a "large" silt load into the dam.

The data obtained from the water balance model was then averaged and is presented in **Table 1**.

Table 1: Average Volumes Released from Omdel Dam and Infiltrated at the Infiltration Sites

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.379	3.378	1.955
19.200	37.389	0.200	3.139	3.973	2.412
20.000	37.389	0.200	3.185	4.005	2.466

The second data set was the every 10th year stochastic runoff data for the 500 5-year sequences with the initial dry river channel losses of 1.000 Mm^3/a for the channel up to Site 1 and an initial loss of 0.050 Mm^3 for the river section from Site 1 to Site 2. For this data set release rates of 9.500 Mm^3/a, 19.200 Mm^3/a and 20.000 Mm^3/a were modelled. The adding of the 19.200 Mm^3/a releases rate is considered to be more relevant as fewer losses occurred to Site 2 and hence a lower release rate was adopted to prevent spilling of the infiltration basins. The initial infiltration for Omdel Dam basin was set to1.000 Mm^3 as the dam already has had 5 flood events that have resulted in a "large" silt load into the dam.

The results obtained from the water balance model were then averaged and the most relevant values are presented in **Table 2**.

Table 2: Average Volumes Released from Omdel Dam and Infiltrated at the Sites Based on 2008/2009 Channel Losses

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)	Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)	Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)
			10% Silt	10% Silt	10% Silt
9.500	37.389	0.200	2.379	3.376	1.957
19.200	37.389	0.200	3.142	3.899	2.648
20.000	37.389	0.200	3.184	3.930	2.693

4. Comparison with Previous Results

The recommendations from the hydrological report (Reference 1) for the short to medium term average volumes available for Omdel Dam for abstraction rates of 9.500 Mm³/a and 20.000 Mm³/a are presented in **Table 3**. These results were based on initial dry channel losses of 1.000 Mm³ per section and the original dam basin storage capacity. Furthermore the initial infiltration into the dry dam basin was set to 2.000 Mm³ and reduced to 1.000 Mm³ over the first 5 flood events.

Table 3: Recommended Short to Medium Term Average Volumes Available for Omdel Dam for Abstraction Rates of 9.5 Mm³/a and 20.0 Mm³/a

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)		Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)		Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)	
			10% Silt	2% Silt	10% Silt	2% Silt	10% Silt	2% Silt
9.500	41.300	0.200	2.575	3.350	2.564	3.935	1.301	2.325
20.000	41.300	0.200	3.453	4.413	3.068	4.549	1.584	2.840

The data from **Table 1** and **Table 2** is based on a 5-year model whereas the data from **Table 3** is based on the synthesised runoff record with silt loads of 10% and 2% respectively.

As one would expect due to reducing capacity of the dam due to a 10% siltation load on average per flood, the long term potential of artificial recharge from the dam is lower than the 5 year potential artificial recharge. The results obtained from the different input data are summarised in **Table 4**.

Table 4: Summary of Results

Release Rate (Mm³/a)	Full Supply Capacity (Mm³)	Dead Storage Capacity (Mm³)	Average Volume Released from Omdel Dam (Mm³/a)		Average Volume Infiltrated at Dam, River System and Sites 1 & 2 (Mm³/a)		Average Volume Infiltrated at Sites 1 & 2 (Mm³/a)	
			10% Silt	2% Silt	10% Silt	2% Silt	10% Silt	2% Silt
(1) 20.000	41.300	0.200	3.453	4.413	3.068	4.549	1.584	2.840
(2) 20.000	37.389	0.200	3.185		4.005		2.466	
(3) 20.000	37.389	0.200	3.184		3.930		2.693	
(4) 19.200	37.389	0.200	3.142		3.899		2.648	

(1): Results based on the initial dry river channel losses of 1.000 Mm³ for each section and the original dam basin storage capacity. Further the initial infiltration into the dry dam basin was set to 2.000 Mm³ and reduced to 1.000 Mm³ over the first 5 flood events.

(2): Results based on the stochastic runoff data for the 500 5-year sequences and with initial dry river channel losses of 1.000 Mm³ along each section.

(3): Results based on the stochastic runoff data for the 500 5-year sequences with initial dry river channel losses of 1.000 Mm³ for the channel up to Site 1 and an initial loss of 0.050 Mm³ for the river section from Site 1 to Site 2.

(4): Results based on the stochastic runoff data for the 500 5-year sequences with the initial dry channel losses of 1.000 Mm³ for the channel up to Site 1 and an initial loss of 0.050 Mm³ for the river section from Site 1 to Site 2.

5. Summary

The average infiltration that can expected at the infiltration sites were calculated using the first 5 years of runoff data obtained from 500 stochastic runoff records. Utilising these stochastic runoff records and considering different input data the average infiltration that can be expected at the infiltration sites vary between 2.466 Mm³/a and 2.693 Mm³/a for the next 5 years. Based on the most recent data available on the dry channel losses the average infiltration that is expected at the infiltration sites is 2.648 Mm³/a with a release rate of 19.200 Mm³/a.

6. Recommendations

It is recommended that:

6.1 the methodology used in these analyses be adopted.

6.2 the combined average infiltration of 2.648 Mm³/a at the two infiltration sites be adopted in further geohydrological studies.

6.3 further ground water monitoring and modelling be undertaken to determine the additional potential infiltration from the dam and river channel areas.

6.4 the hydrology be re-assed with the most recent rainfall and runoff data.

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MANAGER: HYDROLOGY

7. References

7.1 A Comprehensive Assessment of the Hydrology of the Omaruru Delta (OMDEL) Dam to Determine the Volume of Water Expected to be Available for Recharge of the Omdel Aquifer. NWC-HYD-OMDEL HYD: Hydrology NamWater April 2010.

7.2 Water Balance for Omdel Dam during Releases for Artificial Recharge during the 2008/2009 Hydrological Season. Hydrology NamWater April 2010.

Appendix 1

MULTIQUADRIC RAINFALL RESULTS

MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 4													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Rainfall (mm/a)**
1923/24	16.5	32.0	51.0	24.4	67.9	121.0	18.1	2.9	0.7	0.0	0.0	0.0	334.4
1924/25	12.3	16.4	30.2	167.4	107.8	207.1	100.6	9.0	0.0	1.4	0.0	0.1	652.1
1925/26	5.6	11.3	17.7	56.1	25.3	24.8	28.9	6.0	10.7	2.4	0.6	0.6	190.1
1926/27	1.3	70.9	88.5	82.9	16.0	26.2	43.9	0.0	0.0	0.0	0.1	1.7	331.4
1927/28	21.1	35.5	26.7	49.2	27.6	54.4	86.2	0.1	0.0	0.1	0.1	0.6	301.5
1928/29	0.3	6.0	14.8	97.8	55.2	142.0	1.5	0.0	0.0	0.0	0.0	0.5	318.2
1929/30	36.8	4.2	1.2	17.0	15.0	11.9	4.3	0.0	0.0	0.0	0.0	3.0	93.5
1930/31	6.3	15.0	24.5	134.5	114.8	95.7	0.0	0.0	0.0	0.0	0.1	0.0	390.9
1931/32	1.9	26.3	30.5	7.4	5.2	48.7	1.2	17.6	0.0	0.0	0.0	0.1	138.8
1932/33	26.0	5.7	29.1	17.3	29.0	41.0	2.6	0.0	0.0	0.1	0.0	0.1	150.9
1933/34	0.3	6.1	95.2	312.4	252.7	272.4	105.2	4.2	0.0	0.1	0.1	0.0	1048.7
1934/35	1.7	82.4	70.1	135.6	31.5	85.4	19.4	0.8	0.0	0.0	0.0	0.4	427.1
1935/36	4.7	33.6	28.2	98.6	15.5	74.4	9.5	34.8	0.0	0.0	0.0	7.2	306.5
1936/37	0.0	7.6	56.0	135.2	138.7	63.8	18.2	0.0	0.0	0.0	0.0	0.1	419.7
1937/38	10.7	68.5	71.0	133.8	52.1	46.1	65.0	27.4	0.2	0.0	0.0	0.0	474.7
1938/39	20.6	152.2	30.8	46.2	2.9	203.9	44.2	10.9	0.0	0.2	0.3	0.2	512.2
1939/40	31.8	55.4	55.6	129.3	50.9	86.4	30.7	0.0	0.1	0.0	0.0	1.6	441.7
1940/41	25.3	30.2	55.5	65.0	32.5	17.9	29.5	0.0	0.0	0.0	0.0	0.0	255.9
1941/42	41.5	0.0	21.3	24.5	163.6	59.3	122.6	0.2	0.0	0.0	0.0	0.8	433.7
1942/43	31.1	52.4	58.3	31.7	31.7	88.6	82.8	0.0	0.0	0.0	0.3	0.3	376.9
1943/44	0.3	17.5	139.3	261.4	164.9	24.3	0.0	0.0	0.0	0.0	0.0	0.1	607.8
1944/45	2.1	12.6	15.0	43.9	38.1	18.2	6.4	4.6	0.0	0.0	0.0	0.0	140.9
1945/46	0.0	66.6	175.1	12.2	8.7	10.9	6.6	0.0	0.0	0.0	0.0	0.3	280.5
1946/47	0.0	25.4	108.8	80.0	67.0	87.5	94.0	0.2	0.2	0.0	0.0	0.4	463.5
1947/48	0.1	8.6	35.7	26.8	64.4	6.4	9.3	1.9	0.0	0.6	0.0	0.0	153.7
1948/49	9.2	17.8	8.4	41.6	28.4	177.9	63.1	0.0	0.0	0.0	0.0	0.0	346.5
1949/50	2.6	18.0	18.0	213.5	282.7	139.5	84.4	11.3	0.0	0.0	0.0	1.9	772.0
1950/51	0.9	39.0	104.9	20.5	99.8	30.3	36.0	3.5	0.0	0.0	0.0	2.2	337.1
1951/52	36.0	9.4	96.7	16.1	122.2	10.7	15.4	0.0	0.0	0.0	0.0	0.7	307.1
1952/53	9.8	25.6	28.2	67.3	262.7	112.6	18.5	5.4	0.0	0.0	0.0	0.6	530.6
1953/54	34.5	8.0	78.8	73.7	136.9	199.2	20.3	0.6	0.0	0.0	0.0	0.4	552.2

1954/55	27.0	36.5	108.9	49.2	131.6	73.2	73.1	0.0	0.9	0.0	0.0	0.0	500.4
1955/56	12.9	38.7	20.1	149.8	101.8	142.5	10.9	0.5	0.0	0.0	0.0	0.0	477.2
1956/57	1.4	16.4	22.9	135.0	60.3	100.1	17.6	4.0	0.0	0.1	0.2	0.2	358.3
1957/58	4.0	84.0	62.0	119.0	92.3	47.5	12.0	1.0	0.0	0.0	0.0	0.0	421.7
1958/59	8.4	8.3	22.2	61.5	88.5	45.9	23.5	2.3	0.0	0.0	0.0	0.1	260.7

Appendix 2

1959/60	0.2	16.3	7.6	30.1	238.1	11.2	22.8	25.0	0.0	0.0	0.0	2.3	353.4
1960/61	28.6	15.0	5.9	24.1	45.5	92.8	26.8	15.4	14.7	0.0	0.0	0.0	268.7
1961/62	3.1	55.5	5.8	25.1	61.6	30.9	14.8	2.6	2.6	0.0	26.5	0.0	228.5
1962/63	26.9	18.0	19.3	272.3	30.9	180.9	116.1	0.8	0.0	0.0	0.0	8.6	673.8
1963/64	4.0	49.9	54.9	27.9	100.3	33.1	10.2	1.5	0.0	0.0	0.0	0.0	281.8
1964/65	5.3	22.6	13.6	60.8	64.5	99.4	79.3	0.0	0.0	0.0	0.0	4.1	349.6
1965/66	0.8	32.5	0.0	189.2	88.5	75.6	51.8	0.4	0.0	0.0	0.0	26.6	465.5
1966/67	3.4	7.6	70.7	44.4	156.4	94.9	11.1	24.0	0.0	0.0	0.0	0.8	413.3
1967/68	0.6	131.3	112.9	67.6	28.4	166.0	5.8	16.1	0.0	0.0	0.0	0.0	528.8
1968/69	0.9	48.4	28.5	34.1	108.0	122.9	12.1	0.0	0.0	0.0	0.3	0.0	355.3
1969/70	0.0	17.3	41.7	106.3	53.3	30.5	10.4	0.1	0.0	0.0	0.0	0.2	259.8
1970/71	37.7	9.0	38.1	68.7	211.1	42.9	34.4	6.6	8.0	0.0	0.0	0.0	456.4
1971/72	0.4	2.8	11.6	113.4	24.1	219.6	45.0	2.7	1.8	0.0	0.0	0.0	421.5
1972/73	8.8	13.2	12.7	20.9	25.2	63.2	12.5	0.0	0.0	0.0	0.0	0.0	156.5
1973/74	44.4	9.5	30.3	262.1	142.0	64.6	96.3	0.0	1.0	0.0	0.0	0.1	650.2
1974/75	8.8	23.2	20.6	71.7	69.6	108.4	30.9	6.1	0.0	0.0	0.0	0.1	339.3
1975/76	5.7	24.3	16.5	270.5	129.5	93.2	23.4	2.7	0.4	0.0	0.0	0.0	566.3
1976/77	19.1	19.5	11.8	55.6	171.7	40.5	24.5	11.9	0.0	0.0	0.0	0.0	354.7
1977/78	13.3	7.6	49.2	156.1	139.3	37.7	5.8	3.1	0.0	0.0	3.5	0.0	415.7
1978/79	0.0	18.7	10.6	89.9	183.4	8.6	0.0	7.5	1.9	0.0	0.1	6.3	327.0
1979/80	14.5	44.7	23.7	16.3	69.0	120.8	0.0	0.0	0.0	0.0	3.3	8.7	300.9
1980/81	1.2	6.6	37.9	24.1	44.5	44.6	14.1	0.0	0.0	0.0	0.0	0.0	172.9
1981/82	0.0	5.7	2.2	52.1	93.3	62.7	38.1	0.0	0.0	0.0	0.0	0.0	254.2
1982/83	12.0	9.8	88.7	66.4	33.2	25.8	12.8	11.1	19.2	0.0	0.0	0.0	279.0
1983/84	0.8	28.4	41.5	25.1	79.4	52.0	72.3	0.2	0.5	0.0	0.0	0.0	300.3
1984/85	3.0	24.6	25.9	103.0	134.6	49.1	20.3	0.1	0.0	0.0	0.0	0.0	360.4
1985/86	7.1	21.7	13.6	129.7	67.6	100.0	10.8	0.0	0.2	0.0	0.0	1.5	351.9
1986/87	19.8	8.2	25.6	59.7	141.9	43.6	39.7	1.9	0.0	0.0	0.0	0.0	340.4
1987/88	18.5	26.3	25.9	152.0	44.8	24.1	30.6	2.2	0.0	0.0	0.0	0.0	324.3
1988/89	4.4	46.0	81.0	53.8	70.0	16.7	52.3	3.2	0.0	0.0	0.0	0.0	327.4
1989/90	0.7	4.0	10.0	149.8	57.1	132.6	46.0	0.0	0.0	0.0	0.0	0.0	400.3
1990/91	7.5	17.0	21.2	77.7	136.7	40.7	0.3	0.0	0.0	0.0	0.0	12.4	313.6

1991/92	29.9	41.8	75.8	73.2	19.0	37.4	4.1	0.0	0.0	0.0	0.0	0.0	281.2
1992/93	1.4	5.3	2.5	46.0	127.1	80.4	43.4	1.6	0.0	0.0	0.0	0.3	307.9
1993/94	25.6	11.8	32.0	186.6	99.7	6.1	5.1	0.0	0.0	0.0	0.0	0.1	367.0
1994/95	20.6	15.0	8.6	2.1	121.7	35.2	13.2	9.8	0.0	0.0	0.0	2.6	228.7
1995/96	2.4	4.6	6.8	135.2	35.0	29.7	12.3	0.0	0.0	0.0	0.0	0.0	225.9
1996/97	0.0	19.4	19.5	184.8	74.1	69.3	7.9	0.0	0.0	0.0	0.0	0.0	375.0
1997/98	0.4	3.8	67.6	24.3	8.0	40.6	6.1	0.0	0.0	0.0	0.0	0.0	150.9

Appendix 2

1998/99	0.1	1.1	52.8	48.8	46.6	45.5	2.1	1.4	0.0	0.0	0.0	0.0	198.5
1999/00	10.9	28.5	122.9	68.1	94.3	131.2	9.1	14.0	0.0	0.0	0.0	0.0	479.0
2000/01	0.6	0.0	15.5	73.1	63.3	74.6	98.8	2.4	0.0	0.0	0.0	0.0	328.3
2001/02	0.0	0.0	0.0	10.8	73.2	83.9	14.9	0.0	0.0	0.0	0.0	0.0	182.8
2002/03	5.8	25.5	25.0	27.8	92.1	12.1	80.2	0.0	0.0	0.0	0.1	3.8	272.3
2003/04	3.0	18.7	13.4	129.5	78.7	41.7	14.3	0.0	0.0	0.0	0.0	0.0	299.3
2004/05	20.2	83.5	0.0	80.4	123.2	74.5	4.1	0.2	0.0	0.0	0.0	0.0	386.1
2005/06	11.4	5.7	9.6	251.1	169.1	76.1	96.2	5.4	0.0	0.0	0.0	7.3	631.8
2006/07	14.3	12.6	15.5	63.1	16.2	43.5	56.5	0.0	0.0	0.0	0.0	2.9	224.6
2007/08	11.0	7.5	8.5	104.6	228.8	115.1	2.7	1.2	0.0	0.0	0.0	0.0	479.4
2008/09	1.7	66.1	72.4	59.4	328.3	63.6	0.8	0.5	0.0	0.0	0.0	0.0	592.8
2009/10	7.5	5.3	19.2	117.3	40.2	44.2	4.9	0.5	0.0	0.0	0.0	0.3	239.4
Average	10.5	26.3	39.4	88.8	90.4	73.9	31.6	3.8	0.7	0.1	0.4	1.3	367.3
Median	5.7	17.8	25.9	67.6	70.0	62.7	18.2	0.5	0.0	0.0	0.0	0.1	340.4

Appendix 2

MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 3													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Rainfall (mm/a)**
1923/24	11.9	31.8	50.1	11.8	110.4	113.3	50.9	9.1	2.2	0.0	0.0	0.0	391.6
1924/25	8.9	10.8	30.5	191.3	150.3	306.3	114.9	6.5	0.0	1.1	0.0	0.1	820.6
1925/26	4.5	8.3	23.5	84.5	24.6	33.6	24.8	3.5	6.3	1.6	0.4	0.1	215.9
1926/27	0.9	57.3	88.4	45.3	14.7	12.6	67.4	0.0	0.0	0.0	0.0	1.1	287.6
1927/28	19.5	33.0	16.6	53.3	22.3	31.9	57.5	0.0	0.0	0.0	0.0	0.2	234.2
1928/29	0.7	8.7	8.8	72.0	55.0	102.0	2.4	0.0	0.0	0.0	0.0	0.4	249.9
1929/30	32.9	5.7	1.1	16.7	3.3	23.6	5.1	0.0	0.0	0.0	0.0	1.2	89.5
1930/31	3.5	5.8	22.3	84.7	103.0	68.6	0.0	0.0	0.0	0.0	0.0	0.0	287.9
1931/32	6.4	18.0	19.0	8.5	4.1	42.8	1.3	21.8	0.0	0.0	0.0	0.0	122.0
1932/33	30.9	2.2	28.3	12.5	18.5	41.4	2.7	0.0	0.0	0.4	0.0	0.0	136.9
1933/34	0.1	5.8	106.6	254.6	193.3	246.3	90.5	4.1	0.0	0.0	0.0	0.0	901.3
1934/35	1.0	58.3	38.5	87.0	31.9	51.1	19.7	0.0	0.0	0.0	0.0	1.7	289.4
1935/36	1.0	12.8	23.9	57.9	5.0	56.6	7.6	25.3	0.0	0.0	0.0	2.3	192.4
1936/37	0.0	2.3	23.0	126.4	126.7	35.4	8.7	0.0	0.0	0.0	0.0	0.0	322.4
1937/38	2.1	21.2	26.7	84.2	21.4	26.0	42.1	19.9	0.2	0.0	0.0	0.0	244.0
1938/39	9.8	106.3	19.5	25.8	1.6	134.7	25.5	6.0	0.0	0.3	0.9	0.1	330.4
1939/40	15.3	43.7	44.2	59.2	41.4	62.3	17.2	0.0	0.0	0.0	0.0	0.8	284.1
1940/41	14.5	7.0	35.9	35.8	3.4	14.3	9.3	0.0	0.0	0.0	0.0	0.0	120.1
1941/42	33.9	0.2	5.6	18.4	164.9	62.1	82.3	0.0	0.0	0.0	0.0	0.3	367.6
1942/43	17.1	33.1	49.1	15.3	25.9	65.2	78.9	0.0	0.0	0.0	0.2	0.0	284.8
1943/44	1.1	9.6	115.5	246.3	85.3	23.7	0.0	0.0	0.0	0.0	0.0	0.0	481.6
1944/45	0.7	8.3	32.8	48.6	37.6	12.5	0.1	2.3	0.0	0.0	0.0	0.0	143.0
1945/46	0.0	62.1	156.0	7.8	4.2	7.3	9.4	0.0	0.0	0.0	0.0	0.2	246.9
1946/47	0.0	13.6	107.7	41.6	68.5	69.7	46.9	0.0	0.3	0.0	0.0	0.0	348.3
1947/48	0.0	2.9	21.3	30.8	76.1	8.0	4.5	0.0	0.0	0.0	0.0	0.0	143.6

1948/49	7.7	29.3	12.1	41.2	35.6	184.8	78.1	0.0	0.0	0.0	0.0	0.0	388.8
1949/50	2.1	7.4	9.5	159.4	266.7	181.6	74.6	5.5	0.0	0.0	0.0	0.7	707.6
1950/51	1.0	33.9	87.6	38.9	127.2	63.4	64.7	4.1	0.0	0.0	0.0	2.2	423.0
1951/52	20.4	11.9	46.5	7.0	168.5	14.4	8.8	0.0	0.0	0.0	0.0	0.1	277.6
1952/53	9.7	24.2	20.8	65.5	195.6	59.0	17.3	4.7	0.0	0.0	0.0	1.4	398.1
1953/54	21.0	2.4	52.2	61.9	104.0	195.5	24.0	0.5	0.0	0.0	0.0	0.2	461.7
1954/55	17.6	23.5	73.2	35.3	77.2	54.2	75.6	0.1	1.2	0.0	0.0	0.0	357.8
1955/56	17.6	34.2	9.5	134.0	84.8	105.5	11.2	2.1	0.1	0.4	0.0	0.4	399.9
1956/57	0.4	14.2	18.3	111.4	90.1	110.2	9.1	7.4	0.0	0.0	0.1	0.2	361.3
1957/58	1.3	53.7	28.6	64.0	70.1	34.9	4.3	0.4	0.0	0.0	0.0	0.0	257.2
1958/59	3.2	14.7	4.4	30.4	96.8	26.3	21.0	3.4	0.0	0.0	0.0	0.0	200.2

Appendix 2

1959/60	0.0	9.2	2.5	21.9	153.6	9.5	37.5	13.1	0.1	0.0	0.0	2.2	249.5
1960/61	15.3	19.8	8.9	15.1	45.9	44.1	46.7	18.8	11.1	0.0	0.0	9.7	235.4
1961/62	1.4	48.0	5.9	18.8	37.3	10.9	8.7	0.0	0.0	0.0	15.9	0.0	147.0
1962/63	22.1	21.3	18.1	195.7	30.4	181.4	98.2	1.8	0.0	0.0	0.0	6.3	575.3
1963/64	1.2	30.2	22.8	29.5	69.6	29.4	6.0	0.1	0.0	0.0	0.0	0.0	188.8
1964/65	0.3	7.6	9.2	54.0	51.6	92.9	59.0	0.0	0.0	0.0	0.0	3.5	278.2
1965/66	0.5	9.0	8.1	167.7	58.2	94.3	18.9	0.0	0.1	1.1	0.0	28.4	386.3
1966/67	2.8	24.6	65.6	50.7	119.0	102.5	10.4	11.1	0.0	0.0	0.0	1.4	388.1
1967/68	2.9	111.9	78.4	49.0	17.9	140.5	1.8	7.0	0.0	0.0	0.0	0.0	409.3
1968/69	0.0	42.1	18.1	11.5	94.8	97.2	15.4	0.0	0.0	0.0	0.1	0.0	279.2
1969/70	2.3	6.4	14.3	98.6	29.9	16.1	6.9	0.0	0.0	0.0	0.0	0.1	174.5
1970/71	19.4	4.6	30.5	63.5	193.3	61.6	22.4	2.8	5.5	0.0	0.0	0.0	403.6
1971/72	0.5	6.0	23.1	97.5	19.2	178.7	45.2	0.3	0.2	0.0	0.0	0.0	370.6
1972/73	10.7	7.9	11.6	17.4	13.1	77.9	18.8	0.0	0.0	0.0	0.0	0.0	157.4
1973/74	17.2	2.6	7.7	227.0	194.2	54.4	104.2	0.0	1.2	0.0	0.0	0.0	608.4
1974/75	17.7	20.9	21.3	71.2	52.5	94.5	18.4	3.1	0.0	0.0	0.0	0.0	299.5
1975/76	0.9	8.0	6.3	237.4	91.7	121.6	7.5	0.2	0.2	0.0	0.0	0.0	473.9
1976/77	12.9	4.0	8.2	36.8	135.5	38.6	23.7	3.0	0.0	0.0	0.0	0.0	262.6
1977/78	7.3	8.0	24.7	113.6	141.1	73.2	5.9	5.1	0.0	0.0	0.5	0.0	379.5
1978/79	1.7	9.1	17.4	53.3	170.6	8.3	2.8	4.5	3.9	0.0	0.0	2.0	273.5
1979/80	4.8	29.6	23.6	17.0	102.5	108.4	0.0	0.0	0.0	0.0	7.8	2.7	296.4

1980/81	11.5	0.7	35.0	10.9	19.6	20.2	25.5	0.0	0.0	0.0	3.2	0.0	126.6
1981/82	0.0	1.1	15.8	23.0	67.3	71.2	42.4	0.0	0.0	0.0	0.0	2.0	222.9
1982/83	14.5	9.2	51.4	46.2	14.3	29.4	20.4	3.5	33.0	0.0	0.0	0.0	221.7
1983/84	4.7	13.4	18.0	31.3	71.6	55.1	68.7	1.6	0.0	0.0	0.0	0.1	264.4
1984/85	7.5	20.1	4.9	105.6	169.9	41.2	17.6	0.0	0.0	0.0	0.0	0.0	366.8
1985/86	12.1	32.9	24.6	111.4	36.5	47.9	10.4	0.3	3.2	0.2	0.0	4.0	283.5
1986/87	14.9	8.5	25.7	10.2	139.5	20.1	40.0	5.2	0.0	0.0	0.0	0.2	264.3
1987/88	19.4	20.6	20.2	131.5	38.4	11.9	27.9	3.2	0.0	0.0	0.0	0.0	273.0
1988/89	2.9	22.6	32.4	53.0	66.3	39.6	25.4	4.9	0.0	0.0	0.0	0.0	247.2
1989/90	0.0	5.3	2.8	126.4	60.6	106.4	30.1	0.0	0.0	0.0	0.0	0.0	331.7
1990/91	7.7	33.2	20.7	71.2	110.4	60.7	0.4	0.0	0.0	0.0	0.0	6.3	310.5
1991/92	8.0	35.6	56.4	60.8	18.4	18.0	4.4	0.0	0.0	0.0	0.0	2.9	204.5
1992/93	11.0	4.7	11.8	48.8	67.3	70.8	27.7	0.9	0.0	0.0	0.0	0.3	243.3
1993/94	17.6	10.3	15.3	158.6	134.5	10.7	10.0	0.0	0.0	0.0	0.1	0.0	357.2
1994/95	9.0	6.2	14.4	5.1	112.3	46.9	11.7	4.6	0.0	0.0	0.0	1.7	211.8
1995/96	0.1	9.7	13.4	70.2	39.3	26.4	5.1	0.0	0.0	0.0	0.0	0.0	164.0
1996/97	0.5	17.5	25.4	117.9	82.1	65.4	3.3	1.7	0.0	0.0	0.0	0.1	313.9
1997/98	0.0	1.8	66.3	27.6	5.8	24.3	5.5	0.0	0.0	0.1	0.5	2.2	134.2

Appendix 2

1998/99	2.2	7.9	30.8	45.1	31.5	55.0	3.5	1.9	0.0	0.0	0.0	0.0	178.1
1999/00	5.1	19.7	63.9	27.2	68.6	107.4	11.1	8.4	0.0	0.0	0.0	0.0	311.3
2000/01	2.5	2.3	10.8	46.1	77.1	60.7	82.8	6.2	0.0	0.0	0.0	0.3	288.8
2001/02	0.7	2.7	48.7	22.4	80.2	60.1	22.0	0.0	0.0	0.0	0.0	0.0	236.7
2002/03	2.8	24.8	63.6	17.7	88.8	18.0	71.0	0.0	0.0	0.0	1.6	1.5	289.7
2003/04	3.2	43.6	12.7	123.0	68.8	26.1	18.8	0.0	0.0	0.0	0.0	0.4	296.5
2004/05	24.3	80.6	0.0	56.2	86.2	72.2	33.0	2.8	0.0	0.0	0.0	0.0	355.2
2005/06	10.2	1.9	12.2	212.7	164.4	79.3	84.8	0.4	0.0	0.0	0.0	6.5	572.4
2006/07	5.7	4.8	6.5	73.4	6.8	29.5	53.2	0.0	0.0	0.0	0.0	6.0	185.8
2007/08	4.1	4.4	6.9	135.6	252.4	120.0	1.7	0.9	0.0	0.0	0.0	0.0	525.9
2008/09	11.8	79.6	81.1	52.1	375.4	83.8	0.3	0.4	0.0	0.0	0.0	2.8	687.2
2009/10	2.3	3.7	16.7	120.6	39.6	35.5	2.5	0.4	0.0	0.0	0.0	0.3	221.5
Average	7.8	20.4	30.9	71.9	81.9	67.0	28.5	2.8	0.8	0.1	0.4	1.2	313.8
Median	4.5	10.8	21.3	53.3	68.8	55.1	18.8	0.3	0.0	0.0	0.0	0.1	284.8

Appendix 2

MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 2													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Rainfall (mm/a)**
1923/24	3.3	33.7	46.5	6.9	154.6	124.5	43.6	7.7	1.9	0.0	0.0	0.0	422.7
1924/25	21.5	6.4	26.0	232.3	195.3	423.9	128.2	3.1	0.0	1.4	0.0	0.0	1038.1
1925/26	4.2	5.3	30.9	117.8	32.8	57.8	24.8	0.5	3.0	0.2	0.1	0.1	277.5
1926/27	0.1	57.9	127.7	25.2	19.0	4.4	117.3	0.0	0.0	0.0	0.0	0.2	351.7
1927/28	16.9	27.3	8.9	64.3	18.5	23.1	38.7	0.0	0.0	0.0	0.0	0.0	197.7
1928/29	1.1	14.2	2.5	86.4	44.8	46.7	9.4	0.0	0.0	0.0	0.0	0.5	205.7
1929/30	42.9	10.9	1.1	35.0	1.9	17.1	1.9	0.0	0.0	0.0	0.0	0.0	110.8
1930/31	3.3	4.5	42.9	55.1	138.2	54.7	0.0	0.0	0.0	0.0	0.0	0.0	298.5
1931/32	3.5	20.1	26.5	40.6	3.0	17.3	0.6	18.9	0.0	0.0	0.0	0.0	130.5
1932/33	39.1	0.0	44.6	11.4	21.1	34.3	2.9	0.0	0.0	0.2	0.1	0.0	153.9
1933/34	0.0	3.4	92.3	267.5	143.1	283.9	68.7	3.9	0.0	0.0	0.0	0.0	862.7
1934/35	0.2	36.0	25.0	51.6	51.8	31.2	23.1	0.0	0.0	0.0	0.0	2.4	221.4
1935/36	0.2	10.1	10.6	28.6	0.5	59.0	4.1	23.0	0.0	0.0	0.0	0.2	136.3
1936/37	0.0	0.4	14.1	113.8	119.7	46.1	17.4	0.0	0.0	0.0	0.0	0.0	311.5
1937/38	3.8	4.7	18.1	96.5	28.9	11.1	41.2	15.2	0.0	0.0	0.0	0.0	219.6
1938/39	1.5	71.2	6.0	18.0	0.5	82.7	11.1	1.9	0.0	0.4	1.1	0.0	194.4

1939/40	16.2	27.1	44.4	29.3	26.5	50.0	9.2	0.0	0.0	0.0	0.0	0.5	203.0
1940/41	9.8	0.8	22.1	17.3	14.1	11.8	8.3	0.0	0.0	0.0	0.0	0.0	84.2
1941/42	14.0	0.1	5.5	9.9	172.7	59.1	64.2	0.0	0.0	0.0	0.0	0.6	326.1
1942/43	14.0	22.8	74.0	9.6	20.4	43.9	68.2	0.0	0.0	0.0	0.0	0.0	252.9
1943/44	3.4	13.4	87.3	227.9	46.3	63.7	0.0	0.0	0.0	0.0	0.0	0.1	442.1
1944/45	1.8	3.3	14.0	56.5	40.4	9.5	1.1	1.7	0.0	0.0	0.0	0.0	128.2
1945/46	0.0	85.0	142.4	9.2	2.5	4.2	11.6	0.0	0.0	0.0	0.0	0.0	255.0
1946/47	0.0	8.8	100.5	30.4	101.3	83.6	36.2	0.2	0.0	0.0	0.0	0.0	361.1
1947/48	0.1	4.3	34.7	26.7	91.2	4.2	5.6	0.2	0.0	0.0	0.0	0.0	167.0
1948/49	1.4	21.0	16.5	29.4	30.8	170.8	54.5	0.0	0.2	0.0	0.0	0.0	324.4
1949/50	1.6	9.3	5.6	123.3	195.7	202.3	50.1	6.3	0.0	0.0	0.0	0.1	594.4
1950/51	0.2	21.7	48.9	12.9	100.3	40.0	88.2	3.3	0.0	0.0	0.0	0.5	316.1
1951/52	17.8	2.7	24.7	4.1	150.2	16.2	10.9	0.0	0.0	0.0	0.0	0.6	227.2
1952/53	4.9	24.0	25.6	28.3	125.2	47.9	20.9	0.8	0.0	0.0	0.0	0.5	278.0
1953/54	15.5	1.0	22.9	34.4	70.1	133.6	13.4	0.0	0.0	0.0	0.0	0.9	291.8
1954/55	0.8	12.9	29.0	25.6	30.1	83.2	37.6	0.0	0.4	0.0	0.0	0.0	219.6
1955/56	9.3	30.0	6.8	92.7	56.4	90.1	21.9	1.6	0.0	0.2	0.0	0.1	309.0
1956/57	0.2	7.0	5.6	68.2	64.4	92.9	0.9	2.4	0.0	0.0	0.0	0.1	241.7
1957/58	0.1	45.5	27.2	81.0	58.6	24.8	1.5	0.0	0.0	0.0	0.1	0.0	238.7
1958/59	0.1	17.6	0.7	19.2	47.9	23.5	24.5	0.5	0.0	0.0	0.0	0.1	134.0

Appendix 2

1959/60	0.0	5.9	1.1	19.1	89.3	10.2	22.8	10.8	0.1	0.0	0.0	0.8	160.2
1960/61	3.7	6.0	8.1	19.1	28.1	56.3	45.9	9.7	9.9	0.0	0.0	2.3	189.0
1961/62	0.3	39.1	6.5	8.5	32.2	14.6	10.0	0.0	0.0	0.0	3.7	0.0	115.1
1962/63	13.2	4.0	17.8	163.4	26.2	180.6	64.5	2.3	0.0	0.0	4.6	0.4	477.1
1963/64	0.2	31.8	32.5	11.9	61.6	18.9	1.7	0.0	0.0	0.0	0.0	1.2	159.7
1964/65	0.1	3.4	6.2	73.0	38.2	53.6	36.8	0.0	0.0	0.0	0.0	1.8	213.1
1965/66	0.1	8.2	4.5	97.7	53.4	90.0	22.8	0.0	0.1	0.6	0.0	12.9	290.2
1966/67	0.6	10.5	45.0	35.6	86.8	91.6	11.2	9.8	0.0	0.0	0.0	0.6	291.7
1967/68	2.3	116.9	92.4	17.9	14.8	130.4	4.3	6.5	0.0	0.0	0.0	0.2	385.7
1968/69	0.0	26.5	16.0	5.8	87.1	120.5	11.9	0.0	0.0	0.0	0.2	0.0	268.0

1969/70	0.4	5.8	17.3	46.7	37.4	16.2	2.4	0.0	0.0	0.0	0.0	0.0	126.2
1970/71	20.6	5.2	10.2	49.0	154.2	52.9	30.8	3.0	2.8	0.0	0.0	0.0	328.6
1971/72	0.4	3.7	16.9	63.4	27.3	126.9	36.1	0.0	0.0	0.0	0.0	0.0	274.7
1972/73	13.8	6.5	11.4	31.3	15.0	71.7	24.6	0.0	0.0	0.0	0.0	0.0	174.2
1973/74	18.3	0.8	2.8	147.4	149.7	41.5	115.6	0.0	1.1	0.0	0.0	0.0	477.2
1974/75	9.0	17.7	11.1	52.3	48.0	108.1	17.9	3.8	0.0	0.0	0.0	0.0	268.0
1975/76	1.7	20.6	9.3	182.1	80.8	131.3	6.6	0.1	1.3	0.0	0.0	0.0	433.6
1976/77	4.3	0.6	10.0	26.6	98.0	53.6	10.6	5.1	0.0	0.0	0.0	0.0	208.7
1977/78	3.9	3.9	28.9	100.7	111.0	87.7	5.9	0.0	0.0	0.0	0.1	0.0	342.2
1978/79	21.2	6.5	2.5	59.9	112.1	7.6	1.1	1.4	10.0	0.0	0.0	0.0	222.2
1979/80	0.0	13.3	29.6	7.3	78.3	98.0	1.0	0.0	0.0	0.9	11.6	1.6	241.4
1980/81	2.4	1.3	35.1	14.5	10.5	9.3	16.8	0.0	0.0	0.0	1.4	1.1	92.4
1981/82	0.0	0.0	4.7	31.5	50.3	67.0	34.7	0.0	0.0	0.0	0.0	0.6	188.8
1982/83	0.6	1.6	30.0	33.4	7.8	20.2	8.3	0.0	16.7	0.0	0.0	0.0	118.5
1983/84	1.4	16.2	9.2	11.7	37.6	54.7	34.2	0.9	0.0	0.0	0.0	0.0	165.9
1984/85	9.5	7.9	4.4	74.2	124.6	52.2	5.3	0.0	0.0	0.0	0.0	0.0	278.1
1985/86	15.4	31.3	9.1	67.4	21.3	31.2	5.2	0.0	2.4	0.4	0.0	1.9	185.8
1986/87	6.7	10.9	20.1	41.2	75.4	22.0	21.3	4.5	0.0	0.0	0.0	1.3	203.3
1987/88	12.3	11.6	17.2	126.4	23.1	39.2	22.7	3.6	0.0	0.0	0.0	0.0	256.0
1988/89	2.0	23.4	67.1	46.2	38.0	23.6	24.1	4.5	0.0	0.0	0.0	0.0	228.9
1989/90	0.1	4.8	4.0	149.5	58.6	112.0	9.5	0.0	0.0	0.0	0.0	0.0	338.5
1990/91	2.7	17.1	23.9	67.0	75.8	80.8	12.4	0.0	0.0	0.0	0.0	2.9	282.5
1991/92	5.5	29.6	73.9	62.7	16.8	31.4	1.9	0.0	0.0	0.0	0.1	10.8	232.6
1992/93	4.5	4.5	22.9	37.3	58.0	70.2	23.8	0.4	0.0	0.0	0.0	0.4	221.9
1993/94	14.2	28.6	15.6	138.9	130.6	12.1	9.4	0.0	0.2	0.0	0.0	0.0	349.6
1994/95	16.5	4.5	6.3	2.0	112.8	64.1	27.8	4.7	0.0	0.0	0.0	1.3	240.0
1995/96	0.9	16.2	9.6	62.6	54.6	29.5	6.9	0.0	0.0	0.0	0.0	0.7	181.0
1996/97	0.4	26.7	25.6	115.7	73.9	78.2	0.3	0.5	0.0	0.0	0.0	0.4	321.5
1997/98	5.7	2.4	79.1	22.5	5.9	15.9	5.8	0.0	0.0	0.0	0.2	1.0	138.5

Appendix 2

1998/99	3.6	9.1	30.9	58.5	33.0	37.9	11.1	5.4	0.0	0.0	0.0	0.0	189.4
1999/00	5.1	22.6	93.3	46.1	55.5	70.1	11.1	11.9	0.0	0.0	0.0	0.0	315.7
2000/01	2.6	2.1	7.9	84.3	62.3	82.5	99.6	2.4	0.0	0.0	0.0	0.1	343.8
2001/02	1.3	2.8	24.7	23.3	112.8	75.7	29.5	0.0	0.0	0.0	0.0	0.0	270.1
2002/03	1.8	22.8	41.8	23.3	85.7	29.1	70.7	0.0	0.0	0.0	0.3	0.8	276.3
2003/04	9.8	32.2	15.0	131.7	86.6	41.6	26.3	0.0	0.1	0.0	0.0	1.3	344.5
2004/05	21.6	99.2	2.4	80.1	93.6	97.6	34.0	1.6	0.0	0.0	0.0	0.0	430.0
2005/06	9.5	5.2	10.5	189.9	146.9	90.9	94.3	0.0	0.0	0.0	0.0	4.5	551.6
2006/07	17.2	14.9	3.4	53.1	18.3	39.0	57.7	0.0	0.0	0.0	0.0	1.7	205.4

2007/08	8.9	4.6	9.0	154.3	229.3	115.4	6.4	0.0	0.0	0.0	0.0	0.0	528.0
2008/09	25.4	85.1	101.4	81.9	391.0	123.3	1.4	0.0	0.0	0.0	0.0	6.7	816.2
2009/10	10.5	16.3	20.0	121.9	48.7	65.3	11.9	0.2	0.0	0.0	0.0	0.0	294.8
Average	6.7	17.9	28.3	63.9	71.1	66.9	26.1	2.1	0.6	0.1	0.3	0.8	286.4
Median	3.3	10.5	17.8	46.7	55.5	53.6	16.8	0.0	0.0	0.0	0.0	0.0	255.5

Appendix 2

MULTIQUADRIC RAINFALL RESULTS FOR SUB-CATCHMENT 1													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Rainfall (mm/a)**
1923/24	2.9	64.3	79.9	2.0	277.8	250.9	80.1	14.1	3.5	0.0	0.0	0.0	775.5
1924/25	29.7	8.7	38.8	427.7	324.1	718.2	218.4	6.0	0.0	3.9	0.0	0.0	1775.4
1925/26	9.5	11.9	53.7	198.4	29.5	53.3	22.7	0.0	6.2	0.0	0.0	0.5	385.7
1926/27	0.0	45.4	127.7	20.7	16.3	3.2	116.8	0.0	0.0	0.0	0.0	0.0	330.1
1927/28	11.6	25.3	7.4	74.6	16.6	20.6	29.2	0.0	0.0	0.0	0.0	0.1	185.3
1928/29	0.9	11.9	1.5	85.7	27.7	45.0	7.3	0.1	0.0	0.0	0.0	1.8	181.8
1929/30	33.0	11.5	0.0	38.5	2.7	25.7	0.6	0.0	0.0	0.0	0.0	0.0	112.0

1930/31	4.0	4.8	48.6	58.9	179.8	39.4	0.0	0.0	0.0	0.0	0.0	0.0	335.5
1931/32	1.8	23.9	21.6	51.3	0.0	4.0	0.6	24.6	0.0	0.0	0.0	0.0	127.8
1932/33	42.7	0.0	37.0	7.3	21.0	32.5	2.7	0.0	0.0	0.1	0.5	0.0	143.7
1933/34	0.0	2.0	65.9	263.6	151.1	356.0	59.1	4.0	0.0	0.0	0.0	0.0	901.7
1934/35	0.4	20.5	21.7	34.0	64.3	28.7	30.0	0.5	0.0	0.0	0.0	5.6	205.5
1935/36	1.1	10.7	1.5	16.1	0.5	62.5	7.6	26.9	0.0	0.0	0.0	0.2	127.0
1936/37	0.0	2.1	16.5	94.8	114.7	54.0	21.0	0.0	0.0	0.0	0.0	0.0	303.1
1937/38	5.1	5.1	14.7	80.2	30.3	5.1	48.8	13.2	0.0	0.0	0.0	0.0	202.5
1938/39	0.0	61.4	2.5	8.2	0.2	67.0	5.0	0.1	0.0	1.8	0.5	0.0	146.6
1939/40	20.1	8.8	28.2	14.3	17.4	16.2	4.1	0.0	0.2	0.0	0.0	1.9	111.1
1940/41	4.9	0.4	2.3	20.9	20.9	13.2	15.5	0.0	0.0	0.0	0.0	0.0	78.0
1941/42	14.3	0.0	6.6	7.5	190.0	68.9	74.9	0.2	0.0	0.0	0.0	2.0	364.3
1942/43	17.3	23.0	96.6	15.9	20.9	36.6	82.2	0.0	0.0	0.0	0.5	0.4	293.4
1943/44	7.9	24.9	82.2	279.4	47.4	77.3	0.1	0.0	0.0	0.0	0.0	0.2	519.4
1944/45	0.9	8.8	0.0	93.9	48.5	5.3	0.0	1.9	0.0	0.0	0.0	0.0	159.4
1945/46	0.0	107.5	133.9	14.7	1.1	0.0	15.9	0.0	0.0	0.0	0.0	0.0	273.1
1946/47	0.0	6.2	112.2	41.3	83.4	101.6	29.4	1.5	1.3	0.0	0.0	0.0	376.8
1947/48	0.8	0.7	44.8	50.7	123.5	4.5	2.1	0.0	0.0	0.5	0.0	0.0	227.5
1948/49	0.0	23.5	14.0	10.2	9.9	187.7	11.8	0.0	0.7	0.0	0.0	0.0	257.9
1949/50	3.6	3.8	2.8	67.6	85.0	220.0	18.7	3.2	0.0	0.0	0.0	0.0	404.7
1950/51	0.0	20.6	8.7	5.6	105.5	38.6	50.6	3.5	0.2	0.0	0.0	0.0	233.2
1951/52	7.7	0.4	6.9	3.8	78.6	7.8	8.4	0.0	0.0	0.3	0.0	0.6	114.4
1952/53	1.7	29.0	7.9	5.8	77.0	32.0	27.9	1.1	0.0	0.0	0.0	0.0	182.4
1953/54	3.5	0.0	7.7	7.2	18.6	69.6	5.1	0.0	0.0	0.0	0.0	0.0	111.8
1954/55	0.0	16.4	2.9	8.7	12.9	72.7	19.6	0.0	0.0	0.0	0.0	0.0	133.2
1955/56	0.4	3.9	1.3	55.9	5.0	55.2	7.4	2.9	0.0	0.0	0.0	0.0	131.9
1956/57	0.0	5.2	4.1	30.0	35.1	47.9	0.0	0.0	0.0	0.0	0.0	0.0	122.3
1957/58	0.0	15.6	2.6	35.1	21.8	9.4	0.0	0.0	0.0	0.0	0.0	0.1	84.6
1958/59	0.0	3.0	0.0	2.6	6.2	8.9	12.2	1.1	0.0	0.0	0.0	0.0	34.0

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1959/60	0.0	3.3	0.0	5.0	34.5	8.2	9.1	10.7	0.3	0.0	0.0	0.0	71.2
1960/61	0.4	0.0	0.4	2.5	3.4	65.3	10.4	1.5	1.7	0.0	0.0	0.3	85.8
1961/62	0.0	8.1	1.2	0.1	4.2	2.4	1.8	0.0	0.0	0.0	0.9	0.0	18.8
1962/63	5.0	0.0	2.7	77.8	7.4	90.2	11.0	3.5	0.1	0.1	4.9	0.0	202.8
1963/64	0.0	11.1	5.6	0.1	24.8	11.7	0.0	0.0	0.0	0.0	0.0	0.5	53.7
1964/65	0.0	0.6	0.7	66.5	9.5	16.3	21.6	0.0	0.0	0.0	0.0	3.0	118.3
1965/66	0.0	0.6	1.0	40.9	35.8	61.7	25.3	0.0	0.0	0.0	0.0	4.2	169.5
1966/67	0.2	0.6	8.2	14.4	60.6	67.6	3.8	1.4	0.0	0.0	0.0	0.0	156.8
1967/68	0.1	70.2	55.9	0.8	8.4	30.7	3.5	0.0	0.0	0.0	0.0	0.0	169.6
1968/69	0.0	15.7	1.1	0.0	74.6	119.7	5.8	0.0	0.0	0.0	0.0	0.0	217.0
1969/70	0.0	0.0	3.4	26.6	18.7	2.3	0.0	0.0	0.0	0.0	0.0	0.0	51.0
1970/71	5.3	0.8	0.0	12.2	58.5	24.7	7.2	1.1	0.1	0.0	0.0	0.0	109.7
1971/72	3.9	6.5	5.1	31.6	35.8	33.1	16.9	0.0	0.1	0.0	0.0	0.0	133.0
1972/73	3.6	1.0	3.8	25.5	19.5	41.6	26.4	0.0	0.0	0.0	0.0	0.0	121.6
1973/74	10.4	1.3	0.2	105.1	96.8	57.5	116.7	0.1	0.9	0.0	0.0	0.0	389.0
1974/75	9.0	30.7	2.4	18.5	33.6	87.9	16.2	0.5	0.0	0.0	0.0	0.0	199.0
1975/76	2.0	23.6	6.6	112.2	50.7	110.5	2.3	0.7	0.0	0.0	0.0	0.0	308.5
1976/77	0.0	1.8	6.7	21.9	67.9	42.7	7.6	3.6	0.0	0.0	0.0	0.0	152.1
1977/78	5.0	1.3	20.8	81.2	49.6	76.9	7.0	0.0	0.0	0.0	0.0	0.0	241.8
1978/79	34.6	5.0	2.4	55.7	55.1	7.7	0.0	0.0	7.6	0.0	0.0	0.0	168.1
1979/80	0.2	0.4	29.6	3.1	69.8	59.4	7.6	0.0	0.0	0.7	20.1	1.2	192.1
1980/81	0.0	2.5	29.2	17.0	10.9	20.6	11.5	0.0	0.0	0.0	5.1	2.1	98.8
1981/82	0.0	0.9	6.3	33.1	52.0	62.7	30.7	0.0	0.0	0.0	0.0	0.2	185.9
1982/83	1.1	0.0	6.1	19.6	4.7	30.0	6.8	0.0	7.8	0.0	0.0	0.0	76.1
1983/84	1.2	15.5	12.6	3.1	33.4	77.0	22.9	1.4	0.0	0.0	0.0	0.0	167.1
1984/85	15.3	0.0	5.7	44.3	122.0	62.7	5.0	0.2	0.0	0.0	0.0	0.0	255.3
1985/86	24.0	40.4	5.5	35.3	13.0	45.0	0.0	0.0	2.6	0.0	0.0	0.0	165.6
1986/87	5.7	8.6	42.7	70.1	31.0	25.7	9.6	3.7	0.0	0.0	0.0	2.4	199.5
1987/88	13.8	0.0	19.1	119.5	0.3	64.8	5.7	6.1	0.0	0.0	0.0	0.0	229.3
1988/89	2.2	24.1	96.8	41.2	21.1	7.7	11.0	4.6	0.0	0.0	0.0	0.0	208.6
1989/90	0.3	1.5	7.5	149.3	63.4	71.1	0.0	0.0	0.0	0.0	0.0	0.0	293.0
1990/91	0.0	3.1	11.4	50.3	30.1	80.5	16.8	0.0	0.0	0.0	0.0	2.3	194.5
1991/92	3.2	31.1	79.1	32.1	12.6	38.7	0.0	0.0	0.0	0.0	0.9	16.3	214.1
1992/93	0.0	21.6	41.9	75.8	23.4	80.0	28.5	0.0	0.0	0.0	0.0	0.7	271.8
1993/94	17.9	42.0	33.2	91.8	95.9	18.5	2.7	0.0	1.6	0.0	0.0	0.0	303.5
1994/95	21.7	7.8	0.5	2.4	116.2	78.2	12.8	5.4	0.0	0.0	0.0	5.1	250.1
1995/96	0.0	18.0	1.6	78.4	73.2	19.6	9.0	0.0	0.0	0.0	0.0	1.3	201.1
1996/97	0.5	25.5	13.0	78.8	55.9	82.2	0.0	1.6	0.0	0.0	0.0	3.6	261.2
1997/98	12.3	0.0	95.6	35.9	7.6	17.5	3.2	0.0	0.0	0.0	0.0	0.0	172.1

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1998/99	0.0	5.4	4.5	45.5	4.8	21.5	0.0	9.1	0.0	0.0	0.0	0.0	90.7
1999/00	6.2	37.7	84.9	34.9	78.6	103.5	4.8	9.8	0.0	0.0	0.0	0.0	360.5
2000/01	0.3	0.4	2.5	119.7	72.7	98.9	129.7	2.1	0.0	0.0	0.0	0.0	426.2
2001/02	3.7	2.2	120.5	7.2	169.4	83.8	15.7	0.0	0.0	0.0	0.0	0.0	402.4
2002/03	0.0	11.7	144.8	32.9	95.5	3.8	136.1	0.0	0.0	0.0	0.2	0.0	425.0
2003/04	15.9	36.2	20.6	141.6	104.2	61.5	35.5	0.0	0.0	0.0	0.0	2.8	418.3
2004/05	37.1	131.5	1.0	103.1	117.9	121.3	55.6	1.8	0.0	0.0	0.0	0.0	569.4
2005/06	0.0	0.0	13.6	257.8	154.3	108.1	100.4	0.0	0.0	0.0	0.0	2.9	637.0
2006/07	9.4	21.4	6.1	49.2	33.8	23.7	39.1	0.0	0.0	0.0	0.0	0.7	183.3
2007/08	0.6	0.0	0.0	213.1	329.9	190.1	7.4	3.0	0.0	0.0	0.0	0.0	744.0
2008/09	32.8	109.0	122.5	84.3	464.5	160.1	1.5	1.3	0.0	0.0	0.0	9.8	985.8
2009/10	12.2	18.4	33.8	181.2	61.6	85.9	13.0	1.5	0.0	0.0	0.0	0.9	408.5
Average	6.2	16.2	26.7	59.6	63.7	66.7	23.6	2.1	0.4	0.1	0.4	0.8	266.4
Median	1.2	7.8	7.5	35.3	35.1	47.9	9.6	0.0	0.0	0.0	0.0	0.0	199.5

Appendix 2

OBSERVED RUNOFF RECORDS

OBSERVED RUNOFF VOLUMES FOR OMBURO HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1973/74	-	-	-	-	-	-	-	-	-	-	-	0.000	**-**
1974/75	0.000	0.000	0.000	0.020	0.095	0.484	0.000	0.000	0.000	0.000	0.000	0.000	**0.599**
1975/76	0.000	0.000	0.079	17.786	17.063	10.450	0.000	0.000	0.000	0.000	0.000	0.000	**45.378**
1976/77	0.000	0.000	0.000	0.000	2.225	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**2.231**
1977/78	0.000	0.000	0.026	4.442	13.500	0.125	0.000	0.000	0.000	0.000	0.000	0.000	**18.093**
1978/79	0.000	0.000	0.000	0.000	7.274	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**7.274**
1979/80	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	**0.009**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	5.288	10.781	9.218	0.448	0.000	0.000	0.000	0.000	0.000	**25.735**
1982/83	0.000	0.000	15.683	0.138	0.024	0.219	0.000	0.000	0.000	0.000	0.000	0.000	**16.064**
1983/84	0.000	0.000	0.000	0.000	26.524	3.020	29.293	0.000	0.000	0.000	0.000	0.000	**58.837**
1984/85	0.000	0.000	0.000	26.778	40.782	0.564	0.017	0.000	0.000	0.000	0.000	0.000	**68.141**
1985/86	0.000	0.000	0.000	4.492	2.607	0.520	0.000	0.000	0.000	0.000	0.000	0.000	**7.619**
1986/87	0.000	0.000	0.000	0.000	18.493	0.542	0.530	0.000	0.000	0.000	0.000	0.000	**19.565**
1987/88	0.066	0.070	0.728	12.588	0.274	0.000	2.334	0.000	0.000	0.000	0.000	0.000	**16.060**
1988/89	0.000	0.980	1.657	0.677	2.590	0.817	0.196	0.000	0.000	0.000	0.000	0.000	**6.917**
1989/90	0.000	0.000	0.000	12.185	2.026	4.936	4.274	0.000	0.000	0.000	0.000	0.000	**23.420**
1990/91	0.000	0.000	0.059	2.783	11.237	1.936	0.000	0.000	0.000	0.000	0.000	0.000	**16.015**
1991/92	0.000	0.302	1.546	1.098	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**2.946**
1992/93	0.000	0.000	0.000	1.815	11.566	2.621	3.788	0.000	0.000	0.000	0.000	0.000	**19.790**
1993/94	0.000	0.000	0.000	12.787	3.552	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**16.339**
1994/95	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.036**
1995/96	0.000	0.000	0.000	6.434	1.074	0.777	0.000	0.000	0.000	0.000	0.000	0.000	**8.286**
1996/97	0.000	0.716	0.163	20.200	11.393	6.545	0.607	0.000	0.000	0.000	0.000	0.000	**39.624**
1997/98	0.000	0.000	2.308	0.128	0.000	0.519	0.000	0.000	0.000	0.000	0.000	0.000	**2.955**
1998/99	0.000	0.000	0.165	0.100	4.676	2.480	0.000	0.000	0.000	0.000	0.000	0.000	**7.420**
1999/00	0.071	0.268	9.968	2.558	9.832	7.812	0.042	0.000	0.000	0.000	0.000	0.000	**30.551**
2000/01	0.000	0.000	0.000	0.000	0.000	2.088	0.000	0.574	0.000	0.000	0.000	0.000	**2.662**
2001/02	0.000	0.000	0.000	0.000	0.006	0.445	0.489	0.000	0.000	0.000	0.000	0.000	**0.940**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.014	0.158	22.128	0.570	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**22.870**
2004/05	0.000	0.019	0.000	3.404	24.277	11.665	0.000	0.000	0.000	0.000	0.000	0.000	**39.365**
2005/06	0.000	0.000	0.000	7.567	7.186	5.239	0.009	0.081	0.000	0.000	0.000	0.030	**20.112**
2006/07	0.027	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.057**
2007/08	0.000	0.619	0.000	0.000	3.228	8.172	0.007	0.000	0.000	0.000	0.000	0.000	**12.026**
2008/09	0.000	0.346	0.244	1.055	31.448	36.084	5.632	0.000	0.000	0.000	0.000	0.000	**74.809**
2009/10	0.000	0.000	0.000	16.810	24.130	10.380	0.000	0.000	0.000	0.000	0.000	0.000	**51.320**
2010/11	0.000	0.000	0.253	60.145	42.060	27.847	34.469	3.366	0.000	0.000	0.000	0.000	**168.140**
Average	0.004	0.090	0.893	6.579	8.933	4.203	2.220	0.109	0.000	0.000	0.000	0.001	**23.033**
Median	0.000	0.000	0.000	1.098	3.228	0.564	0.000	0.000	0.000	0.000	0.000	0.000	**16.060**

Appendix 3

OBSERVED RUNOFF VOLUMES FOR OMARURU HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1964/65	0.000	0.000	0.000	2.834	1.120	3.595	11.152	0.000	0.000	0.000	0.000	0.000	**18.701**
1965/66	0.000	0.000	0.000	31.403	22.624	9.713	8.735	0.000	0.000	0.000	0.000	0.000	**72.475**
1966/67	0.000	0.000	0.000	0.000	16.986	6.042	0.000	0.000	0.000	0.000	0.000	0.000	**23.028**
1967/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1968/69	0.000	0.000	0.000	0.000	0.000	11.225	0.000	0.000	0.000	0.000	0.000	0.000	**11.225**
1969/70	0.000	0.000	0.000	0.000	2.919	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**2.919**
1970/71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1971/72	0.000	0.000	0.000	3.328	0.000	42.088	16.142	0.000	0.000	0.000	0.000	0.000	**61.558**
1972/73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1973/74	0.351	0.000	0.000	34.492	1.947	0.000	1.096	0.000	0.000	0.000	0.000	0.000	**37.886**
1974/75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	29.671	22.696	22.595	0.000	0.000	0.000	0.000	0.000	0.000	**74.962**
1976/77	0.000	0.000	0.000	0.000	3.061	0.198	0.000	0.000	0.000	0.000	0.000	0.000	**3.259**
1977/78	0.000	0.000	0.000	1.425	25.505	0.368	0.000	0.000	0.000	0.000	0.000	0.000	**27.298**
1978/79	0.000	0.000	0.000	0.000	9.277	1.239	0.000	0.000	0.000	0.000	0.000	0.000	**10.516**
1979/80	0.000	0.000	0.000	0.000	0.000	18.408	0.000	0.000	0.000	0.000	0.000	0.000	**18.408**
1980/81	0.000	0.000	1.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.095**
1981/82	0.000	0.000	0.000	5.443	15.260	7.978	0.000	0.000	0.000	0.000	0.000	0.000	**28.681**
1982/83	0.000	0.000	12.287	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**12.287**
1983/84	0.000	0.000	0.000	0.000	13.863	1.553	22.347	0.000	0.000	0.000	0.000	0.000	**37.763**
1984/85	0.000	0.000	0.000	33.636	40.437	3.238	0.000	0.000	0.000	0.000	0.000	0.000	**77.311**
1985/86	0.000	0.000	0.000	23.258	13.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**36.258**
1986/87	0.000	0.000	0.000	0.000	20.887	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**20.887**
1987/88	0.000	0.000	1.528	54.803	0.000	0.000	6.636	0.000	0.000	0.000	0.000	0.000	**62.967**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1989/90	0.000	0.000	0.000	31.470	11.470	22.403	8.291	0.000	0.000	0.000	0.000	0.000	**73.634**
1990/91	0.000	0.000	0.000	5.565	51.903	7.078	0.000	0.000	0.000	0.000	0.000	0.000	**64.545**
1991/92	0.000	0.000	0.000	3.255	1.386	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**4.641**
1992/93	0.000	0.000	0.000	5.745	49.665	16.394	17.596	0.000	0.000	0.000	0.000	0.000	**89.400**
1993/94	0.000	0.000	0.000	28.582	40.915	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**69.497**
1994/95	0.000	0.000	0.000	0.000	1.016	3.606	0.000	0.000	0.000	0.000	0.000	0.000	**4.623**
1995/96	0.000	0.000	0.000	19.102	1.828	1.431	0.000	0.000	0.000	0.000	0.000	0.000	**22.361**
1996/97	0.000	0.000	0.000	0.000	0.000	12.055	0.001	0.000	0.000	-	-	-	**12.056**
1997/98	-	-	-	-	-	-	-	-	-	-	-	-	**0.000**
Average	0.011	0.000	0.452	9.516	11.144	5.794	2.788	0.000	0.000	0.000	0.000	0.000	**28.831**
Median	0.000	0.000	0.000	0.000	1.947	1.239	0.000	0.000	0.000	0.000	0.000	0.000	**19.794**

Appendix 3

OBSERVED RUNOFF VOLUMES FOR ETEMBA HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1967/68	0.000	4.739	3.503	0.417	0.042	14.869	0.715	0.000	0.000	0.000	0.000	0.000	**24.285**
1968/69	0.000	0.000	0.000	0.000	2.903	19.384	0.000	0.000	0.000	0.000	0.000	0.000	**22.287**
1969/70	0.000	0.000	0.000	0.000	11.749	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**11.749**
1970/71	0.000	0.000	0.000	0.000	73.175	8.405	0.942	0.000	0.000	0.000	0.000	0.000	**82.523**
1971/72	0.000	0.000	0.000	8.514	2.169	48.400	2.582	0.000	0.000	0.000	0.000	0.000	**61.665**
1972/73	0.000	0.000	0.000	0.000	0.000	1.048	1.569	0.000	0.000	0.000	0.000	0.000	**2.617**
1973/74	0.000	0.000	0.000	68.330	51.603	8.465	7.766	0.000	0.000	0.000	0.000	0.000	**136.164**
1974/75	0.000	0.000	0.000	0.000	0.000	0.149	0.000	0.000	0.000	0.000	0.000	0.000	**0.149**
1975/76	0.000	0.000	0.000	15.063	24.610	14.785	0.172	0.000	0.000	0.000	0.000	0.000	**54.630**
1976/77	0.000	0.000	0.000	0.000	0.394	0.031	0.056	0.000	0.000	0.000	0.000	0.000	**0.481**
1977/78	0.000	0.000	0.000	0.881	13.879	0.248	0.082	0.000	0.000	0.000	0.000	0.000	**15.090**
1978/79	0.000	0.000	0.000	0.095	6.104	0.638	0.000	0.000	0.000	0.000	0.000	0.000	**6.836**
1979/80	0.000	0.000	0.012	1.231	0.000	6.636	0.001	0.000	0.000	0.000	0.000	0.000	**7.880**
1980/81	0.000	0.000	0.427	0.000	0.000	0.186	0.000	0.000	0.000	0.000	0.000	0.000	**0.613**
1981/82	0.000	0.000	0.000	1.189	5.980	6.669	0.179	0.000	0.000	0.000	0.000	0.000	**14.017**
1982/83	0.000	0.000	9.568	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**9.580**
1983/84	0.000	0.000	0.000	0.000	14.503	1.917	27.155	0.000	0.000	0.000	0.000	0.000	**43.575**
1984/85	0.000	0.000	0.000	28.083	94.752	7.362	0.000	0.000	0.000	0.000	0.000	0.000	**130.197**
1985/86	0.000	0.000	0.000	2.871	4.348	0.836	0.000	0.000	0.000	0.000	0.000	0.000	**8.055**
1986/87	0.000	0.000	0.000	0.000	23.997	0.947	0.334	0.000	0.000	0.000	0.000	0.000	**25.278**
1987/88	0.000	0.000	0.008	27.629	2.390	0.439	3.955	0.000	0.000	0.000	0.000	0.000	**34.420**
1988/89	0.000	0.222	1.725	2.051	6.472	1.125	1.932	0.000	0.000	0.000	0.000	0.000	**13.527**
1989/90	0.000	0.000	0.000	17.199	18.477	37.831	4.449	0.000	0.000	0.000	0.000	0.000	**77.956**
1990/91	0.000	0.000	0.000	2.546	29.845	4.357	0.000	0.000	0.000	0.000	0.000	0.000	**36.748**
1991/92	0.000	0.000	0.000	1.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.172**
1992/93	0.000	0.000	0.000	0.151	5.760	2.301	3.170	0.000	0.000	0.000	0.000	0.000	**11.382**
1993/94	0.000	0.000	0.000	0.000	11.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**11.550**
1994/95	0.000	0.000	0.000	0.000	1.817	2.986	0.000	0.000	0.000	0.000	0.000	0.000	**4.803**
1995/96	0.000	0.000	0.000	1.777	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.777**
1996/97	0.000	0.000	0.000	14.710	2.350	0.151	0.000	0.000	0.000	0.000	0.000	0.000	**17.211**
1997/98	0.000	0.000	0.563	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.563**
1998/99	0.000	0.000	0.000	0.000	0.883	1.217	0.000	0.000	0.000	0.000	0.000	0.000	**2.099**
1999/00	0.000	0.000	19.792	0.000	0.000	62.195	0.000	0.000	0.000	0.000	0.000	0.000	**81.987**
2000/01	0.000	0.000	0.000	0.000	0.000	0.227	0.370	0.000	0.000	0.000	0.000	0.000	**0.597**
2001/02	0.000	0.000	0.000	0.000	0.613	1.095	0.008	0.000	0.000	0.000	0.000	0.000	**1.716**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	1.206	1.136	0.000	0.026	0.000	0.000	0.000	0.000	0.000	**2.368**
2004/05	0.000	0.138	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.138**
2005/06	0.000	0.000	0.000	15.858	3.780	0.000	0.961	0.153	0.000	0.000	0.000	0.000	**20.752**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	67.068	24.438	0.000	0.000	0.000	0.000	0.000	0.000	**91.506**
2008/09	0.000	0.000	0.000	0.000	23.243	88.170	5.846	0.000	0.000	0.000	0.000	0.000	**117.259**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	0.000	13.760	30.070	26.800	15.930	0.801	0.000	0.000	0.000	0.000	**87.361**
2011/12	0.000	0.000	0.000	3.119	2.082	4.867	4.017	4.091	3.894	1.483	0.000	0.000	**23.553**
Average	0.000	0.113	0.791	5.064	11.950	8.871	1.827	0.112	0.087	0.033	0.000	0.000	**28.847**
Median	0.000	0.000	0.000	0.012	2.350	1.048	0.001	0.000	0.000	0.000	0.000	0.000	**11.749**

COMBINED SYNTHESISED AND OBSERVED RUNOFF RECORD FOR ETEMBA / OTJOMPAUE (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1923/24	0.000	0.000	0.000	0.000	4.460	7.490	0.000	0.000	0.000	0.000	0.000	0.000	**11.950**
1924/25	0.000	0.000	0.000	30.040	26.100	56.490	18.710	0.000	0.000	0.000	0.000	0.000	**131.340**
1925/26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1926/27	0.000	0.000	9.820	3.040	0.000	0.000	3.350	0.000	0.000	0.000	0.000	0.000	**16.210**
1927/28	0.000	0.000	0.000	0.800	0.000	1.800	0.710	0.000	0.000	0.000	0.000	0.000	**3.310**
1928/29	0.000	0.000	0.000	2.650	1.180	11.860	0.000	0.000	0.000	0.000	0.000	0.000	**15.690**
1929/30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1930/31	0.000	0.000	0.190	31.630	24.810	13.050	0.000	0.000	0.000	0.000	0.000	0.000	**69.680**
1931/32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1932/33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1933/34	0.000	0.000	42.810	175.940	112.350	162.100	47.540	0.000	0.000	0.000	0.000	0.000	**540.740**
1934/35	0.000	0.000	0.140	2.690	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**2.830**
1935/36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1936/37	0.000	0.000	0.000	8.740	11.520	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**20.260**
1937/38	0.000	0.000	0.000	22.730	1.760	0.000	14.920	0.130	0.000	0.000	0.000	0.000	**39.540**
1938/39	0.000	16.790	0.000	0.000	0.000	17.370	0.000	0.000	0.000	0.000	0.000	0.000	**34.160**
1939/40	0.000	0.000	0.160	9.700	0.160	2.630	0.000	0.000	0.000	0.000	0.000	0.000	**12.650**
1940/41	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1941/42	0.000	0.000	0.000	0.000	41.180	14.260	10.450	0.000	0.000	0.000	0.000	0.000	**65.890**
1942/43	0.000	1.980	25.610	0.000	5.580	7.600	2.530	0.000	0.000	0.000	0.000	0.000	**43.300**
1943/44	0.000	0.000	40.990	66.280	25.520	0.430	0.000	0.000	0.000	0.000	0.000	0.000	**133.220**
1944/45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1945/46	0.000	5.330	12.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**17.820**
1946/47	0.000	0.000	20.120	12.500	32.990	26.530	10.300	0.000	0.000	0.000	0.000	0.000	**102.440**
1947/48	0.000	0.000	0.000	0.000	1.590	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.590**
1948/48	0.000	0.490	0.000	1.350	0.130	58.350	2.330	0.000	0.000	0.000	0.000	0.000	**62.650**
1949/50	0.000	0.210	0.000	59.560	109.100	66.610	16.500	0.000	0.000	0.000	0.000	0.000	**251.980**
1950/51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1951/52	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1952/53	0.000	0.000	0.000	0.000	20.470	1.680	0.000	0.000	0.000	0.000	0.000	0.000	**22.150**
1953/54	0.000	0.000	2.650	1.530	11.580	27.980	0.000	0.000	0.000	0.000	0.000	0.000	**43.740**
1954/55	0.000	0.000	1.520	0.000	1.620	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**3.140**
1955/56	0.000	0.000	0.000	3.060	0.150	1.780	0.000	0.000	0.000	0.000	0.000	0.000	**4.990**
1956/57	0.000	0.000	0.000	1.720	0.110	0.200	0.000	0.000	0.000	0.000	0.000	0.000	**2.030**
1957/58	0.000	1.590	0.000	3.600	1.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**6.510**
1958/59	0.000	0.000	0.000	0.000	1.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.260**
1959/60	0.000	0.000	0.000	0.000	35.310	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**35.310**
1960/61	0.000	0.000	0.000	0.000	1.010	5.030	0.300	0.000	0.000	0.000	0.000	0.000	**6.340**
1961/62	0.000	0.700	0.000	0.000	0.210	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.910**
1962/63	1.170	0.000	0.000	101.110	0.810	73.570	34.170	0.000	0.000	0.000	0.000	0.000	**210.830**
1963/64	0.000	0.000	0.000	0.000	2.310	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**2.310**
1964/65	0.000	0.000	0.000	0.540	0.340	6.200	1.880	0.000	0.000	0.000	0.000	0.000	**8.960**
1965/66	0.000	0.000	0.000	33.000	7.020	14.740	0.530	0.000	0.000	0.000	0.000	0.740	**56.030**
1966/67	0.000	0.000	1.780	0.740	26.710	10.620	0.000	0.000	0.000	0.000	0.000	0.000	**39.850**
1967/68	0.000	4.739	3.503	0.417	0.042	14.869	0.715	0.000	0.000	0.000	0.000	0.000	**24.285**
1968/69	0.000	0.000	0.000	0.000	2.903	19.384	0.000	0.000	0.000	0.000	0.000	0.000	**22.287**

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1969/70	0.000	0.000	0.000	0.000	11.749	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**11.749**
1970/71	0.000	0.000	0.000	0.000	73.175	8.405	0.942	0.000	0.000	0.000	0.000	0.000	**82.523**
1971/72	0.000	0.000	0.000	8.514	2.169	48.400	2.582	0.000	0.000	0.000	0.000	0.000	**61.665**
1972/73	0.000	0.000	0.000	0.000	0.000	1.048	1.569	0.000	0.000	0.000	0.000	0.000	**2.617**
1973/74	0.000	0.000	0.000	68.330	51.603	8.465	7.766	0.000	0.000	0.000	0.000	0.000	**136.164**
1974/75	0.000	0.000	0.000	0.000	0.000	0.149	0.000	0.000	0.000	0.000	0.000	0.000	**0.149**
1975/76	0.000	0.000	0.000	15.063	24.610	14.785	0.172	0.000	0.000	0.000	0.000	0.000	**54.630**
1976/77	0.000	0.000	0.000	0.000	0.394	0.031	0.056	0.000	0.000	0.000	0.000	0.000	**0.481**
1977/78	0.000	0.000	0.000	0.881	13.879	0.248	0.082	0.000	0.000	0.000	0.000	0.000	**15.090**
1978/79	0.000	0.000	0.000	0.095	6.104	0.638	0.000	0.000	0.000	0.000	0.000	0.000	**6.836**
1979/80	0.000	0.000	0.012	1.231	0.000	6.636	0.001	0.000	0.000	0.000	0.000	0.000	**7.880**
1980/81	0.000	0.000	0.427	0.000	0.000	0.186	0.000	0.000	0.000	0.000	0.000	0.000	**0.613**
1981/82	0.000	0.000	0.000	1.189	5.980	6.669	0.179	0.000	0.000	0.000	0.000	0.000	**14.017**
1982/83	0.000	0.000	9.568	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**9.580**
1983/84	0.000	0.000	0.000	0.000	14.503	1.917	27.155	0.000	0.000	0.000	0.000	0.000	**43.575**
1984/85	0.000	0.000	0.000	28.083	94.752	7.362	0.000	0.000	0.000	0.000	0.000	0.000	**130.197**
1985/86	0.000	0.000	0.000	2.871	4.348	0.836	0.000	0.000	0.000	0.000	0.000	0.000	**8.055**
1986/87	0.000	0.000	0.000	0.000	23.997	0.947	0.334	0.000	0.000	0.000	0.000	0.000	**25.278**
1987/88	0.000	0.000	0.008	27.629	2.390	0.439	3.955	0.000	0.000	0.000	0.000	0.000	**34.420**
1988/89	0.000	0.222	1.725	2.051	6.472	1.125	1.932	0.000	0.000	0.000	0.000	0.000	**13.527**
1989/90	0.000	0.000	0.000	17.199	18.477	37.831	4.449	0.000	0.000	0.000	0.000	0.000	**77.956**
1990/91	0.000	0.000	0.000	2.546	29.845	4.357	0.000	0.000	0.000	0.000	0.000	0.000	**36.748**
1991/92	0.000	0.000	0.000	1.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.172**
1992/93	0.000	0.000	0.000	0.151	5.760	2.301	3.170	0.000	0.000	0.000	0.000	0.000	**11.382**
1993/94	0.000	0.000	0.000	0.000	11.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**11.550**
1994/95	0.000	0.000	0.000	0.000	1.817	2.986	0.000	0.000	0.000	0.000	0.000	0.000	**4.803**
1995/96	0.000	0.000	0.000	1.777	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.777**
1996/97	0.000	0.000	0.000	14.710	2.350	0.151	0.000	0.000	0.000	0.000	0.000	0.000	**17.211**
1997/98	0.000	0.000	0.563	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.563**
1998/99	0.000	0.000	0.000	0.000	0.883	1.217	0.000	0.000	0.000	0.000	0.000	0.000	**2.099**
1999/00	0.000	0.000	19.792	0.000	0.000	62.195	0.000	0.000	0.000	0.000	0.000	0.000	**81.987**
2000/01	0.000	0.000	0.000	0.000	0.000	0.227	0.370	0.000	0.000	0.000	0.000	0.000	**0.597**
2001/02	0.000	0.000	0.000	0.000	0.613	1.095	0.008	0.000	0.000	0.000	0.000	0.000	**1.716**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	1.206	1.136	0.000	0.026	0.000	0.000	0.000	0.000	0.000	**2.368**
2004/05	0.000	0.138	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.138**
2005/06	0.000	0.000	0.000	15.858	3.780	0.000	0.961	0.153	0.000	0.000	0.000	0.000	**20.752**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	67.068	24.438	0.000	0.000	0.000	0.000	0.000	0.000	**91.506**
2008/09	0.000	0.000	0.000	0.000	23.243	88.170	5.846	0.000	0.000	0.000	0.000	0.000	**117.259**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	13.760	30.070	26.800	15.930	0.800	0.000	0.000	0.000	0.000	0.000	**87.360**
2011/12	0.000	0.000	0.000	3.119	2.082	4.867	4.017	4.091	3.894	1.483	0.000	0.000	**23.553**
Average	0.013	0.362	2.333	9.181	11.721	10.974	2.599	0.049	0.044	0.017	0.000	0.008	**37.300**
Median	0.000	0.000	0.000	0.012	1.590	0.947	0.000	0.000	0.000	0.000	0.000	0.000	**11.950**

Appendix 3

OBSERVED RUNOFF VOLUMES FOR NEI - NEIS SABRINA HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1985/86	-	-	-	-	-	-	-	-	-	-	0.000	0.000	**0.000**
1986/87	0.000	0.000	0.000	0.000	1.616	0.022	0.000	0.000	0.000	0.000	0.000	0.000	**1.638**
1987/88	0.000	0.000	0.000	7.853	0.000	0.000	0.417	0.000	0.000	0.000	0.000	0.000	**8.270**
1988/89	0.000	0.110	0.000	0.000	0.204	0.000	0.012	0.000	0.000	0.000	0.000	0.000	**0.326**
1989/90	0.000	0.000	0.000	4.465	0.125	1.760	4.169	0.000	0.000	0.000	0.000	0.000	**10.518**
1990/91	0.000	0.000	0.000	0.273	1.050	0.144	0.000	0.000	0.000	0.000	0.000	0.000	**1.467**
1991/92	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.003**
1992/93	0.000	0.000	0.000	0.000	2.276	0.096	0.000	0.000	0.000	0.000	0.000	0.000	**2.372**
1993/94	0.000	0.000	0.000	6.924	7.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**13.962**
1994/95	0.000	0.000	0.000	0.000	0.398	0.000	0.090	0.000	0.000	0.000	0.000	0.000	**0.488**
1995/96	0.000	0.000	0.000	0.000	0.000	0.141	0.051	0.000	0.000	0.000	0.000	0.000	**0.192**
1996/97	0.000	0.000	0.000	30.696	23.413	19.767	0.055	0.000	0.000	0.000	0.000	0.000	**73.931**
1997/98	0.000	0.000	1.470	0.000	0.000	0.000	-	-	-	-	-	-	**1.470**
Average	0.000	0.009	0.123	4.184	3.010	1.828	0.436	0.000	0.000	0.000	0.000	0.000	**8.818**
Median	0.000	0.000	0.000	0.000	0.301	0.011	0.012	0.000	0.000	0.000	0.000	0.000	**1.470**

OBSERVED RUNOFF VOLUMES FOR NEI - NEIS HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1974/75	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	0.616	0.513	0.088	0.182	0.000	0.000	0.000	0.000	0.000	**1.399**
1976/77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1977/78	0.000	0.000	0.000	0.000	2.423	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**2.423**
1978/79	0.000	0.000	0.000	0.000	0.248	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.248**
1979/80	0.000	0.000	0.000	0.000	0.048	1.627	0.000	0.000	0.000	0.000	0.000	0.000	**1.675**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	0.000	0.131	1.366	0.000	0.000	0.000	0.000	0.000	0.000	**1.497**
1982/83	0.000	0.000	1.260	0.146	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.406**
1983/84	0.000	0.000	0.000	0.000	2.993	0.000	9.638	0.000	0.000	0.000	0.000	0.000	**12.631**
1984/85	0.000	0.000	0.000	8.092	3.274	0.465	0.000	0.000	0.000	0.000	0.000	0.000	**11.831**
1985/86	0.000	0.000	0.000	0.148	0.149	0.062	0.128	0.000	0.000	0.000	0.000	0.000	**0.487**
1986/87	0.000	0.000	0.000	0.000	0.498	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.498**
1987/88	0.000	0.000	0.000	1.631	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.631**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.182	0.000	0.000	0.000	0.000	0.000	**0.182**
1989/90	0.000	0.000	0.000	9.416	3.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**12.537**
1990/91	0.000	-	-	-	-	-	-	-	-	-	-	-	**0.000**
Average	0.000	0.000	0.084	1.337	0.837	0.226	0.633	0.000	0.000	0.000	0.000	0.000	**2.850**
Median	0.000	0.000	0.000	0.000	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.399**

Appendix 3

OBSERVED RUNOFF VOLUMES FOR HENTIES MONUMENT HYDROLOGICAL STATION (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1966/67	0.000	0.000	0.000	0.000	20.529	6.950	0.000	0.000	0.000	0.000	0.000	0.000	**27.479**
1967/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1968/69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1969/70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1970/71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1971/72	0.000	0.000	0.000	0.000	0.000	3.976	0.209	0.000	0.000	0.000	0.000	0.000	**4.184**
1972/73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1973/74	0.000	0.000	0.000	22.871	27.771	3.496	0.027	0.000	0.000	0.000	0.000	0.000	**54.165**
1974/75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	0.000	6.982	9.971	0.000	0.000	0.000	0.000	0.000	0.000	**16.953**
1976/77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1977/78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1978/79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1979/80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1982/83	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.200**
1983/84	0.000	0.000	0.000	0.000	1.206	0.002	3.374	0.000	0.000	0.000	0.000	0.000	**4.582**
1984/85	0.000	0.000	0.000	7.899	114.936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**122.835**
1985/86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1986/87	0.000	0.000	0.000	0.000	1.499	0.072	0.000	0.000	0.000	0.000	0.000	0.000	**1.571**
1987/88	0.000	0.000	0.000	0.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.652**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1989/90	0.000	0.000	0.000	1.323	0.008	0.957	0.617	0.000	0.000	0.000	0.000	0.000	**2.904**
1990/91	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1991/92	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Average	0.000	0.000	0.008	1.259	6.651	0.978	0.163	0.000	0.000	0.000	0.000	0.000	**9.059**
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Appendix 3

OBSERVED RUNOFF VOLUMES FOR OMDEL DAM (Mm^3)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1992/93	0.000	0.000	0.000	0.000	0.477	0.036	0.068	0.000	0.000	0.000	0.000	0.000	**0.580**
1993/94	0.000	0.000	0.000	2.334	0.080	0.000	0.000	0.066	0.000	0.000	0.000	0.000	**2.480**
1994/95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1995/96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1996/97	0.000	0.000	0.000	10.851	3.974	0.172	0.000	0.000	0.000	0.000	0.000	0.000	**14.997**
1997/98	0.000	0.000	1.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.603**
1998/99	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1999/00	0.000	0.000	0.000	0.000	0.000	17.755	0.103	0.000	0.000	0.000	0.000	0.000	**17.858**
2000/01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2001/02	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.015	0.000	0.000	0.000	0.000	**0.071**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2004/05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2005/06	0.000	0.000	0.000	0.000	0.000	0.000	0.501	0.000	0.000	0.000	0.000	0.000	**0.501**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	2.454	0.218	0.181	0.000	0.000	0.000	0.000	0.000	**2.853**
2008/09	0.000	0.000	0.000	0.000	1.474	8.949	0.000	0.000	0.000	0.000	0.000	0.000	**10.423**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	0.000	0.000	0.000	0.680	5.036	0.000	0.000	0.000	0.000	0.000	**5.716**
2011/12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2012/13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Average	0.000	0.000	0.076	0.628	0.403	1.324	0.283	0.004	0.000	0.000	0.000	0.000	**2.718**
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Appendix 3

COMBINED HENTIES MONUMENT AND OMDEL DAM RUNOFF RECORD

OBSERVED RUNOFF VOLUMES FOR HENTIES MONUMENT / OMDEL DAM HYDROLOGICAL STATIONS COMBINED (Mm^3)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1966/67	0.000	0.000	0.000	0.000	20.529	6.950	0.000	0.000	0.000	0.000	0.000	0.000	**27.479**
1967/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1968/69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1969/70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1970/71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1971/72	0.000	0.000	0.000	0.000	0.000	3.976	0.209	0.000	0.000	0.000	0.000	0.000	**4.184**
1972/73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1973/74	0.000	0.000	0.000	22.871	27.771	3.496	0.027	0.000	0.000	0.000	0.000	0.000	**54.165**
1974/75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	0.000	6.982	9.971	0.000	0.000	0.000	0.000	0.000	0.000	**16.953**
1976/77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1977/78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1978/79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1979/80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1982/83	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.200**
1983/84	0.000	0.000	0.000	0.000	1.206	0.002	3.374	0.000	0.000	0.000	0.000	0.000	**4.582**
1984/85	0.000	0.000	0.000	7.899	114.936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**122.835**
1985/86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1986/87	0.000	0.000	0.000	0.000	1.499	0.072	0.000	0.000	0.000	0.000	0.000	0.000	**1.571**
1987/88	0.000	0.000	0.000	0.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.652**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1989/90	0.000	0.000	0.000	1.323	0.008	0.957	0.617	0.000	0.000	0.000	0.000	0.000	**2.904**
1990/91	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1991/92	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1992/93	0.000	0.000	0.000	0.000	0.477	0.036	0.068	0.000	0.000	0.000	0.000	0.000	**0.580**
1993/94	0.000	0.000	0.000	2.334	0.080	0.000	0.000	0.066	0.000	0.000	0.000	0.000	**2.480**
1994/95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1995/96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1996/97	0.000	0.000	0.000	10.851	3.974	0.172	0.000	0.000	0.000	0.000	0.000	0.000	**14.997**
1997/98	0.000	0.000	1.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.603**
1998/99	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1999/00	0.000	0.000	0.000	0.000	0.000	17.755	0.103	0.000	0.000	0.000	0.000	0.000	**17.858**
2000/01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2001/02	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.015	0.000	0.000	0.000	0.000	**0.071**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2004/05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2005/06	0.000	0.000	0.000	0.000	0.000	0.000	0.501	0.000	0.000	0.000	0.000	0.000	**0.501**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	2.454	0.218	0.181	0.000	0.000	0.000	0.000	0.000	**2.853**
2008/09	0.000	0.000	0.000	0.000	1.474	8.949	0.000	0.000	0.000	0.000	0.000	0.000	**10.423**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	0.000	0.000	0.000	0.680	5.036	0.000	0.000	0.000	0.000	0.000	**5.716**
2011/12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2012/13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Average	0.000	0.000	0.038	0.977	3.859	1.133	0.216	0.002	0.000	0.000	0.000	0.000	**6.226**
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Appendix 4

SYNTHESISED RUNOFF RECORD

Synthetic Runoff Record for Omdel Dam based on the combined Henties Monument and Omdel Dam Runoff Records (Mm³)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1926/27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1927/28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1928/29	0.000	0.000	0.000	0.730	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.730**
1929/30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1930/31	0.000	0.000	0.000	1.790	4.980	1.050	0.000	0.000	0.000	0.000	0.000	0.000	**7.820**
1931/32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1932/33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1933/34	0.000	0.000	7.490	26.910	16.220	26.930	5.700	0.000	0.000	0.000	0.000	0.000	**83.250**
1934/35	0.000	0.000	0.000	0.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.260**
1935/36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1936/37	0.000	0.000	0.000	0.110	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.260**
1937/38	0.000	0.820	1.300	3.880	6.820	5.980	1.240	0.000	0.000	0.000	0.000	0.000	**20.040**
1938/39	0.000	3.820	0.000	11.610	8.470	25.890	5.280	0.000	0.000	0.000	0.000	0.000	**55.070**
1939/40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1940/41	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1941/42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1942/43	0.000	0.000	0.120	0.310	0.000	0.130	0.200	0.000	0.000	0.000	0.000	0.000	**0.760**
1943/44	0.000	0.000	3.080	11.380	1.640	0.360	0.000	0.000	0.000	0.000	0.000	0.000	**16.460**
1944/45	0.000	0.000	0.000	0.000	0.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.960**
1945/46	0.000	0.150	3.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**3.160**
1946/47	0.000	0.000	2.110	0.130	1.200	0.880	0.240	0.000	0.000	0.000	0.000	0.000	**4.560**
1947/48	0.000	0.000	0.360	5.340	4.410	7.660	0.190	0.000	0.000	0.000	0.000	0.000	**17.960**
1948/49	0.000	0.000	0.000	0.000	0.000	4.230	0.010	0.000	0.000	0.000	0.000	0.000	**4.240**
1949/50	0.000	0.000	0.000	3.490	7.250	5.240	0.110	0.000	0.000	0.000	0.000	0.000	**16.090**
1950/51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1951/52	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.010**
1952/53	0.000	0.000	0.000	0.000	1.270	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.270**
1953/54	0.000	0.000	0.030	0.000	0.840	3.980	0.000	0.000	0.000	0.000	0.000	0.000	**4.850**
1954/55	0.000	0.000	0.190	0.000	0.350	0.130	0.000	0.000	0.000	0.000	0.000	0.000	**0.670**
1955/56	0.000	0.000	0.000	2.590	3.240	2.150	0.250	0.000	0.000	0.000	0.000	0.000	**8.230**
1956/57	0.000	0.000	0.290	0.710	0.120	0.780	0.050	0.000	0.000	0.000	0.000	0.000	**1.950**
1957/58	0.000	0.070	0.190	4.310	0.130	0.100	0.000	0.000	0.000	0.000	0.000	0.000	**4.800**
1958/59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1959/60	0.000	0.580	1.040	0.000	2.460	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**4.080**
1960/61	0.000	0.000	0.990	0.000	0.400	0.990	0.000	0.000	0.000	0.000	0.000	0.000	**2.380**
1961/62	0.000	0.000	0.000	0.000	0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.950**
1962/63	0.000	0.000	0.000	11.150	0.000	14.840	2.970	0.000	0.000	0.000	0.000	0.000	**28.960**
1963/64	0.000	0.000	0.000	0.000	0.140	2.180	0.000	0.000	0.000	0.000	0.000	0.000	**2.320**
1964/65	0.000	0.000	0.000	0.000	0.400	0.230	0.000	0.000	0.000	0.000	0.000	0.000	**0.630**
1965/66	0.000	0.000	0.000	1.540	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	**1.590**
1966/67	0.000	0.000	0.000	0.000	20.529	6.950	0.000	0.000	0.000	0.000	0.000	0.000	**27.479**
1967/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1968/69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1969/70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Appendix 5

1970/71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1971/72	0.000	0.000	0.000	0.000	0.000	3.976	0.209	0.000	0.000	0.000	0.000	0.000	**4.185**
1972/73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1973/74	0.000	0.000	0.000	22.871	27.771	3.496	0.027	0.000	0.000	0.000	0.000	0.000	**54.165**
1974/75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	0.000	6.982	9.971	0.000	0.000	0.000	0.000	0.000	0.000	**16.953**
1976/77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1977/78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1978/79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1979/80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1982/83	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.200**
1983/84	0.000	0.000	0.000	0.000	1.206	0.002	3.374	0.000	0.000	0.000	0.000	0.000	**4.582**
1984/85	0.000	0.000	0.000	7.899	114.936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**122.835**
1985/86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1986/87	0.000	0.000	0.000	0.000	1.499	0.072	0.000	0.000	0.000	0.000	0.000	0.000	**1.571**
1987/88	0.000	0.000	0.000	0.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.652**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1989/90	0.000	0.000	0.000	1.323	0.008	0.957	0.617	0.000	0.000	0.000	0.000	0.000	**2.905**
1990/91	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1991/92	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1992/93	0.000	0.000	0.000	0.000	0.477	0.036	0.068	0.000	0.000	0.000	0.000	0.000	**0.581**
1993/94	0.000	0.000	0.000	2.334	0.080	0.000	0.000	0.066	0.000	0.000	0.000	0.000	**2.480**
1994/95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1995/96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1996/97	0.000	0.000	0.000	10.851	3.974	0.172	0.000	0.000	0.000	0.000	0.000	0.000	**14.997**
1997/98	0.000	0.000	1.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.603**
1998/99	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1999/00	0.000	0.000	0.000	0.000	0.000	17.755	0.103	0.000	0.000	0.000	0.000	0.000	**17.858**
2000/01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2001/02	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.015	0.000	0.000	0.000	0.000	**0.071**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2004/05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2005/06	0.000	0.000	0.000	0.000	0.000	0.000	0.501	0.000	0.000	0.000	0.000	0.000	**0.501**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	2.454	0.218	0.181	0.000	0.000	0.000	0.000	0.000	**2.853**
2008/09	0.000	0.000	0.000	0.000	1.474	8.949	0.000	0.000	0.000	0.000	0.000	0.000	**10.423**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	0.000	0.000	0.000	0.680	5.036	0.000	0.000	0.000	0.000	0.000	**5.716**
2011/12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2012/13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Average	0.000	0.063	0.253	1.519	2.802	1.816	0.304	0.001	0.000	0.000	0.000	0.000	**6.758**
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.501**

Appendix 5

SYNTHESISED RUNOFF RECORD BASED ON THE AMENDED 1984 RUNOFF

Synthetic Runoff Record for Omdel Dam based on the amended combined Henties Monument and Omdel Dam Runoff Records (Mm³)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1926/27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1927/28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1928/29	0.000	0.000	0.000	0.730	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.730**
1929/30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1930/31	0.000	0.000	0.000	1.790	4.980	1.050	0.000	0.000	0.000	0.000	0.000	0.000	**7.820**
1931/32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1932/33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1933/34	0.000	0.000	7.490	26.910	16.220	26.930	5.700	0.000	0.000	0.000	0.000	0.000	**83.250**
1934/35	0.000	0.000	0.000	0.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.260**
1935/36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1936/37	0.000	0.000	0.000	0.110	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.260**
1937/38	0.000	0.820	1.300	3.880	6.820	5.980	1.240	0.000	0.000	0.000	0.000	0.000	**20.040**
1938/39	0.000	3.820	0.000	11.610	8.470	25.890	5.280	0.000	0.000	0.000	0.000	0.000	**55.070**
1939/40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1940/41	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1941/42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1942/43	0.000	0.000	0.120	0.310	0.000	0.130	0.200	0.000	0.000	0.000	0.000	0.000	**0.760**
1943/44	0.000	0.000	3.080	11.380	1.640	0.360	0.000	0.000	0.000	0.000	0.000	0.000	**16.460**
1944/45	0.000	0.000	0.000	0.000	0.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.960**
1945/46	0.000	0.150	3.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**3.160**
1946/47	0.000	0.000	2.110	0.130	1.200	0.880	0.240	0.000	0.000	0.000	0.000	0.000	**4.560**
1947/48	0.000	0.000	0.360	5.340	4.410	7.660	0.190	0.000	0.000	0.000	0.000	0.000	**17.960**
1948/49	0.000	0.000	0.000	0.000	0.000	4.230	0.010	0.000	0.000	0.000	0.000	0.000	**4.240**
1949/50	0.000	0.000	0.000	3.490	7.250	5.240	0.110	0.000	0.000	0.000	0.000	0.000	**16.090**
1950/51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1951/52	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.010**
1952/53	0.000	0.000	0.000	0.000	1.270	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.270**
1953/54	0.000	0.000	0.030	0.000	0.840	3.980	0.000	0.000	0.000	0.000	0.000	0.000	**4.850**
1954/55	0.000	0.000	0.190	0.000	0.350	0.130	0.000	0.000	0.000	0.000	0.000	0.000	**0.670**
1955/56	0.000	0.000	0.000	2.590	3.240	2.150	0.250	0.000	0.000	0.000	0.000	0.000	**8.230**
1956/57	0.000	0.000	0.290	0.710	0.120	0.780	0.050	0.000	0.000	0.000	0.000	0.000	**1.950**
1957/58	0.000	0.070	0.190	4.310	0.130	0.100	0.000	0.000	0.000	0.000	0.000	0.000	**4.800**
1958/59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1959/60	0.000	0.580	1.040	0.000	2.460	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**4.080**
1960/61	0.000	0.000	0.990	0.000	0.400	0.990	0.000	0.000	0.000	0.000	0.000	0.000	**2.380**
1961/62	0.000	0.000	0.000	0.000	0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.950**
1962/63	0.000	0.000	0.000	11.150	0.000	14.840	2.970	0.000	0.000	0.000	0.000	0.000	**28.960**
1963/64	0.000	0.000	0.000	0.000	0.140	2.180	0.000	0.000	0.000	0.000	0.000	0.000	**2.320**
1964/65	0.000	0.000	0.000	0.000	0.400	0.230	0.000	0.000	0.000	0.000	0.000	0.000	**0.630**
1965/66	0.000	0.000	0.000	1.540	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	**1.590**
1966/67	0.000	0.000	0.000	0.000	20.529	6.950	0.000	0.000	0.000	0.000	0.000	0.000	**27.479**
1967/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1968/69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1969/70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Appendix 6

1970/71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1971/72	0.000	0.000	0.000	0.000	0.000	3.976	0.209	0.000	0.000	0.000	0.000	0.000	**4.184**
1972/73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1973/74	0.000	0.000	0.000	22.871	27.771	3.496	0.027	0.000	0.000	0.000	0.000	0.000	**54.165**
1974/75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1975/76	0.000	0.000	0.000	0.000	6.982	9.971	0.000	0.000	0.000	0.000	0.000	0.000	**16.953**
1976/77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1977/78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1978/79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1979/80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1980/81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1981/82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1982/83	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.200**
1983/84	0.000	0.000	0.000	0.000	1.206	0.002	3.374	0.000	0.000	0.000	0.000	0.000	**4.582**
1984/85	0.000	0.000	0.000	7.899	20.940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**28.839**
1985/86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1986/87	0.000	0.000	0.000	0.000	1.499	0.072	0.000	0.000	0.000	0.000	0.000	0.000	**1.571**
1987/88	0.000	0.000	0.000	0.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.652**
1988/89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1989/90	0.000	0.000	0.000	1.323	0.008	0.957	0.617	0.000	0.000	0.000	0.000	0.000	**2.904**
1990/91	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1991/92	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1992/93	0.000	0.000	0.000	0.000	0.477	0.036	0.068	0.000	0.000	0.000	0.000	0.000	**0.580**
1993/94	0.000	0.000	0.000	2.334	0.080	0.000	0.000	0.066	0.000	0.000	0.000	0.000	**2.480**
1994/95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1995/96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1996/97	0.000	0.000	0.000	10.851	3.974	0.172	0.000	0.000	0.000	0.000	0.000	0.000	**14.997**
1997/98	0.000	0.000	1.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**1.603**
1998/99	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
1999/00	0.000	0.000	0.000	0.000	0.000	17.755	0.103	0.000	0.000	0.000	0.000	0.000	**17.858**
2000/01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2001/02	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.015	0.000	0.000	0.000	0.000	**0.071**
2002/03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2003/04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2004/05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2005/06	0.000	0.000	0.000	0.000	0.000	0.000	0.501	0.000	0.000	0.000	0.000	0.000	**0.501**
2006/07	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2007/08	0.000	0.000	0.000	0.000	2.454	0.218	0.181	0.000	0.000	0.000	0.000	0.000	**2.853**
2008/09	0.000	0.000	0.000	0.000	1.474	8.949	0.000	0.000	0.000	0.000	0.000	0.000	**10.423**
2009/10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2010/11	0.000	0.000	0.000	0.000	0.000	0.680	5.036	0.000	0.000	0.000	0.000	0.000	**5.716**
2011/12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
2012/13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Average	0.000	0.063	0.253	1.519	1.722	1.816	0.304	0.001	0.000	0.000	0.000	0.000	**5.677**
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.501**

***1984/85 February reading was amended from 114.936 to 20.936 Mm^3.**

Appendix 6

MASTER DATA FILE INPUT FOR NAMROM

Master.dat file for the original runoff data		
Main answer file	omdel.ans	
Secondary answer file	omdel.sec	
Data/debug file	omdel.dbg	
INFO1 - Synthesized runoff for Omdel catchment		
INFO2 - Run on 25 Oct 2011		
Type of run and debug index (1 OR 0)	4	0
Start and end year of simulation	1923	2009
Start and end year of flow data and number of seasons	1966	2009
Number of antecedent seasons and weight factor	3	1
ARC ratio for	Season 1	0.10
ARC ratio for	Season 2	0.10
ARC ratio for	Season 3	0.10
Number of sub-catchments		4
osub1.new	3265	1
osub2.new	4512	0.70
osub3.NEW	2362	0.42
osub4.new	1314	0.20
XLOSS, and EXP	21.2	0.20
Do you wish to synthesize		Y
Flow file	omdel.flo	

Master.dat file for the 1984/85 amended runoff data		
Main answer file	omdel.ans	
Secondary answer file	omdel.sec	
Data/debug file	omdel.dbg	
INFO1 - Synthesized runoff for Omdel catchment		
INFO2 - Run on 27 Oct 2011		
Type of run and debug index (1 OR 0)	4	0
Start and end year of simulation	1923	2009
Start and end year of flow data and number of seasons	1966	2009
Number of antecedent seasons and weight factor	3	1
ARC ratio for	Season 1	1.74
ARC ratio for	Season 2	1.74
ARC ratio for	Season 3	1.74
Number of sub-catchments		4
osub1.new	3265	1.00
osub2.new	4512	0.74
osub3.new	2362	0.42
osub4.new	1314	0.20
XLOSS, and EXP	18.40	0.10
Do you wish to synthesize		Y
Flow file	omdel.flo	

Appendix 7