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Namibia Water Corporation Ltd. (Nam Water)

Feasibility Study for Desalination Plant and Water Carriage System to secure Water Supply to Central Coast, Windhoek and en-route Users

FS CHAPTER WATER RESOURCES AND WATER DEMAND PROJECTIONS

19/03/2021

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ABBREVIATIONS AND UNITS

amsl	Above Mean Sea Level
/AE//Gams	AE//Gams Networks (Pty) Ltd.
A	Ampere
AC	Alternating Current
AR	Artificial Recharge
ASME	The American Society of Mechanical Engineers
AOC	Assimilable Organic Carbon
ANSI	American National Standards Institute
API	America Petroleum Institute
AU	Africa Union
AWWA	American Water Works Association
/AE//Gams	/AE//Gams Networks (Pty) Ltd.
bgl	Below Ground Level
B	Boron
BH	Borehole
BON	Bank of Namibia
BWMP	Bulk Water Master Plan
c	Capita
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CAJVC	Central Areas Joint Venture Consultants
CA-Model	Central Area Model
CAN	Central Area of Namibia
CBD	Central Business District
CC	Control Centre
CCA	Central Coastal Area
CCWSS	Cabinet Committee on Water Supply Security
CENELEC	European Committee for Electrotechnical Specification
CEO	Chief Executive Officer
Cl	Chlorine or Chloride (Cl^-)
CML	Cement Mortar Lining
CNA	Central Namib Area, also the Central Coastal Area
CNUC	China National Uranium Corporation Limited
CS	Carbon Steel
CSP	Concentrated Solar Power
CoW	City of Windhoek
CSIR	Council for Scientific and Industrial Research

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ABBREVIATIONS AND UNITS (Continued)

D	Pipeline Diameter
DBP	Disinfection By-Products
DC	Direct Current
DI	Ductile Iron
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
DME	Deutsche Meerwasser Entsalzung
DNI	Direct Normal Irradiation
DOC	Dissolved Organic Carbon
DP	Design Pressure
DPR	Direct Potable Reuse
DRWS	Directorate of Rural Water Supply (now the DWSSC)
DWA	Department of Water Affairs
DWSSC	Directorate of Water Supply and Sanitation Coordination (previously the DRWS)
E	Weld Joint Factor
EC	Electrical Conductivity
	Euro Code
ECB	Electricity Control Board
EDG	Emergency Diesel Generator
EDP	Erongo Desalination Plant
EIA	Environmental Impact Assessment
EII	Environmental Impact Identification
EN	European Norms or European Standards
ENWC	Eastern National Water Carrier, also the Grootfontein – Omakato Canal
EPA	Environmental Protection Agency of the United States (US EPA)
EPL	Exclusive Prospecting Licenses
ERC	Erongo Regional Council
EWF	Erongo Water Forum
F	Fluorine or Fluoride (F^-)
	Factor (design or safety)
FAO	United Nations Food and Agriculture Organisation
FBE	Fusion Bonded Epoxy
FoS	Failure of Supply
FY	Financial Year

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ABBREVIATIONS AND UNITS (Continued)

g	Gravitational Acceleration
GAWRP	Gammams Advanced Water Reclamation Plant
GCF	Green Climate Fund
GDP	Gross Domestic Product
GDWQ	Guidelines for Drinking-Water Quality (WHO)
GHI	Global Horizontal Irradiation
GIPF	Government Institutions Pension Fund
GIS	Geographical Information Systems
GNI	Gross National Income
GWWTP	Gammams Waste Water Treatment Plant
ha	Hectare
h/d	Hours per day
hv	Head loss due to friction
HDPE	High Density Polyethylene
HFY	Historical Firm Yield
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
IAP	Interested and Affected Parties
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ILF	ILF Consulting Engineers
IOM	International Organisation for Migration
IP	International Protection
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IPPR	Institute for Public Policy Research
IRP	Integrated Resource Planning
IRR	Internal Rate of Return
ISA	Instrument Society of Automation
ISO	International Organization for Standardisation
ISOE	Institute for Social-Ecological Research
ISUDP	Integrated Spatial Urban Development Plan
ITU	International Telecommunication Union
IUSDF	Integrated Urban Spatial Development Framework
IWA	International Water Association
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resources Management Plan
IWRMPJVN	Integrated Water Resources Management Plan Joint Venture Namibia
JVC	Joint Venture Consultants

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ABBREVIATIONS AND UNITS (Continued)

kℓ	Kilolitres (1 000 litres or cubic metre)
km	Kilometre
km^2	Square kilometre
kg	Kilogram
kg/m^3	Kilograms per cubic metre
ks	Roughness value of pipe internal surface
kPA	Kilo Pascals
kV	Kilo Volt
kVA	Kilo Volt-Ampere
kW	Kilo Watt
kWh	Kilo Watt Hour
K	Potassium
KfW	KfW Development Bank
KWTP	Karibib Water Treatment Plant
	Bulk Modulus
ℓ/bed/d	Litres per bed (hospital) per day
ℓ/c/d	Litres per capita (person) per day
ℓ/d	Litres per day
ℓ/erf/d	Litres per erf per day
ℓ/house/d	Litres per household per day
ℓ/LSU/d	Litres per (equivalent) large stock unit per day
$ℓ/m^2/d$	Litres per square metre per day
ℓ/pupil/d	Litres per pupil per day
ℓ/SSU/d	Litres per (equivalent) small stock unit per day
LAC	Legal Assistance Centre
LAN	Local Area Network
LCE	Lund Consulting Engineers CC
LCOE	Levelised Cost of Energy
LFPR	Labour Force Participation Rate
LSU	Large Stock Unit (equivalent)
LV	Low Voltage
m^2/d	Square metres per day
m^3	Cubic metres
m^3/a	Cubic metres per annum
m^3/d	Cubic metres per day
m^3/h	Cubic metres per hour
$m^3/ha/a$	Cubic metres per hectare per annum
$m^3/ha/d$	Cubic metres per hectare per day

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ABBREVIATIONS AND UNITS (Continued)

m^3/household/h	Cubic metres per household per day
m^3/m	Cubic metres per month
m^3/s	Cubic metres per second (cumec)
mbgl	Metres below ground level
mg/ℓ	Milligrams per litre (also parts per million)
mm	Millimetres
mm/a	Millimetres per annum
mm/d	Millimetres per day
mS/m	MilliSiemens per metre (a measure of electrical conductivity)
m/s	Metres per second
mwh	Metres Water Head
Mg	Magnesium
Mℓ/d	Mega (million) litres per day
Mm^3	Million cubic metres
Mm^3/a	Million cubic metres per annum
Mm^3/km^2/a	Million cubic metres per square kilometre per annum
Ma	Million years
MAOP	Maximum Allowable Pressure
MAP	Mean Annual Precipitation
MAR	Managed Aquifer Recharge also Mean Annual Runoff
MAWLR	Ministry of Agriculture, Water and Land Reform (previously the MAWF and before that the MAWRD)
MAWRD	Ministry of Agriculture, Water and Rural Development (now the MAWLR)
MDF	Maximum Design Flow
MET	Ministry of Environment and Tourism
MIC	Middle Income Country
MoHSS	Ministry of Health and Social Services
MME	Ministry of Mines and Energy
MN$	Million Namibian Dollars
MNF	Minimum Night Flow
MPa	Mega Pascals
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
MV	Medium Voltage
MW	Mega Watt
MWh	Mega Watt hours

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ABBREVIATIONS AND UNITS (Continued)

ηg/ℓ	Nanograms per litre (also parts per trillion)
n.d.	No date
nm	Nanometre
N$	Namibian Dollar
N	Nitrogen
Na	Sodium
NamPower	The Namibian Power Corporation Ltd
NamWater	The Namibian Water Corporation Ltd.
NBC	Namibian Broadcasting Corporation
NDP	National Development Plan(s)
NGWRP	New Goreangab Water Reclamation Plant
NHE	National Housing Enterprise
NHIES	Namibia Household Income and Expenditure Survey
NMS	Namibia Meteorological Service
NPC	National Planning Commission
NPSH	Net Positive Suction Head
NRA	National Resource Accounts
NRW	Non-Revenue Water
NSA	Namibia Statistics Agency
NRW	Non-Revenue Water
NTU	Nephelometric Turbidity Units
NUST	Namibia University of Science and Technology
NWQG	Namibia Water Quality Guidelines
NWQS	Namibia Water Quality Standard
OGWRP	Original or Old Goreangab Water Reclamation Plant
OOTP	Office of the President
ORA	Omaruru River Aquifer
ORASECOM	Orange-Senqu River Commission
pH	Percentage Hydrogen (measure of acidity or alkalinity)
Pa	Pascals
P	Pressure
PI	Performance Indicators
PID	Pump Installation Depth
PLC	Programmable Logic Controller
PS	Power Supply
PSC	Project Steering Committee
PPP	Public Private Partnership
PV	Photo-Voltaic
Q	Flow rate

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ABBREVIATIONS AND UNITS (Continued)

r	Correlation coefficient
rpm	Revolutions Per Minute
Re	Reynolds Number
REFIT	Renewable Energy Feed-in Tariff
RMU	Ring Main Unit
RO	Reverse Osmosis
s.l.	sensū latō (in the broad sense)
s.n.	sine nōmine (without a name)
$S0_4$	Sulphate
S	Applicable Allowable Stress Value
SADC	Southern African Development Community
SANS	South African National Standards (previously SABS: South African Bureau of Standards)
SCADA	Supervisory Control and Data Acquisition
SCE	Seelenbinder Consulting Engineers CC
SMYS	Specified Minimum Yield Strength
SI	International System of Units
SPC	Stubenrauch Planning Consultants
SSU	Small Stock Unit
STC	Standard Test Conditions
SWRO	Seawater Reverse Osmosis
t	Wall Thickness
T	Temperature
TCE	Technical Committee of Experts
TCS	Telecommunication System
ToR	Terms of Reference
µg/ℓ	Micrograms per litre (also parts per billion)
UD	Urban Dynamics
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCOWHC	UNESCO World Heritage Centre
UPS	Uninterruptible Power Supply
US EPA	U.S. Environmental Protection Agency
UV	Ultra Violet
USA	United States of America
US$	United States Dollar
UWTC	Ujams Wastewater Treatment Company
UWTP	Ujams Wastewater Treatment Plant

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ABBREVIATIONS AND UNITS (Continued)

v	Velocity
V	Volt
VAT	Value Added Tax
VBWTP	Von Bach Water Treatment Plant
VFD	Variable Frequency Drive
VSD	Variable Speed Drive
VDE	Association of German Electrical Engineers
VDI	Association of German Engineers
WAJVC	Windhoek Aquifer JV Consultants
WAS	Water Augmentation Study, being the Pre-Feasibility Study into the Augmentation of Water Supply to the Central Area of Namibia and the Cuvelai
WASH	Water, sanitation and hygiene
WDM	Water Demand Management
Wingoc	Windhoek Goreangab Operating Company
WHO	World Health Organisation
WGII	Working Group II of the Intergovernmental Panel on Climate Change
WL	Water Level
WM	Water Meter
WMARS	Windhoek Managed Aquifer Recharge Scheme
WRMA	Water Resources Management Act (Namibia), Act No. 11 of 2013
WSASP	Water Supply and Sanitation Policy
€	Euro
$	Dollar
Ø	Diameter
%	Percent (also percentile)
°C	Degrees Centigrade

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APPENDICES

Appendix 1: Central Coastal Area
Appendix 2: Central Area of Namibia
Appendix 3: En-Route Users
Appendix 4: Water Demands Assessment and Projections Approvals
Appendix 5: Comment Resolution Sheets

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EXECUTIVE SUMMARY

E1 INTRODUCTION

E1.1 The Need for and Importance of Water Augmentation

Both the CCA and the area around Windhoek (as a portion of the CAN) are strategically important areas within Namibia, in terms of their contribution to the national economy, including employment provision, but in terms of other aspects as well. The CCA, with the Walvis Bay harbour, represents a major gateway, transportation and logistics hub for Namibia and neighbouring countries, whilst Windhoek represents the commercial, economic, political and administrative hub of the country. Windhoek has a good reputation as a regional and international conference venue and a clean and orderly city, with good quality infrastructure, including drinkable tap water. The Hosea Kutako International Airport outside Windhoek is the main point of entry for international and many regional visitors to the country.

In both the CCA and the CAN, water demands have surpassed the capacity of the local conventional water sources and unconventional water sources have been part of the supply mix for some time already. Under this Feasibility Study, it is foreseen that future water deficits, being water demands in excess of the capacity of existing and locally available sources, will be met with desalinated seawater. As a further option, desalinated seawater may also be transferred to Botswana's capital, Gaborone.

Water demands in both the CCA and CAN are currently limited by the capacity of existing and local sources and sustainable, reliable supply augmentation is badly needed to ensure the continued growth and development of these important areas.

In most urban centres in these areas, there is also a need to expand and improve the provision of water supply and particularly sanitation services to informal settlements, which represents a significant latent water demand.

E2 PROJECT AREAS AND SUPPLY SCENARIOS

E2.1 Project Areas

The Project Area entails four large demand areas, namely:

1. The Central Coastal Area (CCA):
   - The large local authorities of Swakopmund, Walvis Bay, Arandis, Henties Bay; other smaller domestic users; the large uranium mines such as the Rössing, Husab and Langer Heinrich Mines,
2. En-route users:
   - Usakos, Omaruru;

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3. A portion of the Central Area of Namibia (CAN):
   - Windhoek, Okahandja, Karibib and various other users[1];
4. Botswana:
   - For the Botswana supply option, a 20 Mm^3/a supply requirement was applied per the ToR.

E2.2 Supply Scenarios

The four project areas have been combined into three basic supply options as specified in the ToR;

1. Supply Scenario 1: Central Coastal Area (SS1 = CCA);
2. Supply Scenario 2: Central Coastal Area, a portion of the Central Area of Namibia, being the area mainly around Windhoek, and the en-route users (SS2 = CCA + CAN + ER);
3. Supply Scenario 3: Central Coastal Area, a portion of the Central Area of Namibia, being the area mainly around Windhoek, and the en-route users as well as Botswana (SS3 = CCA + CAN + ER + Bots).

E3 WATER RESOURCES ASSESSMENT AND WATER DEMAND PROJECTIONS

E3.1 Assessment of Water Resources and Projection of Water Demands

The capacity of existing and local sources were investigated, including the current efficiency of water use (where data allowed, typically on the basis of sustainable yields from the various groundwater and surface water sources). In the case of unconventional sources such as water reuse, best estimates of plant capacity were used.

Based on these analyses, and including consideration of the various factors which influence water demands, various scenarios for the demand projections for the Planning Horizon (up to 2049/50) were prepared for the CAN, CCA and en-route users. These water demand projections for the existing demand nodes were typically divided into low, likely and high scenarios and included considerations of the expected population growth, including urbanisation; future developments and took cognisance of the legal, economic and demographic situation of the Project Area. Separate scenarios were developed for potential future development nodes where applicable, specifically for the large uranium mines in the CCA and for major developments around Windhoek.

[1] This project considered the supply of users downstream of the Von Bach Water Treatment Plant only, as well as the Swakoppoort Dam sub-system. Although Karibib and Otjimbingwe are geographically located in the area of the en-route users, they were included in the modified portion of the Central Area of Namibia in order to correspond with the approach following with previous feasibility studies for water supply to the CAN.

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These demand projections included proposals for improving the efficiency of water use where applicable. Water reuse was also considered; in some instances in terms of a reduction in the projected water demands, but in Windhoek, as part of the supply-side assessment.

Where the projected water demands exceed the sustainable capacities of existing and potential resources, which is in all project areas before 2049/50, supply deficits are generated. These water deficits are assumed to equate the desalination requirement to the different demand nodes.

The initial demand projections were “workshopped” with NamWater, following which the amendments requested by NamWater were affected and the revised projections were provided to representatives of the major local authorities in the Project Area for consideration.

Following a discussion and review of these projections, approval for their use was obtained from the local authorities in the CCA and Windhoek, which demand projections were thus termed the “Client’s Recommendation”. Similarly, different scenarios for the utilisation of the existing and local water resources were prepared and submitted to NamWater for consideration. The combination of water demand scenarios and resource utilisation options resulted in a range of water deficit projections for each of the major demand areas in the Project Area; the CCA, CAN and En-route users.

E3.1.1 Central Coastal Area

Water demand projections for the existing domestic and local authority-type users were generated for low, likely and high scenarios. Five different scenarios for the mining water demands, overwhelmingly dominated by uranium mines, were prepared, varying from no supply for the mines to 100% of projected supply to all currently established mines, including Trekkopje Mine. A total of fifteen demand scenarios were thus generated.

Two water supply options, comprising of groundwater supply from the Kuiseb and Omdel Aquifers, based on the sustainable and expected future yields of these aquifers, were generated. The Client recommended a total sustainable groundwater yield of 12.0 Mm^3/a.

The water deficit, in this case representing the total desalination requirement, was determined as the difference between the future water demands and supply and is summarised in Table E1.

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Table E1: Summary of Demand and Deficits for the Central Coastal Area

Date	Central Coastal Area Water Demands and Deficits (Mm^3/a)			
	Mining Water Demand	Non-Mining Water Demand	Total Water Demand	Water Deficit
2018	10.63	12.87	23.50	11.50
2020	11.31	13.75	25.07	13.07
2025	15.67	16.01	31.68	19.68
2030	18.00	18.46	36.47	24.47
2035	18.00	21.19	39.19	27.19
2040	18.00	23.85	41.85	29.85
2045	18.00	26.83	44.83	32.83
2050	18.00	30.20	48.20	36.20

Notes:
1. The Mining Water Demand in the Central Coastal Area includes the water demands of Rössing Uranium, Husab Mine (Swakop Uranium) and Langer Heinrich Mine per the M2 option selected by NamWater.

E3.1.2 Central Area of Namibia

Water demand projections for the existing consumers were generated for low, likely and high scenarios. The master / development plans available for the major developments, being the Elisenheim, Brakwater, Ongos and Monte Christo developments to the north of Windhoek, are regarded by NamWater as overly conservative in terms of their projected future development / water demands. Four development scenarios for these major developments were prepared, varying from no development to a large extent of development, but not the full development / water demand provided in the master / development plans. A total of twelve demand scenarios were thus generated.

Given the complex water supply situation in the CAN (including reuse, surface water and groundwater sources), various supply options were generated, with further options arising from a combination of individual supply options. A total of sixteen water supply combinations were generated. The Client's recommended water supply scenario represented a total of 39 Mm^3/a of supply from a variety of sources by 2049/50, against a 2049/50 water demand of 69 Mm^3/a.

The water deficit, in this case representing the total desalination requirement is summarised in Table E2.

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Table E2: Summary of Demand and Deficits for the Central Area of Namibia, En-Route Users and Botswana

Date	All values in Mm³/a					
	CAN				En-Route	Botswana
	Mining Water Demand	Non-Mining Water Demand	Total Water Demand	Water Deficit	Water Demand	Water Deficit
2018	1.28	25.53	26.81	0.00	0.70	0.00
2020	1.75	27.16	28.91	1.06	0.72	0.00
2025	1.93	32.35	34.29	4.66	0.84	0.00
2030	1.95	40.33	42.28	10.77	1.03	0.06
2035	1.97	52.37	54.34	20.83	1.32	2.26
2040	2.00	60.75	62.75	27.63	1.86	12.38
2045	2.03	64.55	66.58	29.72	2.33	19.31
2050	2.07	66.70	68.77	30.04	2.54	20.00

Notes:
1. The Mining Water Demand in the CAN includes the water demand of the Otjihase Mine and that of the Swakoppoort Raw Water component; Okongava and Navachab Gold Mine (QKR) per the option selected by NamWater.
2. No mining demand was envisaged for the En-route users, although the possibility of future water use incorporating some form of mining use cannot be entirely eliminated.
3. The Terms of Reference for this Study specify that 20 Mm^3/a is to be transferred from Windhoek towards Gaborone, but does not state the nature of this water use. This water demand is assumed to be for Non-Mining use.

E3.1.3 En-Route Users

Water demand projections for the existing consumers were generated for low, likely and high scenarios. Potential demands or demand nodes arising from the transfer pipeline were incorporated, representing direct users along the pipeline and the potential for a development corridor to become established. Three scenarios were generated for these potential demands, resulting in a total of nine demand scenarios.

Water supply options, comprising of groundwater supply from the Omaruru Aquifer and Usakos boreholes, were based on the best available estimates of the yields from these groundwater sources.

The water deficit, in this case representing the total desalination requirement is summarised in Table E2.

E3.1.4 Botswana

The total desalination supply requirement for this supply node is specified in the ToR and summarised in Table E2. It was assumed that this supply would develop per an S-Curve up to the specified 20 Mm^3/a by 2049/50 and would only start in in 2028/29.

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E3.2 Supply for Possible Irrigation Use

The possibilities of using desalinated water for irrigation were investigated, largely based on the document entitled "*Erongo Coast to Omaruru Agriculture Development Corridor"* provided by the Erongo Water Forum during consultations with them and the Erongo Regional Council. The water demands and unit costs and benefits of this proposal were assessed. This assessment showed that crop irrigation with desalinated water, which is over 100 times more costly than current irrigation water in Namibia, cannot be economically viable unless the cost of water is almost fully subsidised by the Namibian Government. In the context of a struggling economy and the government being heavily indebted, this is unlikely to be possible, and in the context of very low value addition per cubic metre of water used, this would be economically unwise.

It is therefore proposed that for the purposes of this Study, it is assumed that desalinated water will not be supplied for irrigation use. Should the ERC or others wish to pursue plans to develop irrigation projects in the Erongo Region, it is recommended that semi-purified water (treated domestic effluent) be used for irrigation purposes. In this respect, consideration should be given to following the "Israeli model" of water supply, which relies on the augmentation of conventional resources with desalinated brackish and seawater for potable supply, together with treated sewage for agricultural use. The Outapi project under the CuveWaters initiative can serve as a Namibian example of the use of treated domestic sewage for irrigation purposes.

E3.3 Summary of Water Deficits per Supply Scenario

The water deficits derived for the four project areas were combined into the three supply scenarios defined in the ToR and above, namely:

1. Supply Scenario 1: Central Coastal Area (SS1 = CCA);
2. Supply Scenario 2: Central Coastal Area, the Central Area of Namibia and the en-route users (SS2 = CCA + CAN + ER);
3. Supply Scenario 3: Central Coastal Area, the Central Area of Namibia and the en-route users as well as Botswana (SS3 = CCA + CAN + ER + Bots).

A summary of the total desalination requirement for SS1 is provided in Table E3. This amount is equivalent to the deficit / total desalination supply requirement of the CCA.

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Table E3: Water Deficits for the Central Coastal Area

Date	Water Deficits in the Central Coastal Area for SS1 (Mm3/a)		
	Mining Deficit	Non-Mining Deficit	SS1 Total Deficit
2018	10.63	0.87	11.50
2020	11.31	1.75	13.07
2025	15.67	4.01	19.68
2030	18.00	6.47	24.47
2035	18.00	9.19	27.19
2040	18.00	11.84	29.85
2045	18.00	14.83	32.83
2050	18.00	18.19	36.20

Notes:
1. SS1 = Supply Scenario 1.
2. At present, NamWater supplies the mines with desalinated water and the local authority areas and other non-mining demands are supplied with groundwater at a set rate by NamWater, whereafter additional supply is from desalinated water. In line with this approach of NamWater, the option of groundwater supply selected by NamWater, S_2, at 12.0 Mm^3/a was allocated to the Non-Mining Water demands, as is currently the case, to derive the water deficits. The water demands of the mines equates to a deficit as the current supply from the Erongo Desalination Plant is not included in the supply volume, in order to derive a total deficit of desalinated water.

A summary of the total desalination requirement for SS2 and SS3 is provided in Table E4.

Table E4: Summary of Water Deficits for Supply Scenarios 2 and 3

Date	Water Deficit Values in Mm^3/a						
	Water Deficits for SS2			Botswana[5]	Water Deficits for SS3		
	Mining Deficit	Non-Mining Deficit	SS2 Total Deficit		Mining Deficit	Non-Mining Deficit	SS3 Total Deficit
2018	10.63	1.03	11.67	0.00	10.63	1.03	11.67
2020	12.01	2.29	14.30	0.00	12.01	2.29	14.30
2025	17.60	7.03	24.63	0.00	17.60	7.03	24.63
2030	19.95	15.77	35.72	0.06	19.95	15.83	35.78
2035	19.98	28.83	48.80	2.26	19.98	31.09	51.06
2040	20.00	38.79	58.79	12.38	20.00	51.17	71.17
2045	20.03	44.30	64.33	19.31	20.03	63.61	83.64
2050	20.07	48.17	68.24	20.00	20.07	68.17	88.24

Notes:
1. Botswana. The Terms of Reference for this Study specify that 20 Mm^3/a is to be transferred from Windhoek towards Gaborone, but does not state the nature of this water use. This water demand is assumed to be for Non-Mining use.
2. The water deficits = The difference between the Client's recommended water demand projections and the Client's recommended supply scenario for each are / supply scenario.
3. Refer to the main report for the derivations of the water deficits for the mining and non-mining categories.

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E4 DEMOGRAPHIC AND SOCIO-ECONOMIC FRAMEWORK CONDITIONS

A number of demographic and socio-economic factors were assessed, with findings that Namibia's population is still growing overall, but more so in urban areas, with higher rates of growth in urban areas than in rural areas. Population growth rates in the Khomas and Erongo Regions, which cover most of the Project Area inside Namibia, have exceeded the national average since 2001. These two regions are highly urbanised, with 92% and 95% of their respective populations residing in urban areas. In the Otjozondjupa Region, the third region included in the Namibian Project Area, two thirds of the population are in urban centres (2016 estimates).

Measured by household consumption, the Khomas Region, most of whose characteristics can be attributed to Windhoek, is the wealthiest region in the country, followed by the Erongo Region, with both regions featuring household consumption well above the national average (twice the national average in the Khomas Region and 1,5 times the national average in the Erongo Region). The Otjozondjupa Region is the sixth wealthiest in the country, with household consumption marginally below the national average.

Although the Khomas and Erongo Regions are the wealthiest in the country, high levels of income inequality are prevalent in Namibia. With economic growth having slowed markedly since 2015/16, and following layoffs as a result of the contracting economy, poverty and inequality may have increased in the period since. Overall, therefore, the affordability of desalinated water, particularly in informal settlements, but elsewhere as well, is a concern.

E5 LEGAL AND POLICY FRAMEWORK OF THE NAMIBIAN WATER SECTOR

The Namibian water sector falls under the portfolio of the Ministry of Agriculture, Water and Land Reform (**MAWLR**). The implementation of an envisaged desalination plant and a water carriage system from the coast to the central areas of Namibia will involve other ministries, most notably the Ministry of Fisheries and Marine Resources, the Ministry of Works and Transport, the Ministry of Environment & Tourism, the Ministry of Land Reform as well as the Ministry of Urban and Rural Development.

A number of pieces of legislation have a bearing on the various components envisaged by this Feasibility Study and important recommendations are provided should NamWater wish to pursue this project as a public private partnership project under the Public Private Partnership Act 4 of 2007.

However, an important concern regarding the wider water sector in Namibia is the fact that the Water Act from 1956 is still the legally valid legislation, despite being badly outdated. The appointment of the Water Advisory Council and the Water Regulator, even though these bodies are not functioning, and the distribution of the "draft" water quality regulations, the Namibia Water Quality Standards and the Namibia Water Quality Guidelines, under the Water Resources Management Act (WRMA), 11 of 2013 which is not yet

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an applicable law, creates a “grey area” in terms of day to day operations in the water sector. Of even greater concern is that the Omaruru Basin Management Committee and the Upper Swakop Basin Management Committee have been “properly constituted” BMCs under Section 20 of the WRMA, 11 of 2013, even though this not a valid piece of legislation. It is therefore recommended that the MAWLR determines by Government Notice in the Government Gazette the commencement of the Act. This should be done even if the Regulations are not yet finalised.

E6 WATER SUPPLY FRAMEWORK AND BOUNDARY CONDITIONS

Water supplied by NamWater, including that distributed by the Directorate of Water Supply and Sanitation Coordination and local authorities, is supplied against a tariff, and there is no provision of a free basic quantity of water, as is the case in South Africa. End users typically pay a monthly rate which may include a connection and / or water meter fee and a volumetric tariff based on the volume of water used in a given period.

Many local authorities supply water at a relatively low tariff for a minimum “lifeline” volume, with progressively increasing rates for increasing consumption, in what is referred to as a block tariff structure (Heyns et al., 1998).

In the CCA, NamWater operates under the principle that desalinated water is supplied to the uranium mines and groundwater is supplied to the local authority and small consumers (for example along the Omdel – Swakopmund Pipeline). This should be understood in the context of billing / water tariffs, as in reality, the water which reaches Swakopmund and which is thus supplied to the town and the uranium mines consists of a physical mix of groundwater from the Omdel Aquifer and desalinated water from the Erongo Desalination Plant.

Where desalinated water is to be supplied to local authority areas (towns and cities), it is currently proposed that desalinated water will be supplied into the same terminal groundwater reservoirs used for this purpose by NamWater, or if necessary additional reservoirs, for supply to the local authority areas within the Project Area.

The costs of the infrastructure to be proposed under this Feasibility Study are such that a re-assessment of the relationship between costs and tariffs will be required on the part of NamWater and / or the owner / operator of the infrastructure proposed, possibly in the wider water sector in Namibia as well.

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E7 CONCLUSIONS AND RECOMMENDATIONS

E7.1 Conclusions and Recommended Deficit or Augmentation Volumes

Water demands in both the CCA and CAN are currently limited by the capacity of existing and local sources and sustainable, reliable supply augmentation is badly needed to ensure the continued growth and development of these important areas. In most urban centres in these areas, there is also a need to expand and improve the provision of water supply and particularly sanitation services to informal settlements, which represents a significant latent water demand.

The recommended water deficits for 2050 are expected to be 36.20 Mm^3/a in the CCA, 30.04 Mm^3/a in the CAN and 2.00 Mm^3/a for the En-Route users. The transfer of some 20 Mm^3/a to Gaborone is to be investigated per the ToR. These deficits for 2050 have been combined according the specified project options as follows:

1. Supply Scenario 1: CCA: 36.20 Mm^3/a
2. Supply Scenario 2: CCA + CAN + ER: 68.24 Mm^3/a
3. Supply Scenario 3: CCA + CAN + ER + Bots: 88.24 Mm^3/a

E7.2 Recommendations Regarding Further Investigations

Should further projects or investigations regarding desalinated seawater emanate from this Feasibility Study, it is strongly recommended that:

- The water demands be re-assessed on the basis of the expected unit costs derived from the outcome of this Study and that the water demand projections provided and the planning and implementation of augmentation schemes be reviewed and updated at least once every 4 to 5 years;
- NamWater should update or replace their CA-Model with an appropriate yield / planning model which provides sufficient functionality to be able to analyse different options for incorporating desalinated seawater into the CAN supply system, and then conduct such analyses.

E7.3 Additional Implementation Measures

Apart from the source (desalination) options, other measures which can be implemented by the stakeholders associated with this Study include:

- Short-term (±5 years):
    - All local authorities should conduct full non-revenue water and leakage benchmarking exercises to ascertain the level of NRW in their jurisdiction and draw up plans and budgets for addressing these;

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- The MAWLR should by Government Notice in the Government Gazette publish the commencement of the Water Resources Management Act, 11 of 2013;
- The MAWLR should finalise and publish the necessary regulations which are to accompany the Water Resources Management Act, 11 of 2013;
- The MAWLR should finalise the establishment of the Water Regulator, which should establish and publish a tariff setting policy for Namibia;
- NamWater should finalise investigations into the treatment of the Swakoppoort Dam water, the supply of water to Uis, and the supply of water from Abenab Mine / Karst III Aquifer;
- The CoW should finalise investigations into the water quality requirements for artificial recharge of the Windhoek Aquifer, the further treatment of reclaimed water for artificial recharge and the planning of an additional DPR facility for Windhoek;
- The CoW, together with the TCE and NamWater also need to decide whether or not, and to what possible extent, further development of the WMARS project will proceed;
- The Walvis Bay Municipality should finalise their planning for the implementation of direct potable reclamation;

- Medium-term (approximately 5 to 15 years):
  - The most appropriate medium-term options for supply are to be implemented (these are still to be confirmed under a separate feasibility study being undertaken by the TCE);
  - Water reclamation facilities are to be constructed and commissioned in Windhoek (additional) and Walvis Bay;
  - Supply from Abenab Mine / Karst III Aquifer: This supply option is currently under investigation by NamWater with the intention that it be implemented, following a development proposal / feasibility investigation by NamWater in 2014 (NamWater, 2014). Greater confidence in the potential of this resource is urgently needed, either on the basis of groundwater modelling, test pumping or utilisation thereof. It is recommended that the outcomes of any of these measures continue to inform and perhaps lead to revisions to the overall supply strategy;
  - The outcomes of this Feasibility Study would need to be implemented if desalinated water is to be supplied under any supply scenario.

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1 INTRODUCTION AND PROJECT OVERVIEW

1.1 Introduction

1.1.1 Project Background

Between 2013 and 2017, the Ministry of Agriculture, Water and Land Reform (**MAWLR**) conducted an investigation into the augmentation of water supply to the Central Area of Namibia (**CAN**) from the Okavango River as a long-term water supply strategy. This investigation proposed a two-pronged approach; a medium-term strategy based on the upscaling and increased efficiency of existing sources and schemes, and a long-term supply strategy. In terms of the latter, the Okavango River and the desalination of sea water were identified as viable alternatives[2]. Whilst the desalination of seawater was investigated, this was, within the scope of that project, not conducted to the same level of detail as the investigation into the supply of water from the Okavango River. That study consequently recommended that the desalination supply option be investigated on a comparable basis to that of the Okavango River supply option in order that more than one alternative for long-term water supply to the CAN (as at the time) be investigated. This could become an important consideration should Namibia apply to an international financial institution who had signed up to these principles for the funding of a proposed scheme from the Okavango River (LCE-SCE JV, 2017).

In recognition of the above, under the German-Financial Co-operation with Namibia, between the MAWLR and the German Development Bank, KfW, a rapid assessment of the desalination options for Namibia was carried out in 2016, with the support of KfW. This assessment culminated in A Preparatory Study Report for Policy Level Strategy ("the Rapid Assessment") dated August 2016 (BCT and DME, 2016).

This "Rapid Assessment" of desalination options formed the basis of the consulting services for which a prequalification process was launched, under Bid Ref. No. SC/OIB/NW-01/2018, by NamWater, with the support of KfW, in August 2017. A number of bidders submitted Expressions of Interest by the closing date of 06 October 2017, including a consortium of lead by ILF Consulting Engineers (**ILF**). In November 2017, NamWater informed bidders of the five consortia, including ILF who had been shortlisted or prequalified for the project bid.

[2] This was before the design of the Neckartal Dam was completed and the requisite information from that project became available.

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The Terms of Reference (ToR) for Bid Ref. No. SC/OIB/NW-01/2018, based on the 2016 "Rapid Assessment" of desalination options, as well as the Conditions of Tender, were provided to the shortlisted or prequalified consortia in December 2017. A non-compulsory Pre-Bid Meeting was held on 20 and 21 February 2018, following which the bids were due to close on 19 March 2018. On the extended closing date of 29 March 2018, four of the shortlisted consortia submitted separate Technical and Financial Proposals.

On 21 May 2018, NamWater announced the results of the evaluation of the technical proposals received and opened the financial proposals of the three qualifying bidders, including that of ILF. Following the evaluation of the financial proposals and the completion of the tender evaluation procedures, NamWater in a notice dated 10 September 2018, notified ILF that their consortium was selected for the award of Bid Ref. No. SC/OIB/NW-01/2018. Thereafter, NamWater invited ILF to contract negotiations, which took place on 06 and 07 December 2018, following which the consultancy contract between NamWater and ILF was concluded.

The contract arrangements between NamWater and ILF commenced on 01 January 2019, but the consulting services commenced on 26 February 2019.

1.1.2 Project Objective

The primary objective of this Feasibility Study is to provide a comprehensive concept to secure and diversify the sources of Namibia's water supply by combining the conventional water resources with a climate-independent supply of water and thus contribute to increased resilience in the Project Area. This project foresees the supply of future water deficits through suitable seawater desalination at a plant situated on the Atlantic Coast, to the Central Coastal Area of Namibia (CCA), the Central Area of Namibia (CAN), and to Botswana, via pipeline transfer from the desalination plant to the consumers. This Feasibility Study is to examine the technical, technological, environmental, economic, social and financial aspects of these concepts.

In this way, the Project will contribute to enhanced environmental and resource protection and will have positive effects on the socio-economic and health situation of the population and will foster poverty reduction. The Project will therefore contribute to a long-term development of the region and a reduction of social inequalities and will also contribute to good governance and availability and sustainable management of water and sanitation (Sustainable Development Goal 6).

The essential aspects of this feasibility study and the main investment components of the planned project are briefly summarised as follows (excerpt from the ToR):

- Assessment of long-term availability of existing conventional and non-conventional water resources;

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- Analysis of current water demand and consumption pattern and projection of future water demand for domestic, commercial/administrative, mining and industrial consumer groups including aspects of improved unaccounted-for-water and enhanced operation strategies;
- Analysis of the legal framework comprising permits, land requirements and ownership, land use right, servitudes;
- Development of an institutional concept for the project with regard to financing, ownership, future operation & maintenance, market sounding, tender strategy;
- Assessment of the work performance and the residual value of the existing Areva Reverse Osmosis Desalination Plant (Areva SWRO) and preparation of options for allowing the integration of this plant into Namibia's long-term water supply concept;
- Investigation of alternative desalination plant options based on findings of already existing studies and investigations;
- Assessment of alternative desalination options, considering heavy fuel oil (HFO) and liquefied natural gas (LNG) energy generation, based on power plant studies already prepared and / or initiated by NamPower;
- Analysis of the status-quo and the capacity and quality of existing water abstraction and transfer schemes within the Central Coastal Area (Omdel, Wlotzkasbaken, Swakopmund, etc.) and preparation of concepts for future integration;
- Conceptual design of optimised technical and operational concepts for the water transfer system from the coast – via Arandis, Karibib, Okahandja - to Windhoek (pipeline length of about 350 km; total pumping head of about 2 000 m). This comprises the consideration of short and long-term water transfer capacities, the optimised planning of pumping stations, pump types and configuration, storage and balancing reservoir capacities, energy demand and supply, Industry 4 control infrastructure, administration, operation and maintenance facilities, etc.;
- Conceptual design of a technical layout for the water transfer system from Windhoek to Gaborone (supply capacity of about 20 Mm3/a (54 800 m3/d); pipeline length of about 1 100 km). This comprises an optimised planning of the pipeline route, pumping stations, pump types and configuration, storage and balancing reservoir capacities, energy supply, control infrastructure, operation and maintenance facilities, etc.;
- Investigations and elaboration of concepts for solar power generation and / or national grid supply (in close cooperation with NamPower) for the long-term operation of the desalination plant(s) and the water transfer scheme. This shall comprise the planned Concentrated Solar Power Plant (CSP) in Arandis, the construction of a completely new solar power plant for the sole purpose of the project and the long-

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term purchase of energy through NamPower's national grid network as well as possible energy storage solutions;

- Scoping Report (Phase 1 of the ESIA) as part of the Environmental and Social Impact Assessment (ESIA) process and the Public Consultation and Disclosure Plan (PCDP) for the proposed Project in accordance to the Namibian EIA Regulations (Environmental Assessment Policy (1995) established under the Environmental Management Act (2007)) as well as the relevant policies of KfW;
- Comprehensive economic, financial and sensitivity analyses, comprising base, best and worst-case scenarios, including the development of financial modelling software for the evaluation of project configurations such as: (i) Supply to Central Coastal Area only; (ii) Supply to Central Coastal Area, Windhoek and Users en-route; and (iii) In addition supply to Botswana / Gaborone and users en-route; and

Comparative assessment / study of the results of this feasibility study related to water supply for the Central Areas of Namibia (CAN) with the corresponding Okavango study, being "*The Augmentation of Water Supply to the Central Area of Namibia and the Cuvelai: Part I: The Central Area of Namibia: Draft Final Report*" LCE-SCE JV, 2017).

1.1.3 Planning Horizon

The planning horizon for this Feasibility Study is 30 years, with implementation measures which are to be proposed for the short term (5 years), medium-term (15 years) and longer-term (25+ years). It is envisaged that water demand projections and proposals for infrastructure development and other measures will be aligned with these timelines.

1.1.4 Purpose of Document

This document describes the assessment of the water resources available to the project areas, being the CAN, CCA and en-route users between the coast and Windhoek, the assessment of water demands and thus deficits for these areas, as well as to Botswana, and how these are configured for the three supply scenarios to be investigated under this Project. Other aspects assessed include the demographic and socio-economic framework conditions in Namibia and the legal and policy framework of the Namibian water sector. The water resources, demands and deficits are assessed separately for the four project areas (being the CAN, CCA, en-route users and Botswana) and thereafter combined for the three project scenarios, Supply Scenarios 1 to 3, which form the basis of the work of later phases and components of the projects.

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1.1.5 Reference Documents

The following documents form part of the Feasibility Study Project and should be read conjunctively.

Table 1.1: Reference Documents

Document #	Document Title
O992-ILF-REP-0001	Feasibility Study Report
O992-ILF-OD-0013	FS Chapter Desalination Plant Options
O992-ILF-OD-0015	FS Chapter Water Transmission Scheme
O992-ILF-OD-0016	FS Chapter Power Supply Options
O992-ILF-OD-0017	FS Chapter Financing, Management and Operation Concepts
O992-ILF-OD-0017	FS Chapter Financing, Management and Operation Concepts
O992-ILF-OD-0019	FS Chapter Cost Estimate, Financial & Sensitivity Analysis
O992-ILF-OD-0018	Concept Report

1.2 Project Overview

1.2.1 Overview of Namibia

Namibia is the second largest country in Southern Africa, behind South Africa, and is situated roughly between 17° and 29° south of the equator and lies along the south-western coast of the African continent. The country is bounded by Angola and Zambia to the north, Zimbabwe and Botswana to the east, and by South Africa to the east and south. The western, coastal, border with the Atlantic Ocean is some 1,570 km long between the mouth of the Orange River in the south and that of the Kunene River in the north. Namibia covers an area of some 823,680 km2 and spans 1,320 km at its longest, 350 km at its narrowest and 1,440 km at its widest points (after LCE-SCE JV, 2019 and Mendelsohn et al., 2009) and is home to some 2.3 million inhabitants (NSA, 2017b).

Namibia’s climate is governed by its location on the south-western side of the African continent in the Subtropical High Pressure Zone between the Inter-Tropical Convergence Zone to the north and the Temperate Zone to the south.

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Quasi-stationary cells of high pressure dominate this broad area and two of these cells, the Botswana Anticyclone and the South Atlantic Cyclone, are what make Namibia's climate so dry (LCE et al., 2019 and Mendelsohn et al., 2009). Essentially a country sandwiched between two deserts, the Namib and the Kalahari, Namibia is the most arid country in Southern Africa, with the driest climate in Africa south of the Sahara, where it is estimated that on average, only about 2% of the rainfall ends up as surface run-off and a mere 1% becomes available to recharge the groundwater (LCE-SCE JV, 2019). Whilst national rainfall is generally very low, averaging 272 mm/a, it is also unpredictable, unreliable, erratic and spatially unevenly distributed across the country (LCE-SCE JV, 2019).

On a continental scale, with a coefficient of variation greater than 40%, Namibia, together with the Sahara Desert, also has the most variable rainfall in Africa. On a national scale, rainfall varies even more dramatically, with coefficients of variation of ranging between 30% in some areas and over 100% in others (Mendelsohn et al., 2009, LCE-SCE JV, 2019). Low and variable rainfall is further compounded by high rates of evaporation, resulting in a water deficit which varies between 1,300 mm/a and more than 2,500 mm/a across the country. Droughts are frequent, though varying in intensity and duration.

Namibia's water sources are also unevenly distributed across the country, with perennial rivers only located along the country's northern and southern borders, some 700 to 800 km away from major demand centres such as Windhoek. Within a 350 km radius of Windhoek, the nation's capital and major demand node in the interior of the country, all the economically viable conventional water sources (surface and groundwater) are already developed (Bruce and Burger, 2019).

1.2.2 Project Area

In terms of the assessments of water resources and the preparation of water demand projections, the project area can be divided into four components:

1. The Central Area of Namibia (**CAN**);
2. The Central Coastal Area (**CCA**) of Namibia (which is assumed to extend up to Arandis based on the existing configuration of supply and infrastructure);
3. The en-route users between a desalination plant at the coast and Windhoek;
4. Supply to Botswana.

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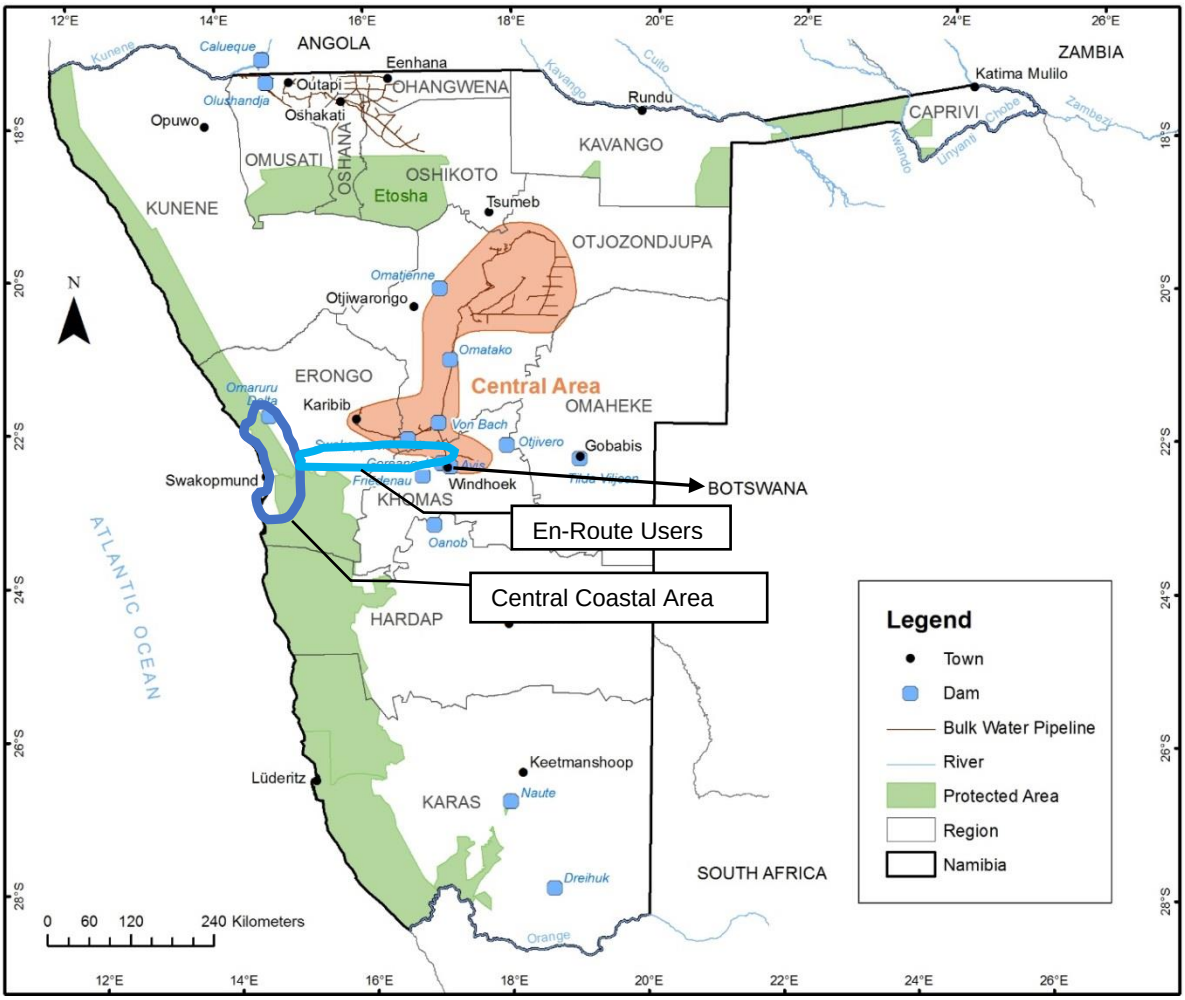

Figure 1.1: Project Areas for this Feasibility Study (LCE-SCE JV, 2017)

In terms of water supply to Botswana, the ToR specify that the proposed scheme is to be sized to a "*water transfer volume / capacity of 20 Mm³/a (about 54 800 m³/d)*". In this respect, no assessments for the "fourth" demand area or component are required and therefore water demand projections will be prepared for the three areas or components within Namibia.

Although Karibib and Otjimbingwe are geographically located in the area of the en-route users, they will be considered as part of the CAN, per the current supply configuration and the approach followed with previous feasibility studies for water supply to the CAN.

Different supply philosophies are proposed for the three different areas or components within Namibia.

The different project areas with Namibia (the CAN, CCA and en-route users) are located in the Khomas, Erongo and Otjozondjupa Regions of the Country.

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1.2.3 General Project Approach

Namibia's arid and variable climate, coupled with a growing and increasingly urbanised population, can be expected to place increasing pressure on the future provision of a continuous and reliable supply of potable water. Climate change effects, which in the western parts of Southern Africa are expected to result in drier and more variable hydrological conditions, are likely to pose major challenges to the future supply of water in the Country.

Current conventional (surface and groundwater) sources are mostly fully developed, and unconventional sources (reclaimed and desalinated water) have already been in use for some time; desalinated water has been part of the supply mix at the CCA since 2013 (for Local Authorities) and Direct Potable Reclamation (**DPR**) has been practiced in Windhoek since 1968.

Whilst there are several areas in Namibia which can be regarded as water-stressed, two areas are of specific importance; the CCA and the CAN, for the following reasons:

- The water demands in both these areas have surpassed the capacity of the local conventional water sources and unconventional water sources have been part of the supply mix for some already;
- Further increases in water demands as a result of general population increase and urbanisation will require further supply capacity which is not readily available in either area;
- Both the CAN and the CCA are important in terms of their contribution to the national economy, including employment provision. The CCA, with the Walvis Bay harbour, represents a major gateway, transportation and logistics hub for Namibia and neighbouring countries, whilst the CAN, specifically Windhoek, represents the commercial, economic, political and administrative hub of the country. Windhoek has a good reputation as a regional and international conference venue and a clean and orderly city, with good quality infrastructure, including drinkable tap water. The Hosea Kutako International Airport outside Windhoek is the main point of entry for international and many regional visitors to the country.

This Feasibility Study aims to examine the long-term provision of water to both the CCA and the CAN, primarily via the provision of desalinated seawater. The first large-scale desalination of seawater was introduced in the CCA in 2010 following the completion of the Erongo Desalination Plant (**EDP**) at Wlotzkasbaken, and this water has been provided to Local Authorities for potable domestic use, as well as mining use, mainly to the Langer Heinrich, Rössing and more recently Husab uranium mines, via NamWater, since 2013. Desalination is already widely used in many countries with similarly arid conditions, for example in the Middle East, with the technology already well established, and having increased in efficiency with increased use worldwide.

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A conceptual overview of the provision of desalinated water to the CCA, the CAN and en-route users envisaged under this Feasibility Study is provided in **Figure 1.2**.

According to the Terms of Reference, the broader aim of this Project, and specifically the water resources and demand projections component thereof, is to investigate the long-term provision of desalinated water to the Central Coastal Area (CCA), the area around Windhoek in the CAN and the communities alongside the proposed transmission pipeline, as well as an option to Botswana's capital Gaborone.

Consultations with key stakeholders is required per the ToR and is an aspect of the study which has been highlighted by NamWater as being of particular importance (further details below).

Based on the present and projected future growing water demands and related deficits, various options below will be investigated in this Study:

1. Low, likely and high likely domestic future water demand projections, as well as varying scenarios for the water demands of the current and potential future coastal uranium mines;
2. Desalination water supply options may include i) upgrading the EDP; ii) upgrading and extending the EDP; iii) a new desalination plant and iv) a combination of (ii) and (iii);
3. Bulk power source options may include PV, CSP and feasible options.

The above options will be investigated, assessed and appraised by NamWater and key stakeholders. The selected options and their proposed corresponding infrastructure (desalination plant, conveyance pipeline, pump stations, power sources, reservoirs) will be sized accordingly at conceptual feasibility stage level. The related financial social-economic impacts (affordability and tariffs) as well as environmental impacts (scoping level refer to ToR) will be assessed before concluding and recommending on this feasibility study.

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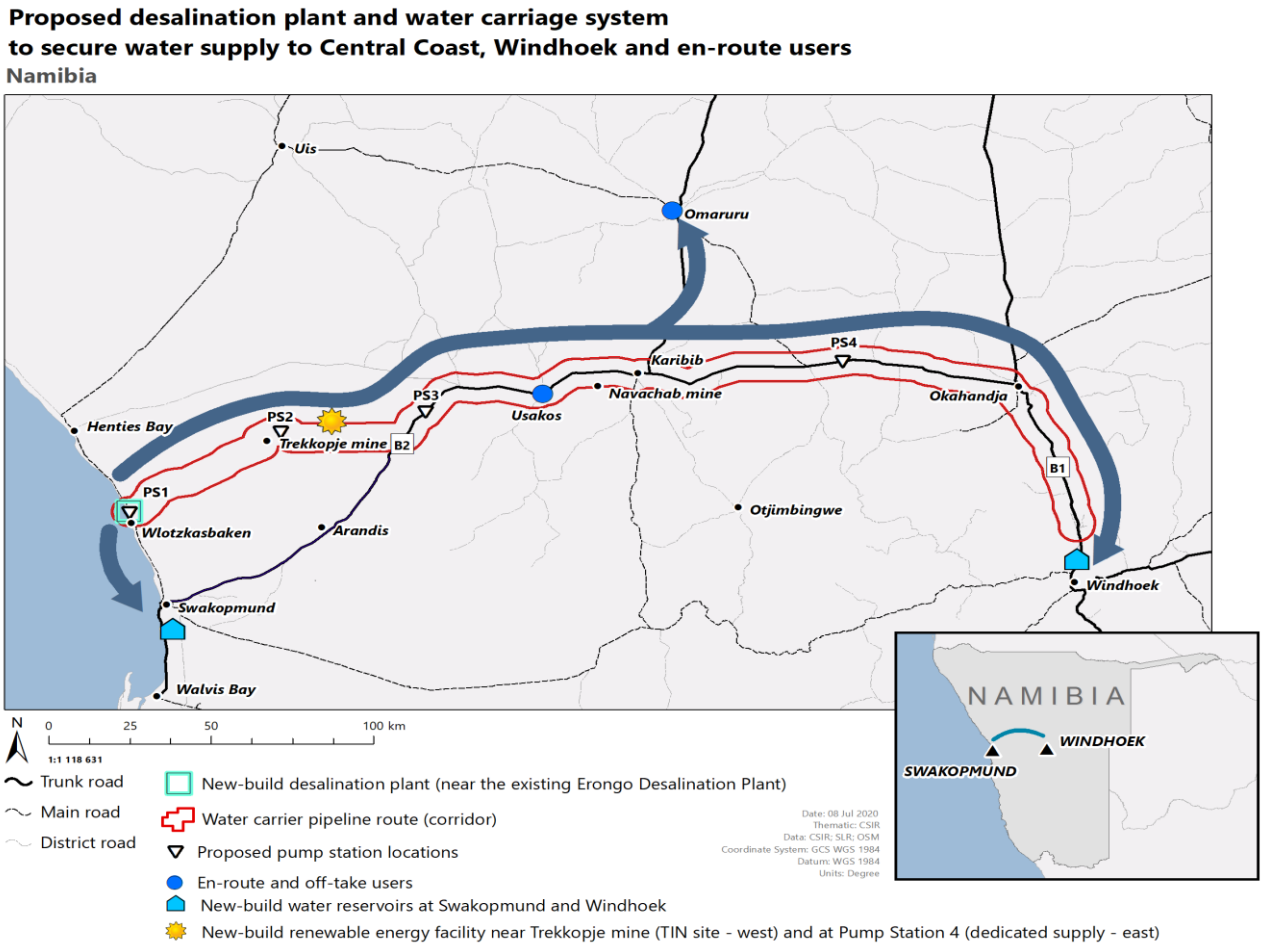

Figure 1.2: Conceptual Overview of this Feasibility Study

1.3 Brief Overview of Water Resources and Water Supply

The CCA, which is located in the Erongo Region, is defined by NamWater as that area along the central Namib coastline which is supplied from the alluvial aquifers in the lower Kuiseb and Omaruru Rivers (now also including supply from desalinated sea water) and which includes the Walvis Bay, Swakopmund, Henties Bay and Arandis local authority areas, as well as the uranium mines and some smaller consumers (NamWater, 2009).

The CAN, which is sometimes also referred to as NamWater's Central Water Supply Area, encompasses those areas supplied with water by the Eastern National Water Carrier (ENWC) Canal and the 3-dam system of the Von Bach, Swakoppoort and Omatako Dams. This area covers portions of the Otjozondjupa, Khomas and Erongo Regions, and includes the capital city of Windhoek, as well as Okahandja, Karibib, Okakarara and other areas and smaller consumers. The CAN is also supplied with groundwater, mostly from sources in the Karst areas and from reclaimed domestic effluent (in Windhoek only).

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1.3.1 Major Water Sources

The major water sources in the Project Areas within Namibia are as follows:

- In the Central Coastal Area, water supply from NamWater comprises the following:
  - The Kuiseb Alluvial Aquifer, which mostly supplies Walvis Bay and other smaller consumers, with some of this water being transferred northwards to Swakopmund;
  - The Omaruru Alluvial Aquifer, via the Omdel Scheme, which supplies water to Henties Bay, Swakopmund, Arandis and the uranium mines, as well as smaller on-line consumers along the transfer pipelines;
  - The Erongo Desalination Plant (EDP) at Wlotzkasbaken which belongs to Orano, and from which NamWater purchases water by agreement, for distribution and sale to their customers. This water is mixed with that of from the Omdel Scheme[3] and is supplied to Swakopmund, Arandis and the uranium mines, as well as smaller on-line consumers along the transfer pipelines;
- The Central Area of Namibia:
  - The 3-dam system of the Omatako, Swakoppoort and Von Bach Dams, which are located on ephemeral rivers in the central portion of the country. These dams belong to and are operated by NamWater;
  - Groundwater sources and schemes in the Karst Area, comprising the Brandwag and Kombat Boreholes in the Karst I Aquifer and the Berg Aukas Mine Scheme in the Karst II Aquifer, which belong to and are operated by NamWater. Groundwater is transferred from these aquifers into the ENWC Canal for supply to downstream users, mainly the Waterberg Water Supply Area, and eventually to Windhoek;
  - Groundwater from the Seeis Alluvial Aquifer, which belongs to and is operated by NamWater, to supply water to the Hosea Kutako International Airport;
  - Groundwater from the Windhoek Aquifer, which under a managed aquifer recharge scheme, comprises abstraction and artificial recharge of this resource which belongs to and is operated by the City of Windhoek;

[3] Desalinated sea water from the EDP is supplied into the Omdel – Swakopmund Pipeline at a connection point to the east of the EDP and thus a mix of groundwater from the Omaruru Aquifer and desalinated water is supplied to users downstream. NamWater officially supplies primarily groundwater to the local authority areas and some smaller consumers, with supply above an agreed amount from desalinated water, and desalinated water to the uranium mines. In reality, due to the nature of the infrastructure, the water supplied south of the connection point on their Omdel – Swakopmund Pipeline consists of a mixture of groundwater and desalinated water and the billing allocation is conducted on a volumetric basis.

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- Semi-purified water which is supplied in Windhoek for restricted irrigation, by the City of Windhoek;
- Reclaimed potable water which is supplied from the New Goreangab Reclamation Plant which belongs to the CoW and which is operated by a private company, Wingoc, under contract with the CoW;

- The En-route users:
  - Usakos is supplied with groundwater from the Khan River alluvial aquifer, partly by a scheme belonging to and operated by NamWater and partly by a scheme belonging to and operating by the Town Council;
  - Karibib Town, the Otjimbingwe scheme and others are supplied with water from the Swakoppoort Dam by NamWater;
  - Omaruru Town is supplied with groundwater from the Omaruru River Aquifer by a scheme belonging to and operated by the Town Council.

The majority of water sources in the Project Areas within Namibia are rainfall-dependent, either directly, such as surface and groundwater sources, or indirectly, such as reclaimed water (semi-purified and potable) and managed aquifer recharge. Whilst groundwater sources are not subject to the same “immediate” variability as surface water sources (there being a “lag” and attenuating effect compared with surface water sources[4]), the extreme variability of rainfall in Namibia (refer above) directly impacts on the variability of water sources and hence the security of water supply (or the lack thereof).

Water supply in the CAN is highly complex, due to the variability of rainfall which effects the majority of the supply which is from the 3-dam system, the integrated and conjunctive nature of supply which incorporates different types of reuse in Windhoek, groundwater use and aquifer recharge, inter-basin transfer schemes, extensive infrastructure components and the involvement of different role players associated with different sources and schemes.

1.3.2 Major Water Demands

The major water demand nodes in the CCA comprise the local authorities, the largest of which is Walvis Bay, as well as the uranium mines, particularly Husab Mine (Swakop Uranium).

[4] Based on the work of Mark Cuthbert from Cardiff University's School of Earth and Ocean Sciences, whose work has found that groundwater reserves in arid areas take far longer to respond to alterations in climate than do surface waters (Long, 2019) and than groundwater reserves in more humid climates (Galey, 2019).

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By far the largest water demand in the CAN is Windhoek, which represents a challenge to water supply, in that most of the water supply / transfer is from north to south through the CAN, which with Windhoek located at the southernmost part of the CAN, and implies that the majority of the water has to be transferred over the greatest distance.

1.3.3 Perspectives on Recent Water Supply Schemes and Investments

Following the establishment of the Namibia Water Corporation Ltd. (NamWater), under the Namibia Water Corporation Act, Act No. 12 of 1997, the central Namibian Government has, played a limited role in the funding and implementation of “bulk” water supply infrastructure, as this has been viewed to be the mandate of NamWater. The Government, via the MAWLR, has however significantly expanded water supply to rural areas of the country. Overall however, there has been insufficient investment in the development of additional sources and (bulk) water supply infrastructure, which aspects have not kept pace with the growth in population and water demand. For example, no external source has been linked to the CAN in past 20 years, despite the population of Windhoek more than doubling between 1999 (214 996 ca) and 2018 (433 166 ca; CoW data). Major “recent” developments in the water sector in Namibia include:

- The completion, by NamWater, of a new pipeline between Wlotzkasbaken and their Swakopmund Reservoirs to facilitate the transfer of larger volumes of desalinated water from the EDP to Swakopmund and onwards to the various Uranium mines;
- The construction, by the MAWLR, of the Neckartal Dam in southern Namibia. This dam, with a live storage of some 841 Mm^3, is located on the Fish River, some 25 km north of Seeheim and some 40 km northwest of Keetmanshoop. The purpose of this dam was to provide irrigation water to an agricultural development under the Government’s Green Scheme Policy initiative some 21 km away. However, although the dam is nearly complete (2019), there is some uncertainty as to how, when and in what format the agricultural development is to proceed. At present (2019), the dam does not supply water to any user. Counterintuitively, the construction of this dam may have the effect of jeopardising water security in Namibia, as a result of the massive cost overruns on the construction budget, which have occurred following an economic downturn in Namibia (refer below), which has placed severe strain on the Government’s finances, thus limiting their ability to fund other badly needed developments;
- In the case of Windhoek, the largest demand node in the CAN and Namibia, the Windhoek Managed Aquifer Recharge Project was in 2004 identified as the next major scheme / source development needed to secure the medium-term water supply security to the CAN. Since this source and scheme falls within the jurisdiction of the City of Windhoek (CoW), the responsibility for its development has fallen to them. The CoW’s finances have however become increasingly strained and the full implementation of this scheme is beyond the financial resources of the CoW. As a result, implementation thereof has lagged far behind what was originally

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planned. During the 2015 – 2017 drought, the central Government, via the Cabinet Committee on Wate Supply Security and the Technical Committee of Experts, provided some funding assistance to the CoW from the fiscus to drill additional boreholes to avoid a major water shortage in Windhoek and the wider CAN.

Namibia's economy has contracted since the second quarter of 2016 (refer below), which has placed major strain on Government's fiscal position and thus their ability to fund much-needed water supply infrastructure. Unfortunately this has come at a time of constrained supply (2015-2017 and 2018/19 droughts) and following years of under-investment in the sector, both of which have heightened the need for future investments. The outlook for future water supply security in the CAN and CCA in particular therefore appears constrained from the perspective of supply and the investments needed and the possibility of implementing these with locally available funding.

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2 DEMOGRAPHIC AND SOCIO-ECONOMIC FRAMEWORK CONDITIONS

2.1 Namibia's Economy

2.1.1 General Information on the Namibian Economy

Namibia's estimated Gross Domestic Product (GDP) for 2018 was N$ 192.138 billion, or approximately US$ 13.571 billion[5]. According to GDP per capita, Namibia's economy is ranked 115th in the world, and according to GDP purchasing power parity, 136th in the world (Countries of the World, 2017). Namibia is ranked as the 28th largest economy in Africa by Gross National Income (GNI) according to purchasing power parity, with a 0.2% share of the continent's population and a 0.5% share of the continent's GNI by purchasing power parity.

For 2011, the Namibian GDP per capita is given as US$ 5,601 (current US$ terms; World Bank, 2017[3]) or US$ 7,600.00 (Countries of the World, 2017). If these values are used as a proxy for Gross National Income (GNI) per capita, they both fall within the per capita GNI range for 2011 of US$ 1,026 to US$ 12,475 (World Bank, 2017[2]), which would categorise Namibia as a Middle-Income Country (MIC).

For 2012, Namibia's GDP per capita is given as US$ 5,749 (current US$ terms; World Bank, 2017[3]) or US$ 7,800.00 (Countries of the World, 2017). Again, using these values as a proxy for GNI per capita, Namibia would be categorised as a MIC, based on GNI per capita between US$ 1,036 and US$ 12,615 (Investopedia, 2017[1]).

More specifically, for a per capita GNI between US$ 4,086 and US$ 12,615, Namibia is rated as an upper-middle-income nation (Investopedia, 2017[1]). The World Bank uses these categories to "*classify economies for operational and analytical purposes*" (Investopedia, 2017[1]).

2.1.2 Major Sectors of the Namibian Economy

Common consensus is that Namibia's economy is "*heavily dependent on the extraction and processing of minerals for export. Mining accounts for 11.5% of GDP, but provides more than 50% of foreign exchange earnings*" (CIA, 2017). However, as shown by **Figure** 2.1, tertiary industries contribute the largest share towards GDP.

In 2018, the majority of GDP was contributed by tertiary industries (58%), whilst primary industries and secondary industries contributed 21% and 15% to GDP respectively; NSA, n.d.[3]).

[5] At 1 US$ = 14.1577 N$ on 08 April 2019, per the Bank of Namibia: https://www.bon.com.na/

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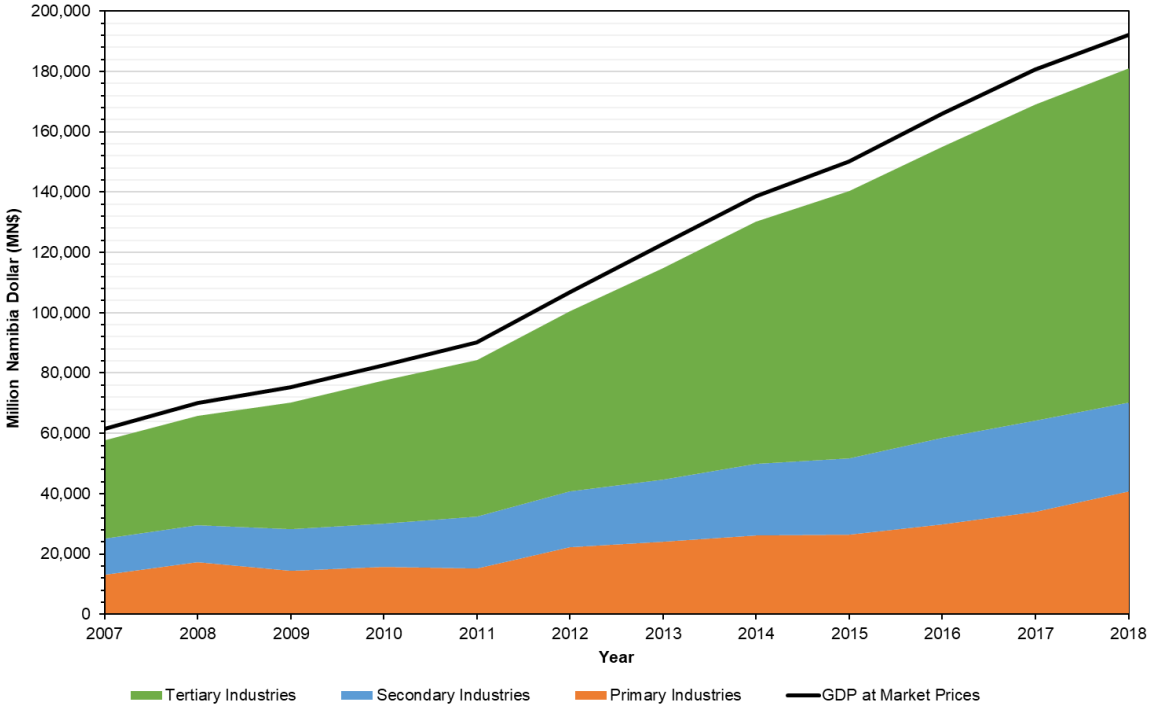

Figure 2.1: Gross Domestic Product in Namibia by Sector in Current Prices (NSA)

Notes:
1. Data from the 2018 Preliminary Annual National Accounts (NSA, n.d.[3]).
2. The difference between GDP at Market Prices and the total of the GDP contribution of primary, secondary and tertiary industries is the value of "*Taxes less subsidies on products*" (NSA, n.d.[3]).

2.1.3 Economic Growth

Namibia's estimated Gross Domestic Product (GDP), defined as the monetary value of all the goods and services produced by an economy during a specific period of time, was N$ 166.006 billion in 2016, which increased to N$ 180.605 billion in 2017 and to N$ 192.138 billion at current market prices (NSA, n.d.[3]). In terms of constant 2010 prices however, GDP peaked in 2016 (N$ 109.892 billion), declining in 2017 (N$ 108.938 billion) and again in 2018 (N$ 108.857 billion), to a level below that recorded in 2015 (N$ 108.671 billion). (NSA, n.d.[3]).

GDP is normally expressed in comparison to the value from a previous year or quarter, as a percentage value, indicating the economic growth (or contraction, if negative) over the period. Changes in quarterly and annual GDP from 2008 onwards are shown in **Figure 2.2**. The quarterly data suggests that the economy "turned" in the third quarter of 2015 as growth slowed thereafter. Negative growth (contraction of the economy) was first recorded in the second quarter of 2016 and for the period since, giving eleven consecutive quarters of negative growth (a "recession" is defined as two consecutive quarters of falling GDP).

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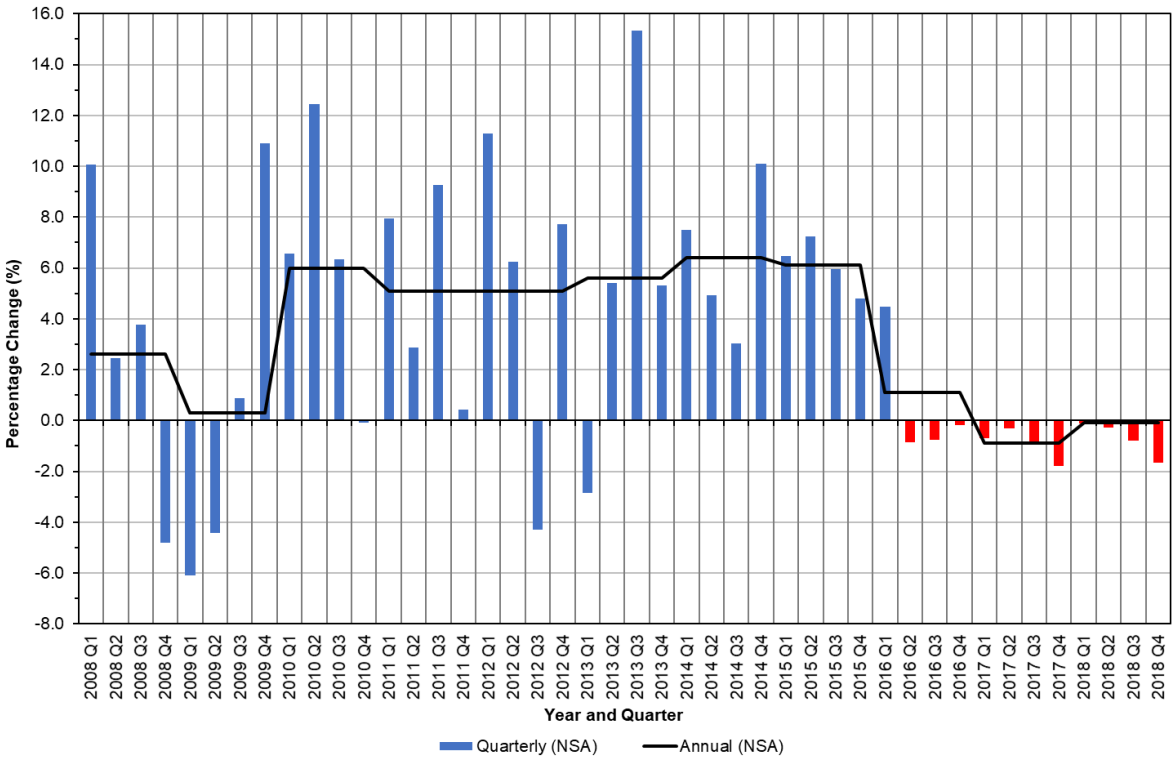

Figure 2.2: Quarterly and Annual Gross Domestic Product Growth in Namibia (NSA)

Note: Data from the National Statistics Agency.

The contraction of the Namibian economy is shown by a GDP in terms of constant 2010 prices which was lower in 2018 (N$ 108.857 billion) than in 2015 (N$ 108.671 billion; NSA, n.d.[3]).

It is therefore clear that since 2015/16, the "macroeconomic environment in Namibia has started to deteriorate, as a combination of factors have come together to dampen growth and drive imbalances within the local economy" (Brown, 2017). The following factors have "*all had a negative impact on the economy directly*" (Brown, 2017):

- The end of "*historically low interest rates*";
- Reduced "*foreign investment into the economy*";
- A "*weaker external environment – particularly in Angola and South Africa*", the latter being a major trading partner;
- Weaker global commodity prices;
- National and regional (in South Africa) drought;
- Government policy which has been "*concerning*" and a "*high base*".

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With the Namibian Government heavily indebted and the economy contracting persistently, the current (2019) economic climate is therefore poor and the general outlook for the immediate future is weak. On a national level, the poor current climate and immediate future outlook can be expected to impact adversely on the Government's ability to afford a large water augmentation scheme, including its ability to borrow large sums of money to fund construction thereof. In terms of water demands, the poor current climate and immediate future outlook can be expected to result in proposed or new developments being likely to take longer to commence, and grow or develop at slower than historical rates (for example new housing developments). On household and individual levels, the affordability of water tariffs may be problematic, especially in terms of a large new desalination scheme, and particularly in rural areas.

2.2 Namibia's Population and Demographics

2.2.1 Namibia's Population

Namibia's population, estimated at 2.324 million in 2016 (NSA, 2017b), up from 2.113 million counted with the 2011 census (NSA, 2012a), is very unevenly spread across the country. Large areas of land are uninhabited and many others are very sparsely populated, whilst people are concentrated in towns and a few rural areas.

The Project Areas shown in **Figure 1.1** cover parts of the Erongo, Otjozondjupa and Khomas Regions of Namibia, which will thus be analysed in more detail than the other regions of the Country.

Population density varies dramatically across the CAN, which generally has a low population density, as large portions thereof are farmland. Inhabitants are concentrated in the main towns and cities, whilst the areas served by the pipeline network of the Waterberg Water Supply Area feature population densities higher than those of the surrounding areas, though not as high as in the Cuvelai for example. Due to the scarcity of water supplies, some areas in the eastern parts of the Omaheke and Otjozondjupa Regions are very sparsely populated.

In the Erongo Region, inhabitants are concentrated at the coastal towns, as well as Arandis, Usakos and Karibib (urban centres), in the Otjimbingwe area and areas around Omaruru, Okombahe and Uis, which are mostly "rural" areas. Apart from these towns and "rural" areas, large parts of the Erongo Region are essentially uninhabited, due to the scarcity of water supplies and economic activities.

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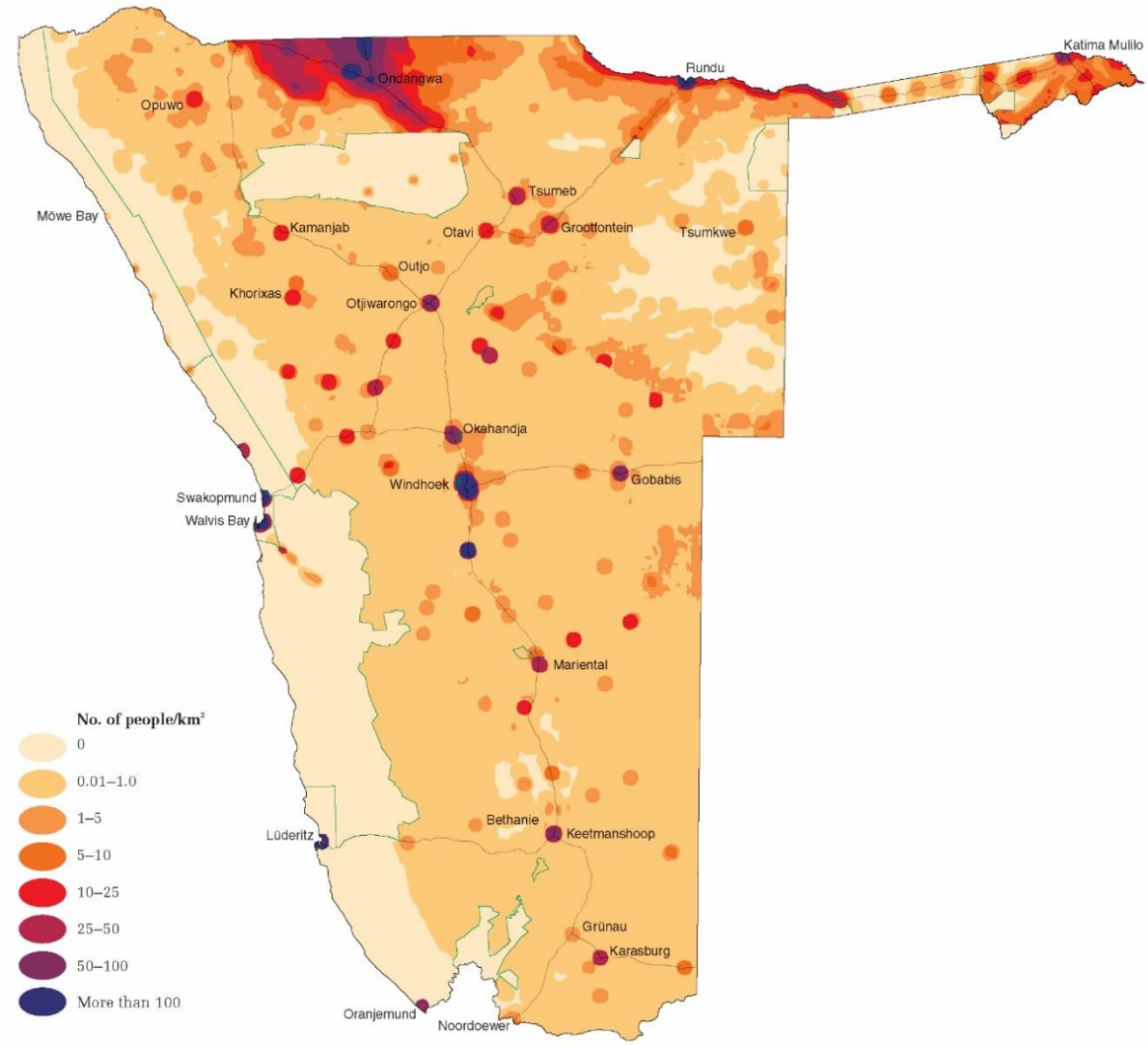

Figure 2.3: Population Density across Namibia (Mendelsohn et al., 2009)

2.2.2 Historical Population Numbers, Growth Rates and Age Distribution

Namibia has since independence conducted 3 major population censuses at 10-year intervals, in 1991, 2001 and 2011. In 2016 for the first time, the National Statistics Agency (NSA) conducted an inter-censal demographic survey, targeting private households, to obtain population information at a 5-year interval, midway between major censuses (NSA, 2017b).

Namibia's population increased at 2.6% per annum between 1991 and 2001, thereafter at a slower rate of 1.4% per annum between 2001 and 2011. The overall population growth rate increase slightly to 1.9% between 2011 and 2016.

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Table 2.1: Population Totals and Growth Rates for Namibia's Regions

Region	2001 Census[1] (Capita)	2011 Census[2] (Capita)	2016 Estimate[3] (Capita)	Annual Regional Growth Rate (Percentage per Annum)[4]	
				2001 – 2011	2011 – 2016
Zambezi[5]	79 826	90 596	98 849	1.3	1.8
Erongo	107 663	150 809	182 402	3.4	3.9
Hardap	68 249	79 507	87 186	1.5	1.9
!Karas	69 329	77 421	85 759	1.1	2.1
Kavango East	202 694[6]	136 823[7]	148 466	1.0	1.6
Kavango West		86 529	89 313		0.6
Khomas	250 262	342 141	415 780	3.2	4.0
Kunene	68 735	86 856	97 865	2.4	2.4
Ohangwena	228 384	245 446	255 510	0.7	0.8
Omaheke	68 039	71 233	74 629	0.5	0.9
Omusati	228 842	243 166	249 885	0.6	0.5
Oshana	161 916	176 674	189 237	0.9	1.4
Oshikoto	161 007	181 973	195 165	1.2	1.4
Otjozondjupa	135 384	143 903	154 342	0.6	1.4
Total	**1 830 330**	**2 113 077**	**2 324 388**	**1.4**	**1.9**
Urban	603 612	903 434	1 112 868	4.1	4.3
Rural	1 226 718	1 209 643	1 211 520	-0.1	0.03

Notes:
1. Results of the 2001 population census (NSA, 2012a).
2. Results of the 2011 population and housing census (NSA, 2017b).
3. Results of the 2016 Inter-censal Demographic Survey (NSA, 2017b).
4. Calculated growth rates. There are small differences between the calculated growth rates between 2001 and 2011 and those given by the NSA (NSA, 2012a).
5. Previously the Caprivi Region.
6. The Kavango Region before it was divided into the Kavango East and Kavango West Regions.
7. At the time of the 2011 census, the Kavango Region was one region. The population numbers for the Kavango East and West Regions are provided in the 2017 NSA publication.

There are several factors which influence population growth rates, of which the prevalence of HIV/AIDS, increasing access to anti-retroviral medication, declining fertility rates and rural-urban migration are probably the most pertinent to an estimation of the urban population growth rates (LCE-SCE JV, 2017).

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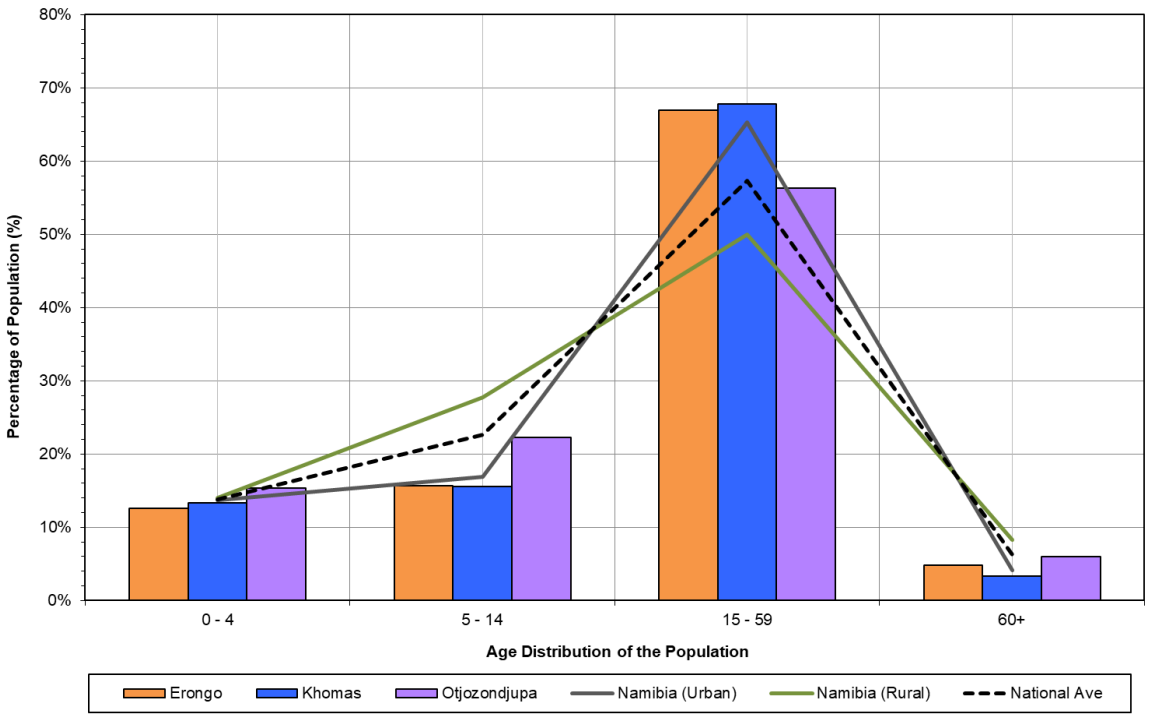

Figure 2.4: Population Age Distribution in Selected Regions in Namibia (NSA, 2017b)

Namibia's population is relatively youthful, nationally, in urban and rural areas and in the Erongo, Khomas and Otjozondjupa Regions, with the majority of working age (15-59 years; NSA, 2017b). A slightly higher portion of working age (15-59 years) people are located in the Erongo (67%) and Khomas (68%) Regions than in the Otjozondjupa Region (56%), which correlates with the urbanisation rates of the three regions (refer below); working age people are likely to migrate to the urban areas in search of employment opportunities. There are markedly more school-age children (5-14 years) in the rural areas than in urban areas and the three regions in the Project Area, and double the portion of elderly (60+ years) in rural areas (8.3%) than in urban areas (4.1%) and a greater portion in rural areas than in the three regions in the Project Area (Erongo: 4.8%; Khomas: 3.3% and Otjozondjupa: 6.0%; NSA, 2017b). This would suggest that grandparents in the rural areas are looking after school-age children whilst their parents are working in the urban areas of the country.

2.2.3 Population Projections

There are several factors which influence population growth rates, of which the prevalence of HIV/AIDS, increasing access to anti-retroviral medication, declining fertility rates and rural-urban migration are probably the most pertinent to an estimation of the urban population growth rates. Based on the 2001 census results, the Central Bureau of Statistics in the National Planning Commission (**NPC**) generated population projections national and per region for 30 years until 2031 (NPC, 2006).

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The NPC population projections of 2006 are based on the United Nations' software package, MORTPAK, which uses a variety of input criteria, 12 in total, such as mortality rates, fertility rates, fertility patterns, life expectancy, migration rates and patterns. The input criteria "mortality rate" for example is influenced by the access to health facilities. Should a number of clinics be built in the short term, the access to health facilities would change drastically and with it the mortality rate and the population growth rate. The NPC multiplied the figures generated by the MORTPAK package with adjustment factors in order to derive final projection figures for each region, so that the aggregate of the regions' populations would tally with the national population estimate (LCE-SCE JV, 2017).

Low, medium and high variant population projections based on assumptions regarding the "*future course of mortality and fertility during the Vision period*" are included in Vision 2030 (OOTP, 2004). More recently, the National Planning Commission prepared population projections for 2012 to 2015 based on the 1.4% per annum growth rate observed between the 2001 and 2011 censuses[6]. These three sets of population projections, together with the population counts of the different censuses, are shown in **Figure 2.5**.

It can be seen that the low variant population projection from the NPC is that which most closely matches the actual population growth since 2001. For example, the low variant population projection for the Khomas Region for 2011 was 343 339, whilst 342 141 people were counted in the 2011 census (**Table 2.1**); a difference of 0.35%. By contrast, the high variant projection from 2006 (NPC) and the medium and high projections included in Vision 2030 appear to overly optimistic regarding the population growth potential for Namibia.

Table 2.2: National Population Numbers and Growth Rates from Different Projections

Projections / Source	Scenario / Variant	Population Estimate for 2030 (Million ca)	Growth Rate (% p.a.)[3]
2006 Projecttions[1]	Low	2.757	1.42%
	Medium	2.998	1.72%
	High	3.233	1.98%
Vision 2030 Projecttions[2]	Low	2.980	1.70%
	Medium	3.490	2.25%
	High	4.270	2.96%

Notes:
1. 2006 Projections obtained from NPC, 2006.
2. Vision 2030 projections obtained from OOTP, 2004.
3. Growth rates are equivalent or effective growth rates, percentage per annum, between 2001 and 2030.

[6] Figure 1 of this document gives population projections for 2012 to 2015 "*projected at 1.4 growth rate*" [sic] (NPC, 2015). However, the numbers provided in the figure are truncated and not possible to discern accurately. The Consultant's calculation using a 1.4% per annum growth rate from the 2011 population census total does not yield the same values as those discerned from this Figure 1.

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The population projections of the NPC (2006) and Vision 2030 (OOTP, 2004), assume decreasing growth rates over successive five-year periods between 2001 and 2030. The overall population growth rates between 2001 and 2030 are provided in **Table 2.2**.

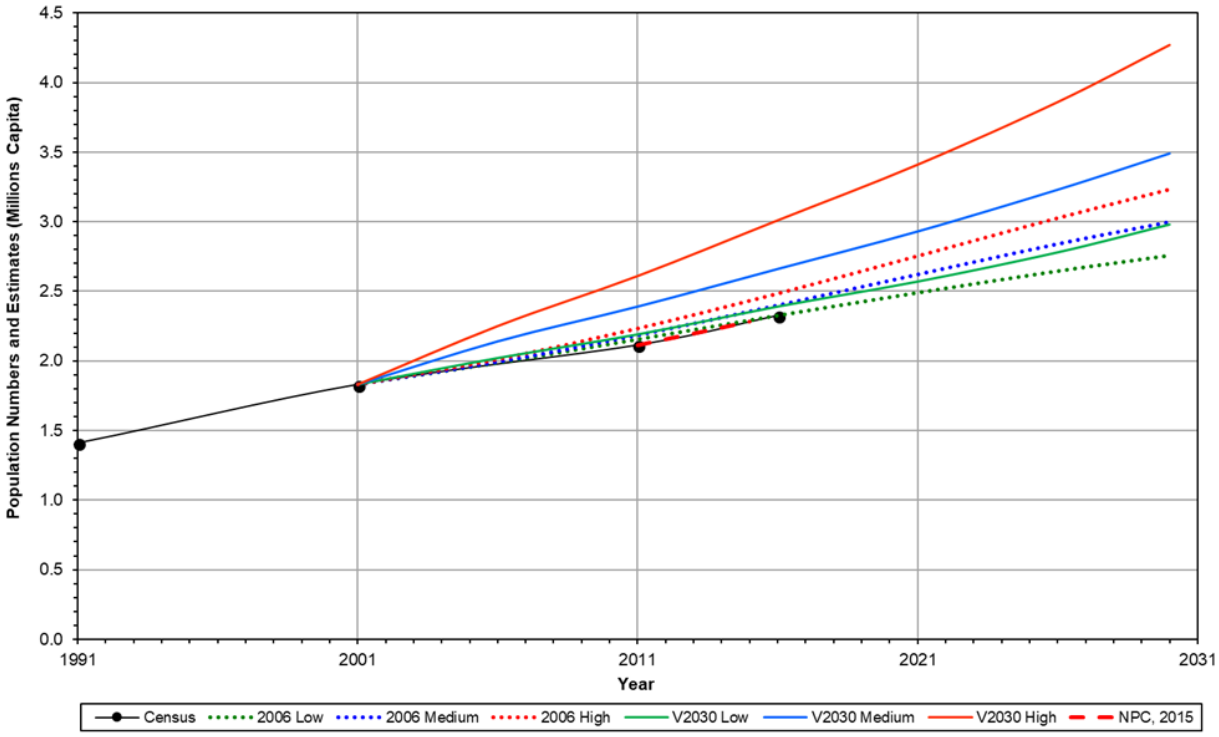

Figure 2.5: National Population Numbers and Selected Projections

Notes:
1. Population censuses were conducted in 1991, 2001 and 2011. An intercensal demographic survey was conducted in 2016.
2. 2006 Projections obtained from NPC, 2006.
3. Vision 2030 projections obtained from OOTP, 2004.
4. NPC, 2015 projections obtained from a policy brief by NPC (2015).

2.2.4 Urbanisation

Rural-urban migration is a well-known, though until recently relatively poorly documented phenomenon in Namibia. As shown in **Table 2.1** and **Figure 2.6**, the urban population has increased at over 4% per annum since 2001 (since 1991 in fact), which rate is well above the national average. As a result, the portion of the total population residing in urban areas has increased steadily from 27% of the population at independence in 1991 to nearly half (48%) in 2016. By contrast, the rural population peaked in 2011 and growth in this demographic has largely stalled, after an increase of 1.8% per annum between 1991 and 2001, a negative growth rate of (-)0.1% per annum was recorded between 2001 and 2011, and most recently a 0.03% growth rate is observed between 2011 and 2016.

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Recent studies indicate that migrants to cities and towns come from the rural areas in search of employment opportunities and to have a better urban life, for education, improved services and facilities and as a result of climate effects (Olivier, 2016).

Table 2.3: Portions of the Urban and Rural Populations in Selected Regions

Region	1991 Census[1]		2001 Census[2]		2011 Census[2]		2016 Estimate[3]	
	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)
Erongo	63%	37%	80%	20%	87%	13%	92%	8%
Khomas	88%	12%	93%	7%	95%	5%	95%	5%
Otjozondjupa	46%	54%	41%	59%	54%	46%	66%	34%
Total Namibia	**28%**	**72%**	**33%**	**67%**	**43%**	**57%**	**48%**	**52%**

Notes:
1. Anomalies have been found in the results of the 1991 census and these values should be treated as indicative only. In 1991, Walvis Bay was not part of Namibia, still being under South African sovereignty, formally becoming part of Namibia on 01 March 1994.
2. Results of the 2011 population and housing census (NSA, 2017b).
3. Results of the 2016 Inter-censal Demographic Survey (NSA, 2017b).

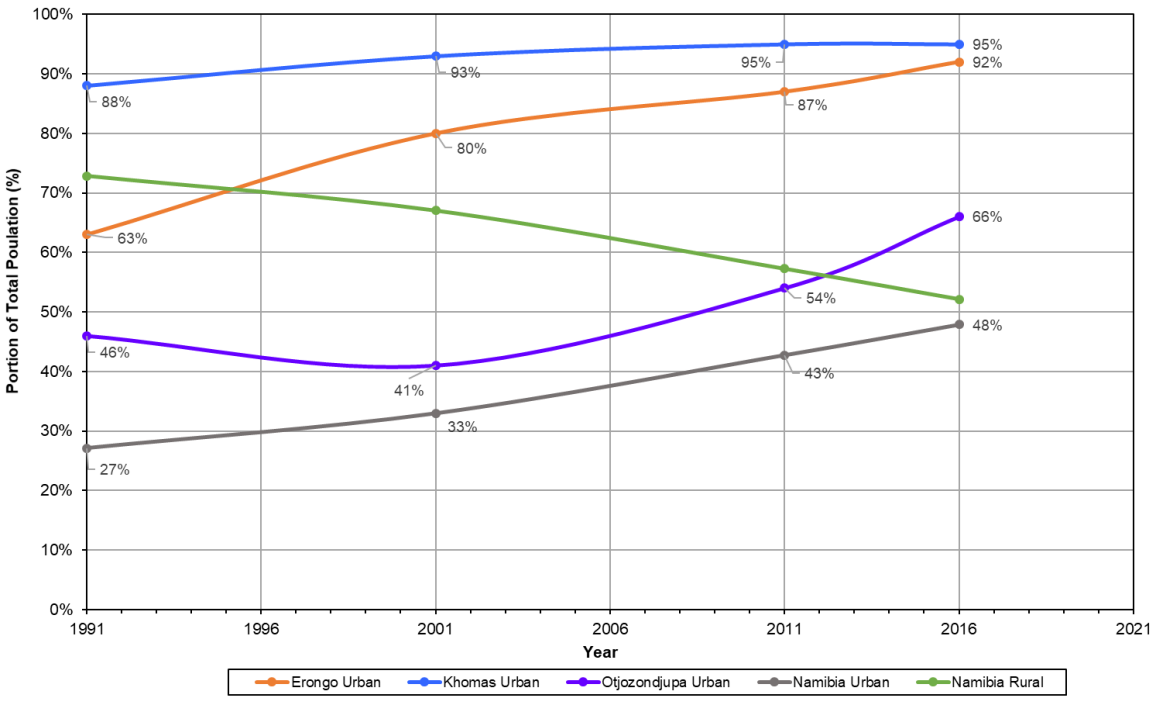

Figure 2.6: Portions of the Urban Populations in Selected Regions in Namibia

Notes: Data from the 2011 population and housing census (NSA, 2012a) and the 2016 Inter-censal Demographic Survey (NSA, 2017b).

In 2001, 2011 and 2016, urbanisation rates in the Erongo, Khomas and Otjozondjupa Regions were above the national averages, markedly so in the case of the first two regions. The Otjozondjupa Region experienced the greatest increase in urbanisation over this period, although urbanisation also increased significantly in the Erongo Region.

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The relatively stable rate of urbanisation in the Khomas Region between 2011 and 2016 may suggest an upper urbanisation bound of approximately 95% for that region, and possibly the Erongo Region in future as well.

Table 2.4: Population Totals and Growth Rates for the Erongo Region

Selected Urban Areas in the Erongo Region	Census Figures for Urban Centres per Date			Growth Rates (% per annum)	
	1991	2001	2011	1991-2001	2001-2011
Walvis Bay	22 999	43 611	62 096	6.6%	3.6%
Swakopmund	17 681	23 808	44 725	3.0%	6.5%
Arandis	4 303	3 974	5 214	-0.8%	2.8%
Henties Bay	1 612	3 285	4 720	7.4%	3.7%
Karibib	3 067	3 726	5 132	2.0%	3.3%
Usakos	3 548	2 926	3 583	-1.9%	2.0%
Omaruru	4 851	4 761	6 300	-0.2%	2.8%
Total	**58 061**	**86 091**	**131 770**	**4.0%**	**4.3%**
Population Totals: Erongo Region					
Urban	34 946	86 130	131 204	9.4%	4.3%
Rural	20 524	21 533	19 605	0.5%	-0.9%
Total	**55 470**	**107 663**	**150 809**	**6.9%**	**3.4%**

Notes:
1. Anomalies have been found in the results of the 1991 census and these values should be treated as indicative only. In 1991, Walvis Bay was not part of Namibia, still being under South African sovereignty, formally becoming part of Namibia on 01 March 1994.
2. The 2016 Inter-censal Demographic Survey (NSA, 2017b) was conducted on a regional basis only; i.e. not for the individual towns, and thus the most recent population totals available for individual towns date from the 2011 national population census.
3. Walvis Bay, Swakopmund, Arandis and Henties Bay are located in the Central Coastal Area, as defined, whilst Usakos and Omaruru are located in the area defined as “en-route” users. Karibib located in the Central Area of Namibia water supply area.

Between 2001 and 2011, the urban areas of the Erongo Region experienced an average growth rate of 4.3% per annum, which is close to the national average for urban areas (4.1%) and approximately three times the national average population growth rate over the same period (1.4%). The number of people in rural areas actually declined over this period, confirming a strong rural-urban movement of people.

The increasing urbanisation of the population in the Erongo Region should drive policy responses, including the prioritisation of housing and services in the urban centres above development in rural areas.

The urban centres in the CAN also experienced growth rates above the national average between 2001 and 2011, but, with the exception of Okahandja, these are generally lower than the growth rates experienced by the major urban centres in the CCA.

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The relatively high growth rate of Okahandja (4.9% per annum) is matched by a high negative growth rate in the rural population of the Otjozondjupa Region (-1.9% per annum) over the period 2001 to 2011.

Table 2.5: Population Totals and Growth Rates for Urban Areas in the Central Area of Namibia

Urban Areas in the CAN	Census Figures for Urban Centres per Data			Growth Rates (% per annum)	
	1991	2001	2011	1991-2001	2001-2011
Windhoek	147 056	233 529	325 858	4.7%	3.4%
Karibib	3 067	3 726	5 132	2.0%	3.3%
Okahandja	11 040	14 039	22 639	2.4%	4.9%
Total	**161 163**	**251 294**	**353 629**	**4.5%**	**3.5%**

Notes:
1. Anomalies have been found in the results of the 1991 census and these values should be treated as indicative only.
2. The major urban centres of the CAN are all in different regions; Windhoek in Khomas, Okahandja in Otjozondjupa and Karibib in Erongo.
3. The 2016 Inter-censal Demographic Survey (NSA, 2017b) was conducted on a regional basis only; i.e. not for the individual towns, and thus the most recent population totals available for individual towns date from the 2011 national population census.

The census data clearly shows that Namibia is becoming more urbanised, which is the trend typically followed with developing countries over time. This data strongly suggests that further population growth rates can be expected to be largely confined to the urban areas, and it can be expected that by the next census in 2021, the majority of Namibia's population will reside in urban areas.

2.2.5 Informal Settlements

As shown previously, Namibia's population is becoming more urban, due in large part to urban-rural migration (the portion of the rural population is declining), driven by migrants fleeing climate effects and seeking better employment opportunities (63% of respondents) and prospects in urban areas (after Olivier, 2016). These trends imply the migration or movement of people within and between regions in Namibia, as well as, though to a lesser extent, from outside Namibia.

In 2011, 44% of residents in the Erongo Region were born in that region, 45% in the Khomas Region and 65% in the Otjozondjupa Region (NSA, 2015). This data indicates that a larger portion of the populations in the Erongo and Khomas Regions were borne elsewhere, compared with the Otjozondjupa Region, later moving into these regions, and presumably to the urban centres. In the case of the Erongo Region, the largest portions of migrants originated from the Omusati (9%), Ohangwena (8%), Khomas (6%), Oshana and Oshikoto (both 5%) Regions, with lower portions from other regions and 5% from outside Namibia (NSA, 2015).

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In the case of the Khomas Region, the largest portions of migrants originated from the Ohangwena and Omusati Regions (both 9%), the Oshana and Oshikoto Regions (both 5%), with lower portions from other regions and 8% from outside Namibia (NSA, 2015).

Large portions of the populations in the Erongo (44%), Khomas (42%) and Otjozondjupa (30%) Regions reside in improvised housing (shacks; NSA, 2017b; refer also below). It can reasonably be assumed that the majority of households in informal housing reside in informal settlements around the main urban centres in each region.

The constraints in urban planning, housing and social service delivery in urban areas contribute to limited access to affordable housing and basic services such as electricity, water and sanitation and health services (Olivier, 2016), as local authorities are unable to address the housing backlog and keep pace with the influx of migrants. These factors increasingly pose challenges to people's well-being and these informal settlements have poor sanitation, with significant associated health risks (refer to **Section 2.2.12**), aggravated by overcrowded housing, and most of the migrant households are poor and food insecure (Olivier, 2016).

Conditions in Namibia's informal settlements have been described as "harsh" (Olivier, 2016) and it is clear that where households have low levels of education, have low income and / or are unemployed and as a result are "*poor and food insecure*", they will "*only be able to afford paying very little towards meeting their housing needs*" (Olivier, 2016), and the affordability of basic services such as water and sanitation will be problematic. With the introduction of desalinated water into the supply mix to local authorities likely to result in higher tariffs, as has been the case in the CCA (refer to **Section 4.1.3**), the affordability of desalinated water, particularly in informal settlements, but elsewhere as well, is a concern.

2.2.6 General Household Characteristics

General household characteristics are analysed in this section, whilst household consumption values, incomes, access to water supply and sanitation and language preferences are analysed in separate sub-sections.

The average size of households has declined since 2001, across all three regions in the Project Area, in urban and rural areas and according to the national average (2001: 5.1; 2016: 3.9). This is likely related to the increased rates of urbanisation across the country (refer above), and especially in the Project Area; whereby in particular more expensive housing in the urban areas may encourage smaller families.

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It is interesting to note that households are smallest in the Erongo Region and largest in the Otjozondjupa Region, likely reflecting the differing urbanisation rates between these two regions (larger households in more rural areas). Despite being slightly more urbanised than the Erongo Region, households in the Khomas Region are marginally larger, perhaps a reflection of the relatively larger numbers of people in the informal areas of Windhoek.

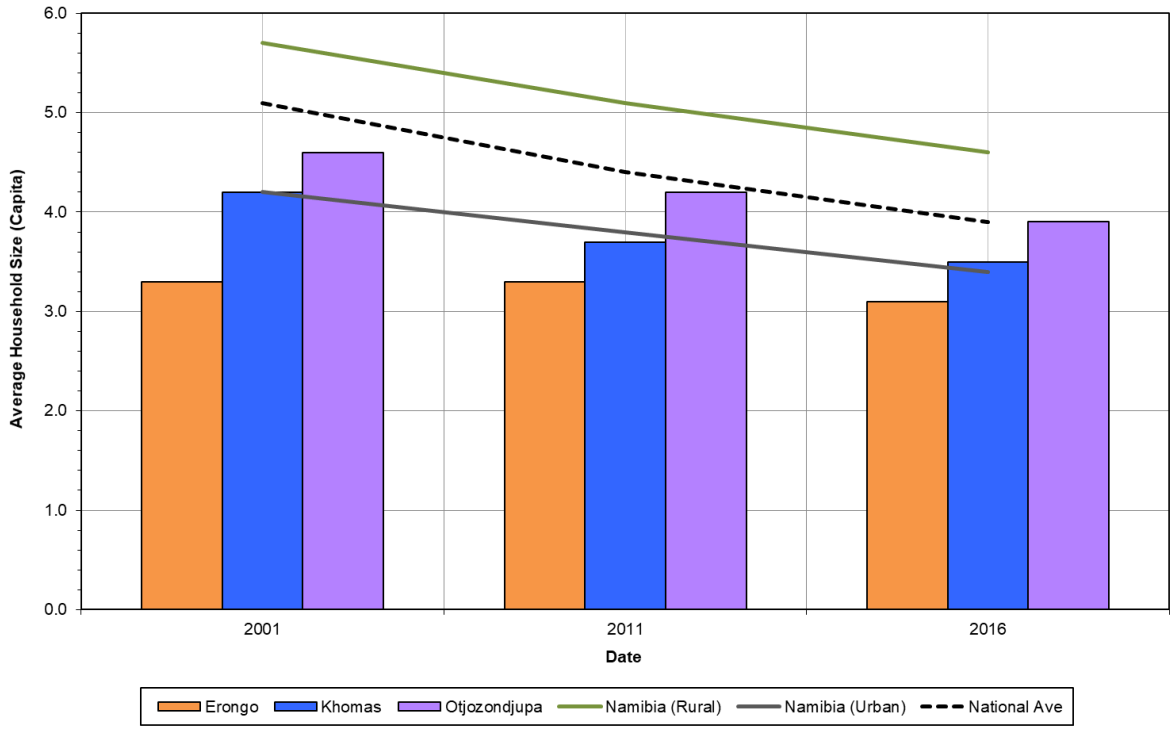

Figure 2.7: Average Household Size per Region and Year in Selected Regions in Namibia (NSA)

Notes:
1. 2001 data from the 2011 census report (NSA, 2012a).
2. 2011 and 2016 data from the 2016 Inter-censal Demographic Survey (NSA, 2017b).

Across Namibia, more households were in 2016 headed by males (54%) than females (46%), which is unchanged in relative terms from 2011. More households are male-headed in both in urban (M:56%; F: 45%) and rural (M: 51%; F:49%) areas, though the difference is markedly smaller in rural areas (NSA, 2017b). In the Erongo, Khomas and Otjozondjupa Regions, approximately 60% of households are male-headed, which rates are among the highest in the country on a regional basis (NSA, 2017b). All three regions (Erongo: 0.9%; Khomas: 0.6% and Otjozondjupa: 1.0%) have a lower portion of households headed by children (18 years and younger) than the national average (1.2%). All three regions (Erongo: 0.1%; Khomas: 0.1% and Otjozondjupa: 0.3%) also have a lower portion of orphan-headed households than the national average (0.3%; NSA, 2017b). These trends correlate with the relative wealth of these three regions (**Table 2.6**).

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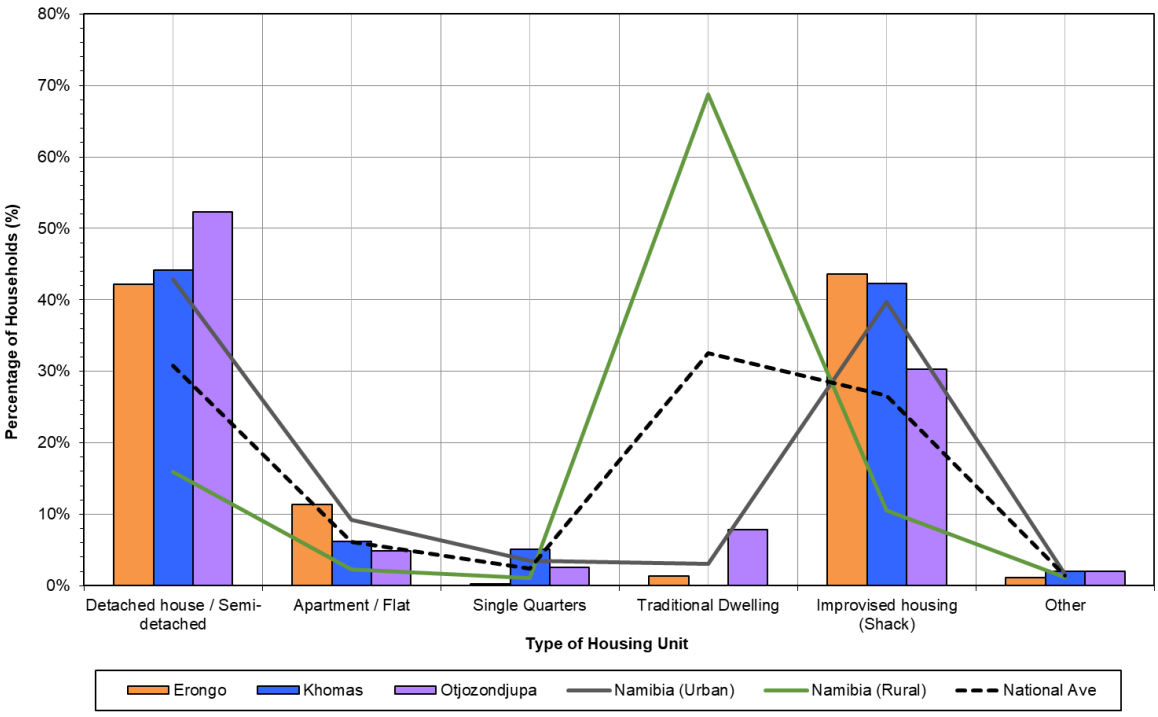

Figure 2.8: Type of Housing Unit in Selected Regions in Namibia (NSA, 2017b)

In the Erongo and Khomas Regions, roughly equal numbers of households live in detached or semi-detached housing units (Erongo: 42%; Khomas: 44%) than lice in informal housing or shacks (Erongo: 44%; Khomas: 42%). A greater portion of households in the Otjozondjupa Region live in detached or semi-detached housing units (52%) than do in informal housing or shacks (30%).

The majority of housing in rural areas comprises traditional dwellings (69%), whilst in urban areas, housing is not likely to be a traditional dwelling (3%) and is approximately evenly split between detached or semi-detached housing units (43%) and informal housing or shacks (40%; NSA, 2017b).

Water use patterns are influenced by the high numbers of people (households) living in informal housing or shacks in urban areas. Historically, large numbers of people migrating to urban areas (refer above) have found shelter in this manner, served largely by communal standpipes, resulting in relatively low per capita consumption rates. This is why in Windhoek for example, the rate of increase in water demand has not corresponded with the rate of increase of the capital's population. In the future, should the Namibian Government succeed with initiatives to provide more formal housing, water demand can be expected to increase, since unit water consumption rates increase from service provision with standpipes to serviced erven (yard connections) and again to housing with plumbing.

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For example, a 2010 assessment of Windhoek's household level water consumption rates found unit consumption rates in the informal settlements of 21 ℓ/c/d at community taps, 29 ℓ/c/d at prepaid or public taps and 109 ℓ/c/d on serviced erven (tap on property), illustrating how unit consumption generally increases as the source distance and number of users decrease (Uhlendahl et al., 2010).

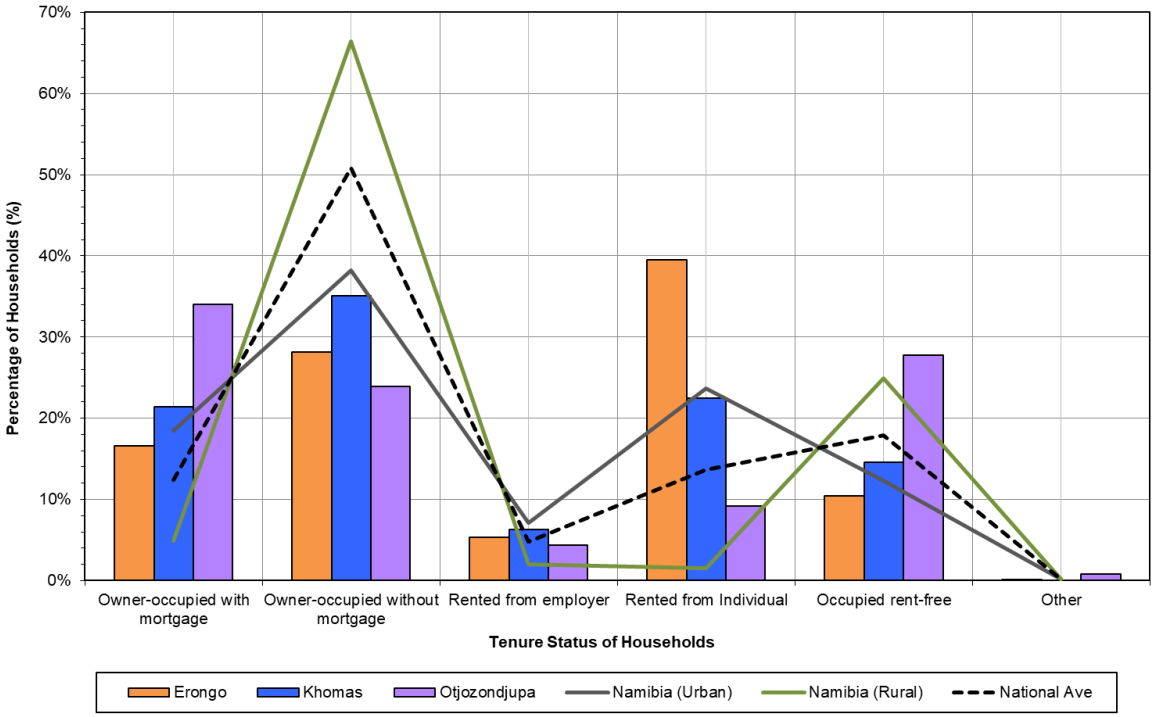

Figure 2.9: Tenure Status of Households in Selected Regions in Namibia (NSA, 2017b)

The tenure of households, being the conditions which govern their rights to occupy dwelling units (NSA, 2017b), varies substantially across the Project Area and between urban and rural areas in the country. In the Erongo and Khomas Regions more households occupy their dwellings free of mortgage (Erongo: 28%; Khomas: 35%) than do so with a mortgage (Erongo: 17%; Khomas: 21%), whilst the opposite is true in the Otjozondjupa Region (with mortgage: 34%; without: 24%). In the Erongo Region, the majority of housing is rented (45%), whilst more than a quarter (28%) is occupied rent-free in the Otjozondjupa Region (NSA, 2017b). The majority of housing in rural areas which consists of traditional dwellings (69%) is owned (66%; mortgage-free) whilst a quarter (25%) is occupied rent-free, and little property is rented (3.5%; NSA, 2017b).

2.2.7 Analysis of Household Consumption

Consumption gives an indication of the expenditure of households. The results reveal the huge disparity between rural and urban areas, where the average annual consumption per capita in rural areas is N$ 16 848 compared with the N$ 41 575 in urban areas. Rural areas represent 46% of the households and 53% of the population, but they account for only 31.5% of the total consumption (NSA, n.d[1]).

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Measured by household consumption, the Khomas Region, most of whose characteristics can be attributed to Windhoek, is the wealthiest region in the country, followed by the Erongo Region, with both regions featuring household consumption well above the national average (twice the national average in the Khomas Region and 1,5 times the national average in the Erongo Region). The Otjozondjupa Region is the sixth wealthiest in the country, with household consumption marginally below the national average.

Table 2.6: Results of Namibia Household Income and Expenditure Surveys (NHIES)

Region	2015/16 NHIES Survey[2]			2009/10 NHIES Survey[3]
	Portion of National Population (%)	Average Household Consumption per Annum (N$)	Annual Consumption per Capita (N$/capita)	Poor in Region (%)
!Karas	3.7	116 875	32 760	15.3
Erongo	7.7	128 617	42 752	5.1
Hardap	3.8	146 157	35 675	17.2
Kavango East	6.4	698	12 091	43.4[5]
Kavango West	3.9	73 358	12 006	
Khomas	17.5	209 555	58 807	7.6
Kunene	4.2	62 612	14 059	16.8
Ohangwena	11.1	94 482	18 082	23.7
Omaheke	3.2	79 140	20 992	20.9
Omusati	10.9	67 792	14 484	12.6
Oshana	8.2	117 508	28 541	13.5
Oshikoto	8.4	89 944	19 352	33.9
Otjozondjupa	6.7	99 805	25 051	22.9
Zambezi (Caprivi)[6]	4.3	55 112	12 446	41.7
Total	**100**	**119 065**	**28 434**	**19.5**
Urban	46.9	150 692	41 575	9.5
Rural	53.1	81 742	16 848	27.2

Notes:
1. NHIES = National Household Income and Expenditure Survey.
2. Data from the 2015/16 NHIES Survey (NSA, n.d.[1]).
3. Data from the 2009/10 NHIES Survey (NSA, 2012b).
4. Note that the same data is not provided for the 2015/16 NHIES survey as for the 2009/10 survey, thereby preventing the direct comparison of values between the surveys and also necessitating the use of some values from the 2009/10 NHIES which are not provided in that of 2015/16.
5. The Kavango Region before it was divided into the Kavango East and Kavango West Regions. These changes were made after the 2009/10 NHIES.
6. Previously the Caprivi Region.

Household consumption across all categories measured is higher in the Khomas Region than in the Erongo and Otjozondjupa Regions (**Figure 2.10**).

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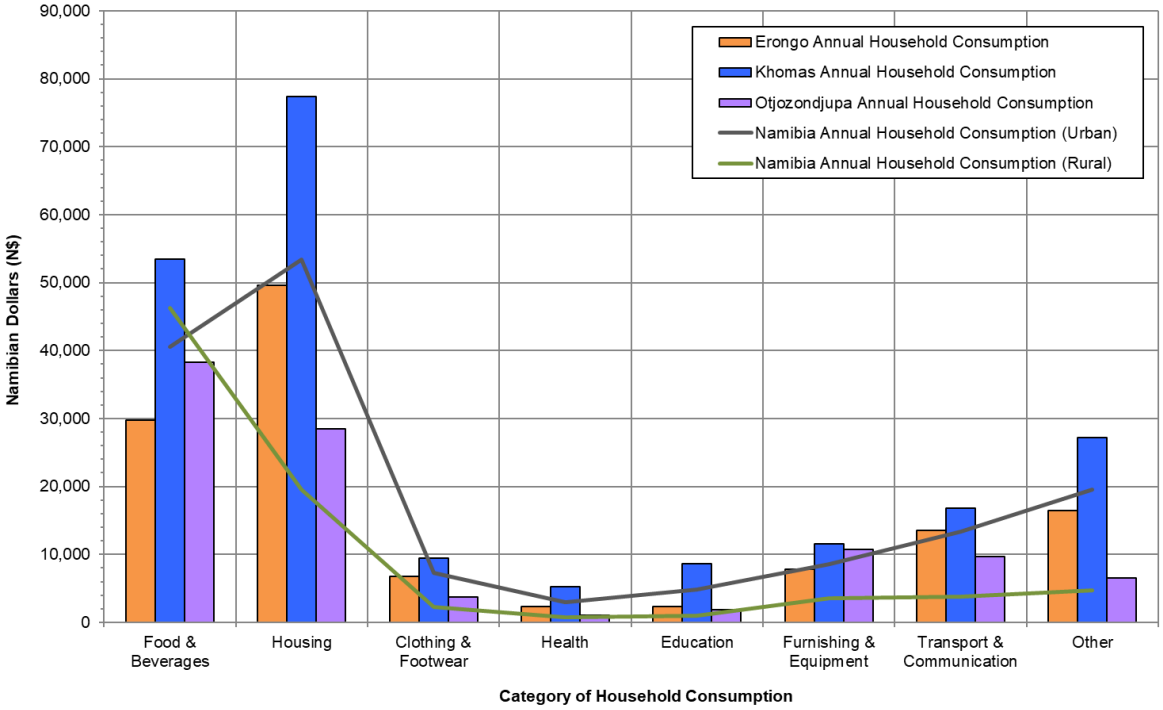

Figure 2.10: Average Annual Household Consumption in Selected Regions in Namibia (NSA)

Note: Data from the 2015/16 NHIES Survey (NSA, n.d.[1]).

Interestingly food and beverages and furnishings and equipment are the only categories where household consumption is higher in the Otjozondjupa Region than in the Erongo Region. Household consumption in the Khomas Region is higher across all categories than the national average for urban areas; again indicating the relative wealth of this region, or Windhoek, its main centre. Household consumption in the Erongo Region is reasonably close to the national average for urban areas.

In 2009/10, the Khomas and Erongo Regions were the only two in the country where the two less than 10% of the regional population were classified as poor (NSA, 2012b), again indicating that these are the two wealthiest regions in the country.

2.2.8 Analysis of Incomes

By far the largest portions of household incomes in the Erongo (80%), Khomas (73.2%) and Otjozondjupa (69.2%) regions derive from salaries and wages. The relative distribution of these rates corresponds with the urbanisation rates of these three regions in the Project Area, indicating that salaried and waged income dominates in urban areas, which is to be expected. Less than 10% of households derive their incomes from any of the other categories (**Figure 2.11**), with the exception of business incomes in the Khomas Region (12.8%). The relative distribution of incomes across categories in these three regions also much more closely matches the national average for urban areas than for rural areas, confirming the effect of high rates of urbanisation, particularly in the Erongo and Khomas Regions.

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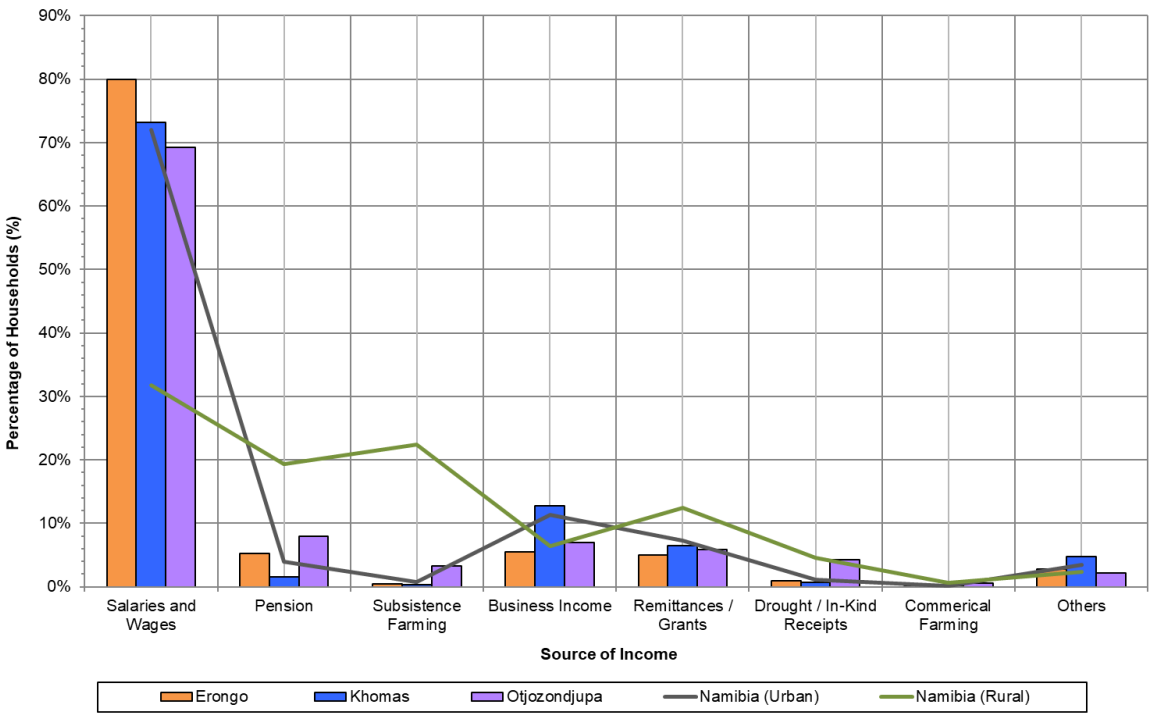

Figure 2.11: Sources of Household Income for Selected Regions in Namibia (NSA)

Note: Data from the 2015/16 NHIES Survey (NSA, n.d.[1]).

2.2.9 Analysis of Employment

Although roughly similar portions of the population were employed over the period between 2013 and 2018 (±69-71%), the numbers of people employed in Namibia have varied more substantially. Employment declined markedly in 2016, from a relative 2-year high in 2014 (**Figure 2.12**), corresponding with the contraction of the economy over this period (refer to **Section 2.1**). Somewhat surprisingly, the NSA's latest labour force survey shows that employment numbers increased markedly in 2018, to the highest portion and number of people employed since 2012.

The labour force survey conducted by the NSA employed a methodology and definitions consistent with local, SADC, AU and international standards "for comparability purposes" (NSA, 2019). In terms of economic activity and employment, only the portion of the population above 15 years of age are considered. People who are not economically active (economically inactive) include those younger than 15 years, and those older than 15 years who are not in employment or who are not available for work since they are full-time learners or students, homemakers, ill, disabled or retired (NSA, 2019). The "labour force" consists of all persons of working age (15+) who are either employed or not employed.

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The Labour Force Participation Rate (LFPR) is the portion of the economically active population in a given population (i.e. the number of persons in the labour force as a percentage of the working age population) (NSA, 2019).

The employment to population ratio is defined as the portion of the working age population (15+) who are employed (NSA, 2019).

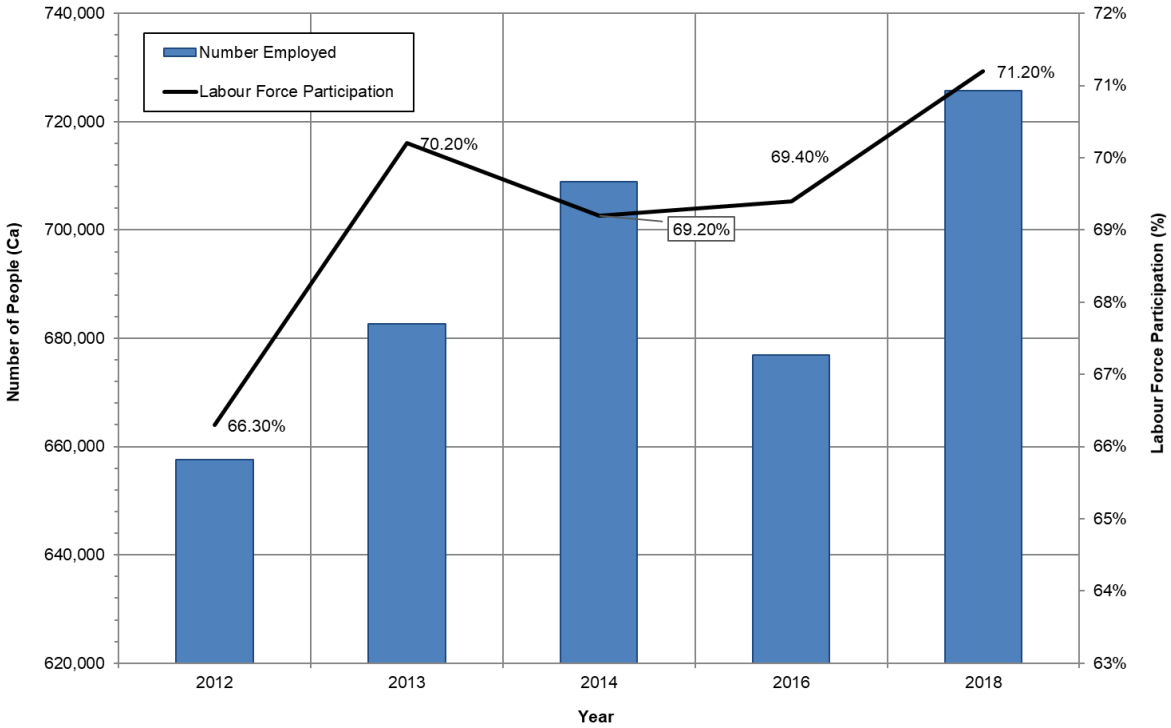

Figure 2.12: Employment in Namibia (NSA, 2019)

Note: SADC Minimal Indicator List per the Namibia Labour Force Survey 2018 Report (NSA, 2019)

On a regional basis, the population of the Otjozondjupa Region is younger than that in the Erongo and Khomas Regions (**Figure 2.13**). The employment statistics and employment rates follow a similar pattern between the three regions in the Project Area; highest in the Erongo Region, lowest in the Otjozondjupa Region, with *in-between* values for the Khomas Region. Informal employment (without social protection) is highest in the Otjozondjupa Region, perhaps reflecting the higher portion of rural population in this region relative to the other two. As could be expected, employment metrics are higher in the urban areas than in the rural areas and informal employment higher in the rural areas than in the urban areas. Employment metrics in the Erongo and Khomas Regions are higher than the national average for urban areas, reflecting the very high rates of urbanisation in these two regions. The employment metrics for the Otjozondjupa Region generally fall between the national averages for urban and rural areas, indicated the more mixed nature of settlement in this region (66% urban population) relative to the other two regions.

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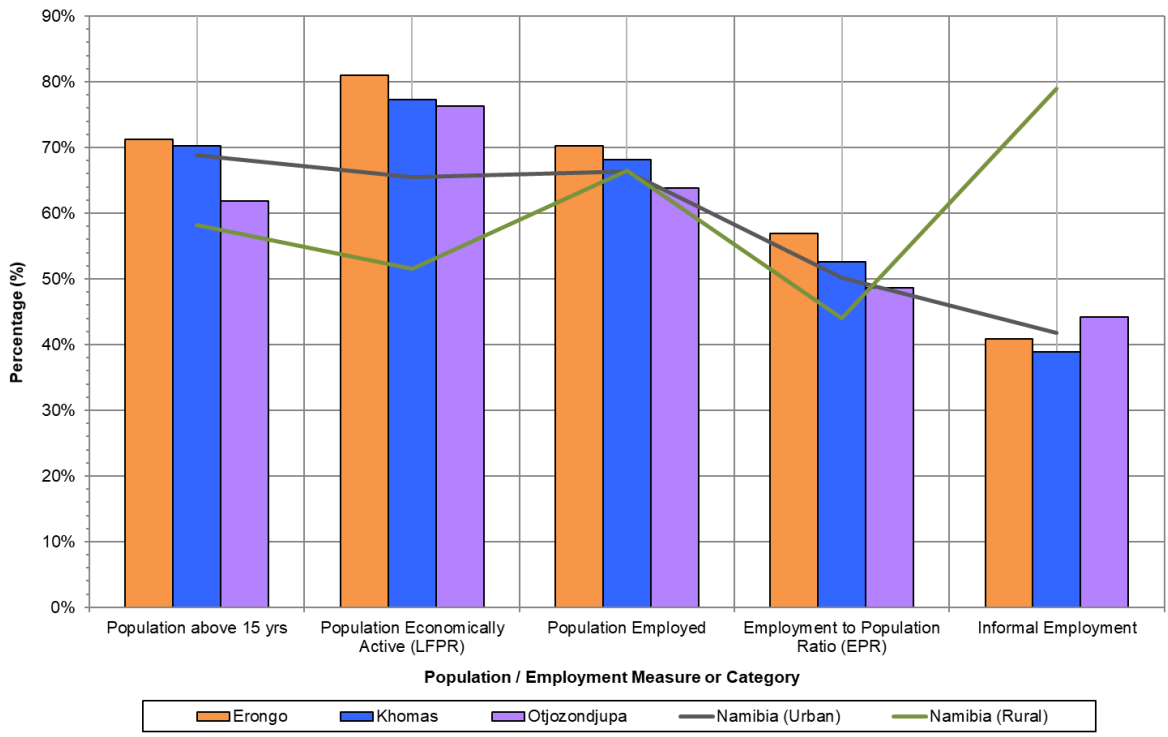

Figure 2.13: Employment Metrics in Selected Regions in Namibia (NSA, 2019)

Notes:
1. Data from The Namibia Labour Force Survey 2016 Report (NSA, 2019).
2. The population above the age of 15 years is the portion of the population considered eligible for employment.
3. The Economically Active population or Labour Force Participation Ratio is of the portion of the population 15 years and older who are economically active (i.e. those not studying, homemakers, disabled, ill or retired).
4. The Employment to Population Ratio is defined as the portion of the population 15 years and older who are employed.
5. Informal Employment indicates the portion of those employed who do not have access to some form of social protection; i.e. no pension scheme, medical aid and / or social security.

Overall, the higher rates of employment in the Erongo Region (**Figure 2.13**) correlate with higher portions of households receiving their income from salaries and wages in this region (**Figure 2.11**) and the relative prosperity of this region in the national context (**Table 2.6**).

2.2.10 Poverty Aspects

Poverty thresholds are used for mapping the occurrence of poverty, creating poverty profiles and estimating deprivation indices. In 2003/04, Namibia introduced a paradigm shift with the measuring of the poverty threshold, away from the conventional food consumption ratio to the use of a cost of basic needs approach (NSA, n.d.[1]). Two poverty lines were defined; an upper and a lower bound. People below the upper bound poverty line are classified as “poor”, whilst those below the lower bound are regarded as “severely poor”. Since the 2003/04 survey, similar methods have been used to calculate these bound lines, with the figures adjusted for inflation effects (NSA, n.d.[1]).

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Table 2.7: Namibia's Poverty Thresholds (NSA)

Poverty Lines	Poverty Lines (N$ / adult / month)		
	2003/04	2009/10	2015/16
Food Poverty Line (Food Poor)	127.15	204.05	293.10
Lower Bound Poverty Line (Severely Poor)	184.56	277.54	389.30
Upper Bound Poverty Line (Poor)	262.45	377.96	520.80

Notes:
1. Data from the 2015/16 NHIES Report (NSA, n.d.[1]).

Individuals falling below the upper bound poverty line are considered poor while those falling below the lower bound poverty line are considered severely poor. Individuals falling below the food poverty line are food poor since their total consumption expenditure is insufficient to meet their daily calorific needs (NSA, n.d.[1]).

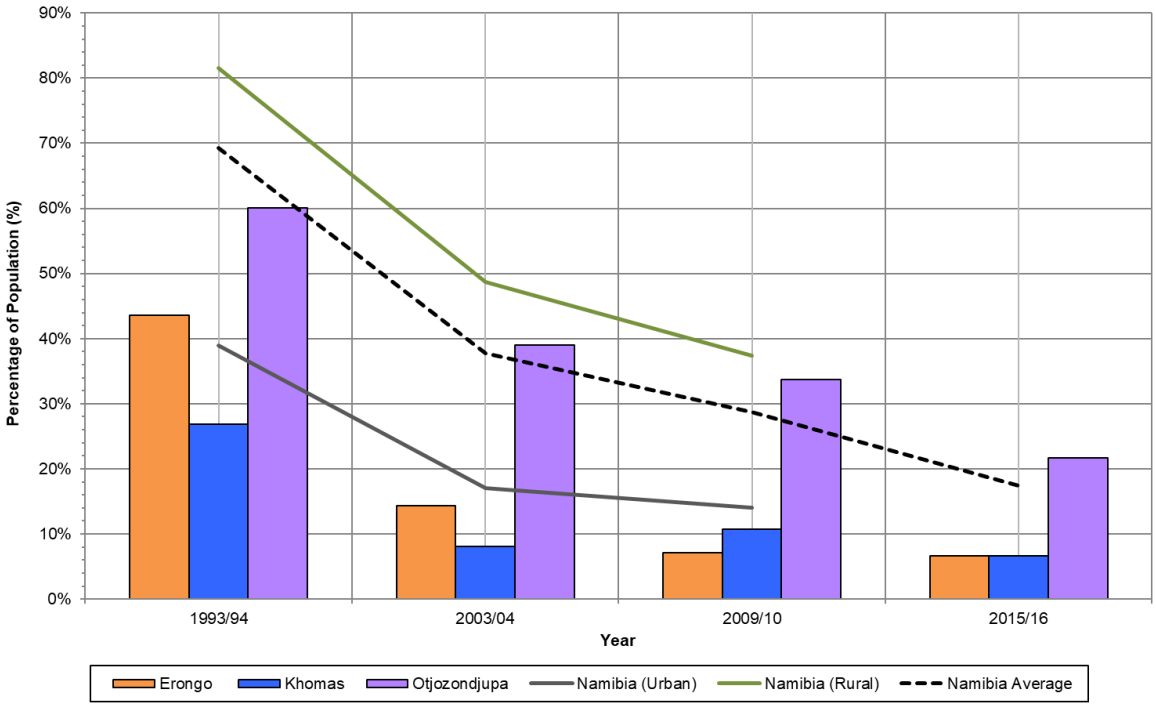

Figure 2.14: Incidence of Poverty in Selected Regions in Namibia (NSA)

Notes:
1. Data from 1993/93, 2003/04 and 2009/10 from The Poverty Dynamics in Namibia Report (NSA, 2012c).
2. Data from 2015/16 for the 2015/16 NHIES Survey (NSA, n.d.[1]). This report only contains regional data in a colour-coded map plot (i.e. not disaggregated values per region and no values for urban and rural areas). The average of the values for the different colour shades have been applied for each region.

The incidences of both poverty (**Figure 2.14**) and severe poverty (**Figure 2.15**) have generally decreased over time on both regional and national levels, and in both urban and rural areas. The anomalous exceptions have been the small increases in poverty and severe poverty in the Khomas Region between 2003/04 and 2009/10. Overall, however, the trends of decreasing poverty over a period of 22 years are clear.

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This could be attributed to generally good economic growth over the period, both in terms of GDP and GDP per capita.

Poverty incidence is higher in rural areas than in urban areas, corresponding with the disparity in consumption rates between these areas. Incidences of both poverty and severe poverty are higher in the Otjozondjupa Region than in the Khomas and Erongo Regions, mirroring the lower household consumption and incomes from salaries and wages in the Otjozondjupa Region. In 2009/10, the last period for which disaggregated regional data is available, the Erongo Region featured lower numbers of poor and severely poor than even the Khomas Region.

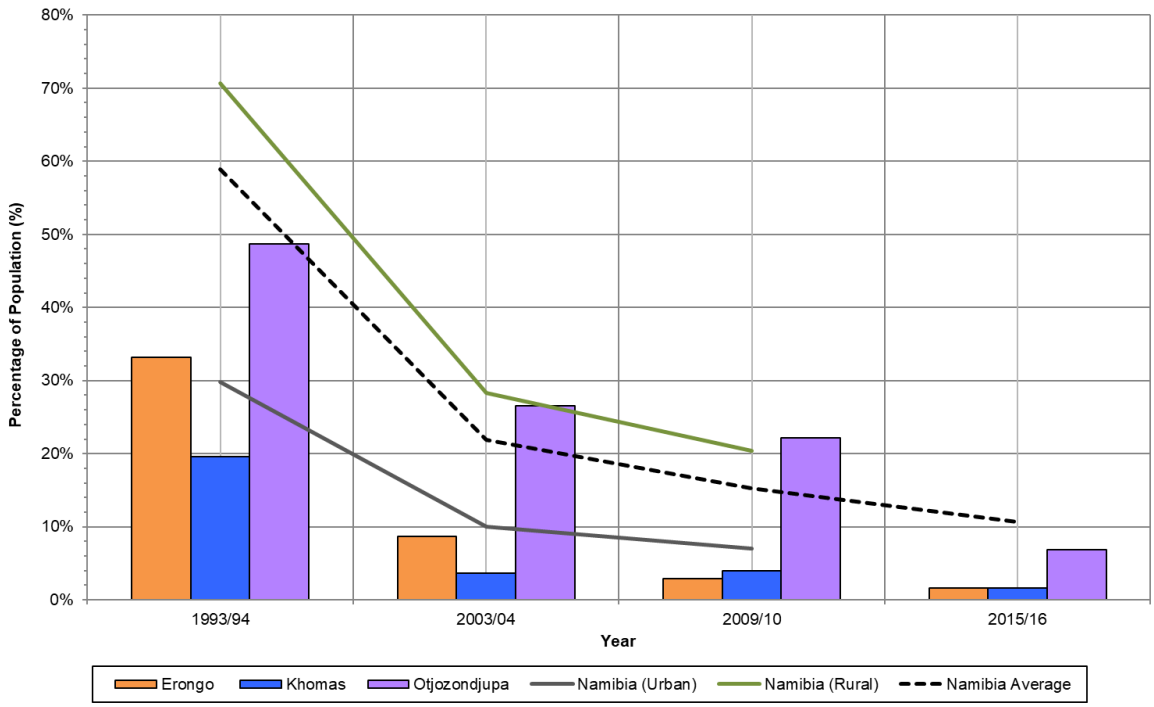

Figure 2.15: Incidence of Severe Poverty in Selected Regions in Namibia (NSA)

Notes:
1. Data from 1993/93, 2003/04 and 2009/10 from The Poverty Dynamics in Namibia Report (NSA, 2012c).
2. Data from 2015/16 for the 2015/16 NHIES Survey (NSA, n.d.[1]). This report only contains regional data in a colour-coded map plot (i.e. not disaggregated values per region and no values for urban and rural areas). The average of the values for the different colour shades have been applied for each region.

Economic growth has slowed markedly since 2015/16 (**Figure 2.2**), with Namibia in recession since the second half of 2016, which makes it likely that some of the gains over the period between 2003/04 and 2015/16 may have been at least partially reversed. As a result of a contracting economy, including layoffs in particularly the construction sector (Nakashole, 2017), poverty and inequality may have increased in the period since 2015/16.

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2.2.11 Inequality Aspects

2.2.11.1 Inequality and the Gini Coefficient

The Gini coefficient is the most widely used measure to assess inequality, and as such, is a key metric tracked by the World Bank and others. This coefficient is "*a measure of statistical dispersion intended to represent the income or wealth distribution of a nation's residents*" (Wikipedia, 2019[1]).

In simplified terms, a Gini coefficient of zero represents perfect equality, where all people would have the same income, whilst a Gini coefficient of one (or 100%) represents "maximal inequality", where for a large number of people, only one person has all the income and the others none (Wikipedia, 2019[1]).

Whilst this is a simplified explanation[7], since it may technically be possible to have a coefficient value greater than one, this interpretation of the Gini coefficient provides an easy to understand index which can be used to interpret the income inequality within a country and to compare the inequality between different countries and regions in the world.

Gini coefficients can be interpreted as follows (Wikipedia, 2019[1]):

- Low inequality: A Gini coefficient below 30, for example countries such as Austria, Germany and the Scandinavian countries;
- Medium inequality: A Gini coefficient of 30 and above for example countries such as Vietnam, Mexico, Poland, the United States, Russia, and Venezuela;
- High inequality: A Gini coefficient of 50 and above, for example countries such as Brazil, Chile, Botswana, and Honduras.

2.2.11.2 Income Inequality Across the World

A map which indicates the Gini coefficients of countries across the world is provided as **Figure 2.16**.

Whilst the coefficient values may not be up to date and the colouring is simplistic, this map does provide an indication of relative income inequality around the world; very low in the Scandinavian countries, low in Europe, India, Canada and Australia, medium in the USA and Russia and high in Mexico, some African countries, to very high across South America, Central and Southern Africa.

[7] The Gini coefficient is a relative measure and its proper use and interpretation is considered somewhat controversial (Garett, 2010), including its use as an indicator of poverty. However, for the purposes of this report its use is considered appropriate, since it is a widely used and easily understood index of inequality and a means to compare inequality between countries and track changes in inequality within a country over a period of time.

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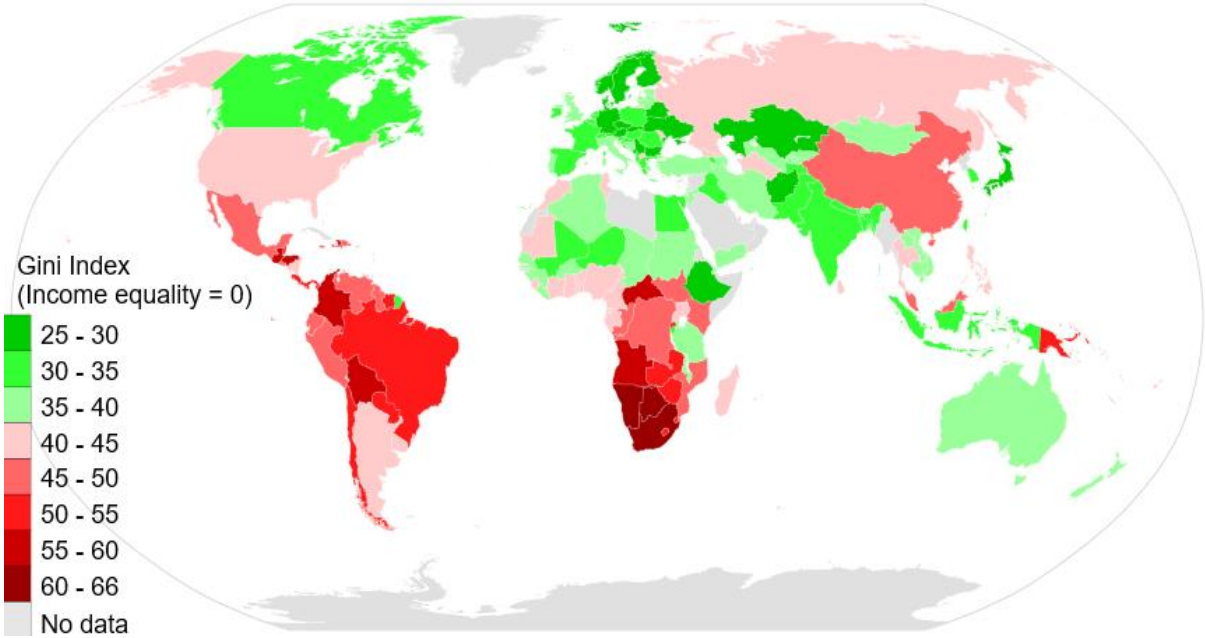

Figure 2.16: Income Inequality Across the World (Hunter, 2014)

2.2.11.3 Income Inequality and Poverty in Namibia

The Gini coefficient (income inequality) is tracked, together with poverty indicators, under the regular National Household Income and Expenditure Surveys (NHIES) conducted by the NSA. These values over the period 19939/4 to 2015/16 are shown below.

Table 2.8: Inequality and Poverty Estimates for Namibia (NSA, n.d.[1])

Indicator / Date	Unit	1993/94	2003/04	2009/10	2015/16
Population	ca		1 817 251	2 066 398	2 280 716
Average annual per capita consumption	N$/c/a	3 031	8 839	14 559	28 434
Gini coefficient	%	70.1	60.0	59.7	56.0
Poor households (incl. severely poor)	%	N/A	27.6	19.5	17.4
Severely poor households	%	N/A	13.8	9.6	10.7
Upper Poverty Line	Head count ratio %	N/A	37.5	28.8	17.4
Lower Poverty Line	Head count ratio %	N/A	21.8	15.4	10.7
Food Poverty Line	Head count ratio %	N/A	11.0	7.2	6.1

Notes:
1. Results of the 2001 population census (NSA, 2012a).
2. All other data from the 2015/16 NHIES NSA, n.d.[1] Only the Gini coefficient is available from 1993/94.

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The Gini coefficient, as well as the portions of the total population below each poverty line or bound, has decreased over the period between 2003/04 and 2015/16. This could be attributed to generally good economic growth over the period, both in terms of GDP (refer to **Section 2.1**) and GDP growth per capita. Whilst these statistics indicate good progress in the reduction of poverty and inequality in Namibia, a Gini coefficient of 56% in 2015/16 is very high, making Namibia among the most inequal countries in the world in terms of income distribution (with reference to **Figure 2.16**).

However, the Gini coefficient has not decreased by the same extent as poverty generally; for example, the 20% less of the population fall below the Upper Poverty Line between in 2015/16 compared with 2003/04, whilst the Gini coefficient has decreased by only 4% over the same period.

This is most likely due to the fact that economic growth over this period has not been fully inclusive: “a rising tide may lift all boats”, but not all are lifted to the same extent. With 17% of the Namibian population classified as “poor”, many people still struggle to survive and meet their basic needs with dignity.

As noted in the section above, with economic growth having slowed markedly since 2015/16, and following layoffs as a result of the contracting economy, poverty and inequality may have increased in the period since.

2.2.12 Water Supply and Sanitation

2.2.12.1 Access to Water Supply

Increasing the availability of access to safe water has been one of the Namibian Governments key aims with Vision 2030, successive National Development Plans and The Harambee Prosperity Plan. Significant progress has been made in this regard, such that 92.9% of the population is considered to have access to safe drinking water, up from 80% in 2011. In 2016, 99.4% of the population in urban areas and 85% of that in rural areas had access to safe drinking water (NSA, 2017b).

Basically the whole (99.6%) of the Khomas Region and nearly all of the Erongo (97.4%) and Otjozondjupa (98.3%) Regions have access to safe drinking water, most of which is piped either inside or outside the household.

However, significant portions of the population (Erongo: 14.7%, Khomas: 32.5% and Otjozondjupa: 25.6%) rely on public standpipes for water supply (NSA, 2017b), most likely in the high density residential and informal areas.

It is interesting to note the higher portion of households served by public standpipes in the Khomas Region, which is mostly likely due to the relatively larger numbers of people in the informal areas of Windhoek.

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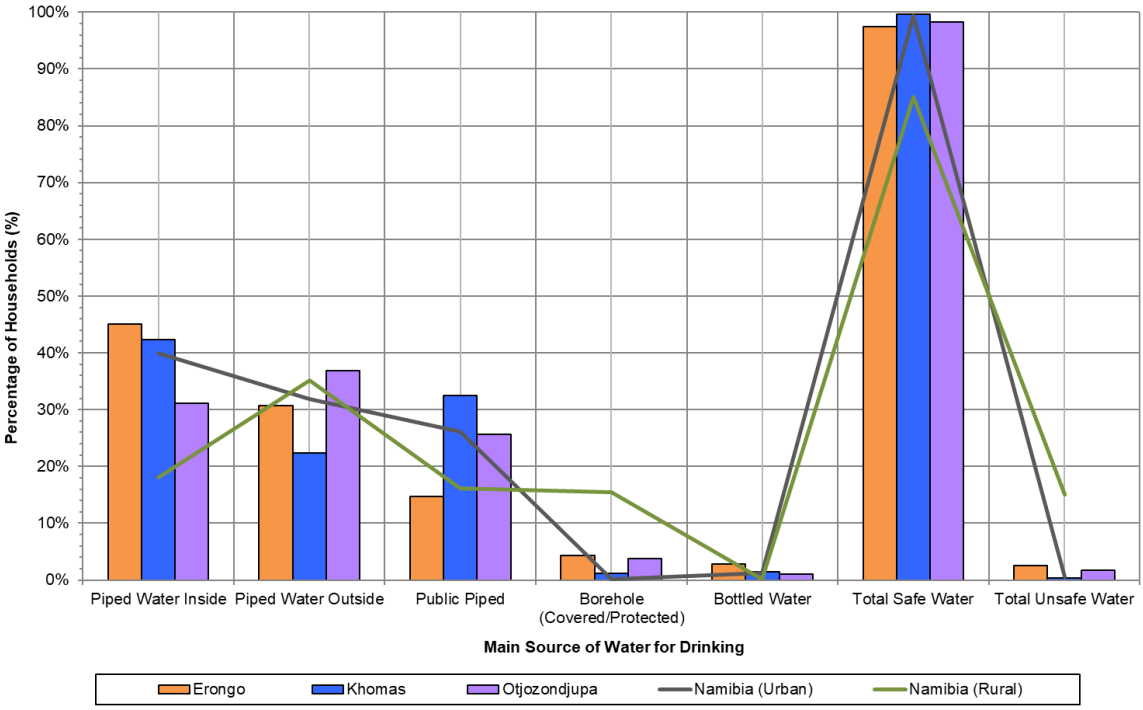

Figure 2.17: Access to Drinking Water in Selected Regions in Namibia (NSA)

Note: Results of the 2016 Inter-censal Demographic Survey (NSA, 2017b).

Other aspects of access to drinking water such as distance to point of supply, waiting time (at communal standpipes), household expenditure and percentage of income spent on water and gender aspects of the abovementioned are not available from formal statistics.

2.2.12.2 Access to Sanitation

The re-naming of the Directorate of Water Supply and Sanitation Coordination in 2008 (previously the Directorate of Rural Water Supply) and the publication of the Water Supply and Sanitation Policy in July 2008 notwithstanding, improved sanitation coverage has not enjoyed the same focus, application of resources (including funding) or success as has improved access to water supply. As a result, nearly half of households (45.7%) in 2016 had no toilet facilities, with a much higher portion of households so affected in rural areas (70%) compared with urban areas (26%; NSA, 2017b).

More households in the Erongo Region have access to flush toilets (75.6%) than in the Khomas (71.4%) or Otjozondjupa (48.0%) Regions. In the case of all three regions, this access is greater than the national average for urban areas (63.2%), markedly so in the case of the former two. However, relatively large portions of households have no access to flush toilets or any other type of toilet facility; 24.3% in the Erongo Region, 28.6% in the Khomas Region and 52.1% in the Otjozondjupa Region (NSA, 2017b).

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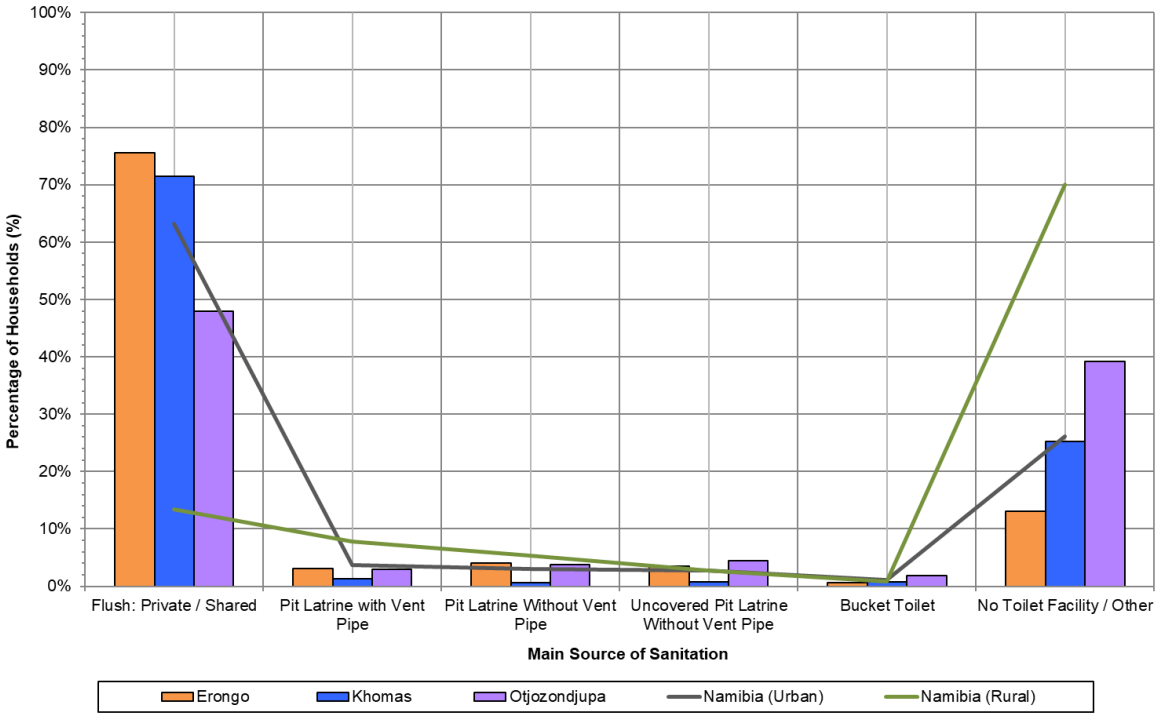

Figure 2.18: Access to Sanitation in Selected Regions in Namibia (NSA)

Note: Results of the 2016 Inter-censal Demographic Survey (NSA, 2017b).

2.2.12.3 Occurrence of Hepatitis

It is further interesting to note that occurrences of Hepatitis in the coastal towns of Walvis Bay, Swakopmund and Henties Bay were reported to the Consultant during consultations with the various local authorities during March 2019 (refer to **Section 4.4.1** for the record of consultations). Towards the end of 2017 and into early 2018, an outbreak of Hepatitis E occurred in some areas of Windhoek. First reported in October 2017, and outbreak was declared on 14 December 2017 (reliefweb, 2018 and Kapitako, 2019). In Windhoek, the outbreak was reported to be concentrated in the informal settlements of Havana, Goreangab, Hakahana, Greenwell Matongo, Ombili and the broader Katutura. The majority of the patients were from the informal settlements of Havana and Goreangab (reliefweb, 2018). The disease has since spread to other regions except the Zambezi and !Karas Regions and by 27 January 2019, the Ministry of Health and Social Services (MoHSS) reported a total of 4 432 Hepatitis E cases in the country and a total of 40 deaths (Kapitako, 2019a), leading to concerns by the Minister of the MoHSS, Dr. Shangula, that the disease may become endemic in some areas (Kapitako, 2019).

Hepatitis E is a liver infection which is spread by the faecal-oral route, including by contamination of food or water, and is fuelled mainly by a lack of clean water, poor sanitation and personal hygiene (reliefweb, 2018).

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These developments are likely caused by large numbers of people settling in the informal areas of various towns, having left the rural areas to do so, likely in search of better opportunities, where water and sanitation services are either inadequate or non-existent. This may serve as a warning of some of the possible consequences of unplanned urbanisation and inadequate infrastructure.

2.2.12.4 Other Aspects Related to Health and Sanitation

Two different officials in the Ministry of Health and Social Services (MoHSS) were approached for information regarding other water, sanitation and hygiene (WASH)-related information, including on the incidences of diseases such as diarrhoea, typhoid, dysentery and cholera; the Acting Director for Primary Health Care and the National Surveillance Officer, Epidemiology Division. Neither of these attempts were successful and no further information could be obtained from official sources regarding WASH-related diseases, or information such as deaths, lost productive time and resources and overall reduced livelihoods for the affected individuals or communities.

The occurrence of Hepatitis in the (mostly) informal settlements in the urban centres in the Project Area is an indication of poor sanitation / hygiene, which has several contributory factors, including the following (Dr. Miller[8], 2019 pers. comm., 16 July):

- People collect water at communal standpipes, which is stored for a few days before use. During this time the chlorine residuals degrade, which means that the water is not properly disinfected at the time of use;
- Many of the residents in the informal settlements come from the rural areas where open defecation is practiced, and who are not accustomed to using “normal” toilets. Open defecation is not as much a health risk in the rural areas due to the lower densities of people, but in the informal settlements with much higher population densities, this is a health risk;
- The local authorities cannot keep up with the influx of people into informal settlements in terms of the provision of services, resulting in a much higher loading on the services (for example number of people per toilet) than was designed for;
- Traditionally, communal hand washing is practiced, where a bowl of water is used for hand washing by a number of people. Whilst this may be advantageous from a water conservation perspective, it is not a hygienic practice.

[8] Dr. L. A. Miller of the American Centre for Disease Control which has since 2002 been assisting the MoHSS with funding support and technical assistance to build the capacity of Namibia’s healthcare workforce.

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2.2.12.5 Water Demand Associated with Improved Service Levels

Should the Namibian Government succeed with initiatives to formalise and improve the levels of water and particularly (wet) sanitation services to households, for which there is significant scope and need, water consumption can be expected to increase, markedly in the case of the latter. Whilst affordability remains a major concern, both at individual / household (refer to **Section 2.2.10** on poverty aspects and **Section 2.2.11** on inequality aspects and the Gini coefficient) and public sector levels, there is believed to be a significant latent demand should the service level of water supply and sanitation be improved and the prosperity of inhabitants in the informal settlements improve.

2.2.13 Gender Issues and Education

The 2016 National population (2 324 388) is slightly more female (51.4%) than male (48.6%), which is very similar to the situation in 2011 (51.6% female), 2001 (51.5% female) and 1991 (51.3% female; NSA, 2017b), giving a sex ratio of 95 males per 100 females in 2016 (NSA, 2017b). Particularly among older groups of the population (49+), there is a greater portion of females than males (NSA, 2017b).

The sex ratios in urban and rural areas are very similar, both to each other and the national figure; 51.2% female in urban areas and 51.6% in rural areas. However, there are more males in the Erongo (52.9% male) and Otjozondjupa (51.5%) Regions. In the case of the former, this could be explained by employment opportunities in the mining sector, which is likely male-dominant. In the Erongo Region, the male LFPR is 86%, whilst for females, it is 75%. The disparity in employment rates is much smaller in the Khomas Region (LFPRs 80% male, 74% female) and Otjozondjupa Region (LFPRs 79% male, 73% female; NSA, 2019).

Of the population aged 15 years and older, the majority are not married (64%), with 31% married either conventionally (16% with certificate) or on a customary basis (6% married traditionally and 9% consensually). The number of female-headed households is however slowly increasing, from 39% of households in 1991 to 46% in 2016 (NSA, 2017b).

The population with disabilities is almost evenly split between males (4.8%) and females (4.6%). However, proportionally slightly more females suffer from hearing (M: 14.2%; F: 17.8% and visual impairments (M: 26%; F: 32.6%), while more males suffer from physical impairments (upper and lower limbs; M: 50.9%; F: 43.2%; NSA, 2019b).

Of the population 15 years and older, those with disabilities causing them difficulties with engaging in any economic activity, are split nearly equally between the sexes (M: 62.8%; F: 64.2%). Overall, more people thus affected are in rural areas (69%) than in rural areas (53%). There are no major differences based on sexes in the Erongo, Khomas and Otjozondjupa Regions (NSA, 2017b).

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The population aged 0 – 5 years attending Early Childhood Development is slightly more female (25.1%) than male (24.2%). However, overall, attendance is relatively poor, with only 25% of children attending. Attendance rates in the Erongo (38%) and Khomas (34%) rates are higher than the national average and lower in the Otjozondjupa Region (18%; NSA, 2017b). Primary school enrolment, for children 7 to 13 years old was 95% nationally, and slightly higher among females (95.6%) than males (93.8%).

This gender difference was maintained in urban and rural areas, though urban areas had higher enrolment rates (97%) than rural area (93.4%). Gender parity of enrolment was found in the Erongo Region, with slightly more males enrolled in the Khomas Region and a larger male-weighted disparity in the Otjozondjupa Region (NSA, 2017b).

Of the population aged 15 years and older, more females have completed primary, secondary and tertiary education than males (NSA, 2017b). Less males than females (M: 47.7%; F: 51.4%) have completed primary education, whilst more males have completed secondary education (M: 23.3%; F: 21.9%).

The mortality of males is higher than that of females nationally, in urban and rural areas, in the Khomas and Otjozondjupa Regions, but not in the Erongo Region. The mortality of males is higher among the working age groups, but higher among females in infants (0 – 4 years) and those older than 90 years (NSA, 2017b), which in the case of the latter is to be expected, since there are proportionally more females among the older age groups.

Overall, there appears to be no major gender discrepancies among the basic statistics. The relatively higher educational attainment of females is not significantly different to the results from the 2011 census, indicating that the gains made in this area have been sustained. The increase in female-headed households is however noticeable.

2.2.14 Social Structure

Nearly half of Namibian households are Oshiwambo-speaking (49.7%), which comprises by far the largest language or ethnic group. Other significant language or ethnic groups include the Nama/Damara (11%), the Kavango (10.4%), Afrikaans (9.4%) and Herero (9.2%), with other language or ethnic groups comprising small portions of households (**Figure 2.19**).

The majority of Oshiwambo-speaking households (Oshikwanyama, Oshimbadja, Oshindonga, Oshigandjera, Oshikwaluudhi, Oshikwambi, Oshikolonkadhi, Oshimbalantu and Eunda) reside in the four north-central regions of Namibia (Omusati, Oshana, Ohangwena and Oshikoto). The Kavango-speaking households (Rumanyo, Thimbukushu and Rukwangali) mostly reside in the Kavango East and West Regions. The San-speaking households (Ju/’hoansi and Naro) mostly reside in the eastern Otjozondjupa and Omaheke Regions, with Khwedam-speaking households residing in the western portion of the Zambezi Region. The Zambezi-speaking households mostly reside in the Zambezi Region (Mendelsohn et al., 2009).

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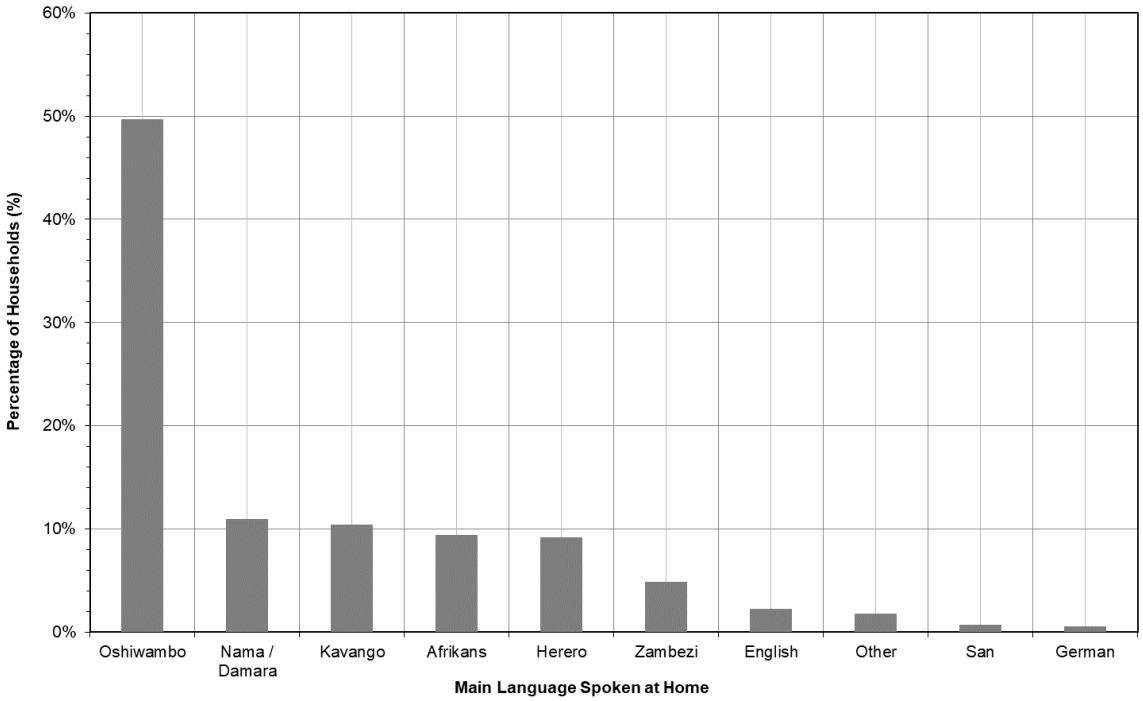

Figure 2.19: Distribution of Households by Home Language (NSA, 2017b)

Notes from NSA, 2017b:
1. Zambezi Languages include Silozi (Sikololo), Sifwe, Sisubiya, Siyeyi (Yei) and Totela.
2. Herero Languages include Otjiherero, Otjimbanderu, Oruzemba, Otjizimba, Otjihakahona, Otjindongona and Otjitjavikwa.
3. Kavango Languages include Rukwangali, Rushambyu, Rugciriku, Thimbukushu, Rumanyo and Rukavango.
4. Other includes Twsana (0.3%), other European (0.1%) and African (0.5%) Languages as well as “Other Languages (1%).

The majority of Nama Khoekhoe-speaking households reside in the Hardap and //Karas Regions, whilst the majority of Otjihimba-speakers reside in the Kunene Region in the north west. The majority of Damara and Otjiherero-speakers reside across the central parts of Namibia (Mendelsohn et al., 2009).

As noted earlier, household and per capita consumption rates provide an indication of the expenditure and thus relative wealth of households and individuals. The language-based distribution of per capita consumption shows that the Zambezi and Rukavango-speakers have below average individual consumption (**Figure 2.20**), which mirrors that observed for the Zambezi and Kavango East and West Regions on a regional basis (**Table 2.6**), due to the strong language-biased residence in these regions. German and English speakers show the highest per capita consumption, followed by other language and other European language-speakers, all of which represent small portions of the total population (NSA, n.d.[1]). The Khoisan, representing 1.5% of the population have by far the lowest per capita consumption (NSA, n.d.[1]) and represent the most marginalised group in Namibia.

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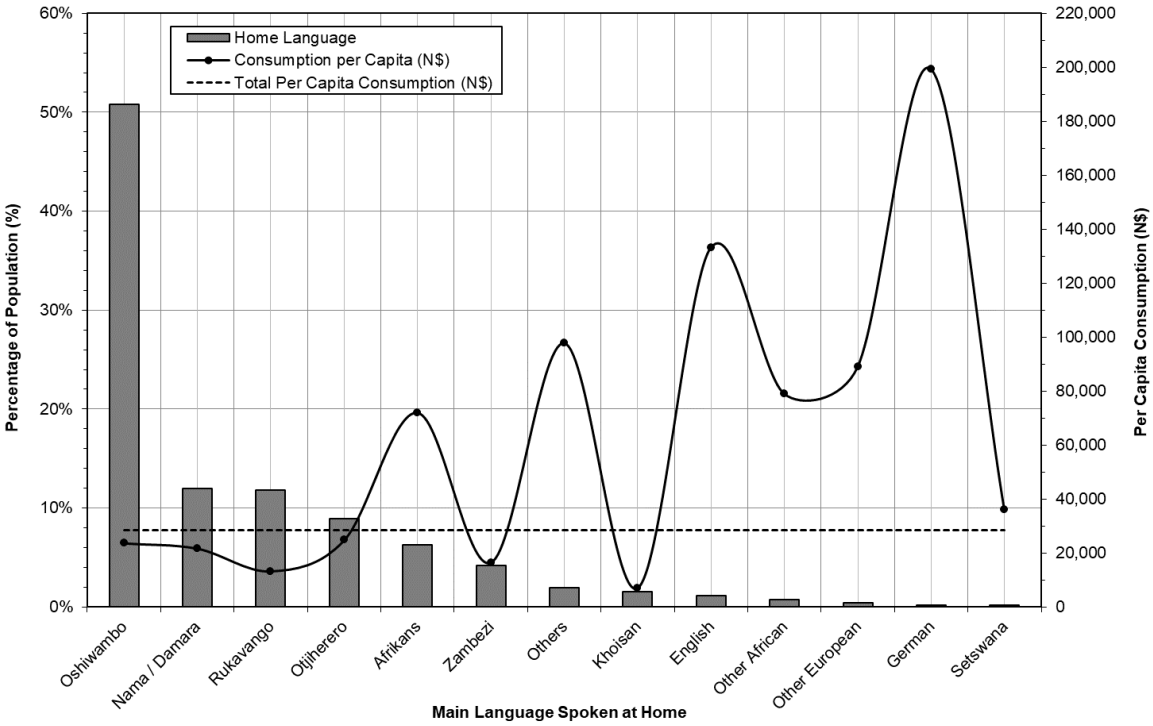

Figure 2.20: Per Capita Consumption by Home Language (NSA, n.d.[1])

Notes:
1. Data from the Namibia Household Income and Expenditure Survey (NHIES) 2015/2016 Report (NSA, n.d.[1]).
2. Main language spoken shown per portion of the population shown.
3. Consumption per capita and per main language spoken.
4. "Total' per Capita Consumption of N$ 28 434 given, matches the figure in **Table 2.6** from the same source.

The distribution of language or ethnic groups is not available on a rural / urban basis. On a regional basis, the majority of households in the Erongo and Khomas Regions are Oshiwambo-speaking, whilst the majority in the Otjozondjupa Region are Otjiherero-speaking.

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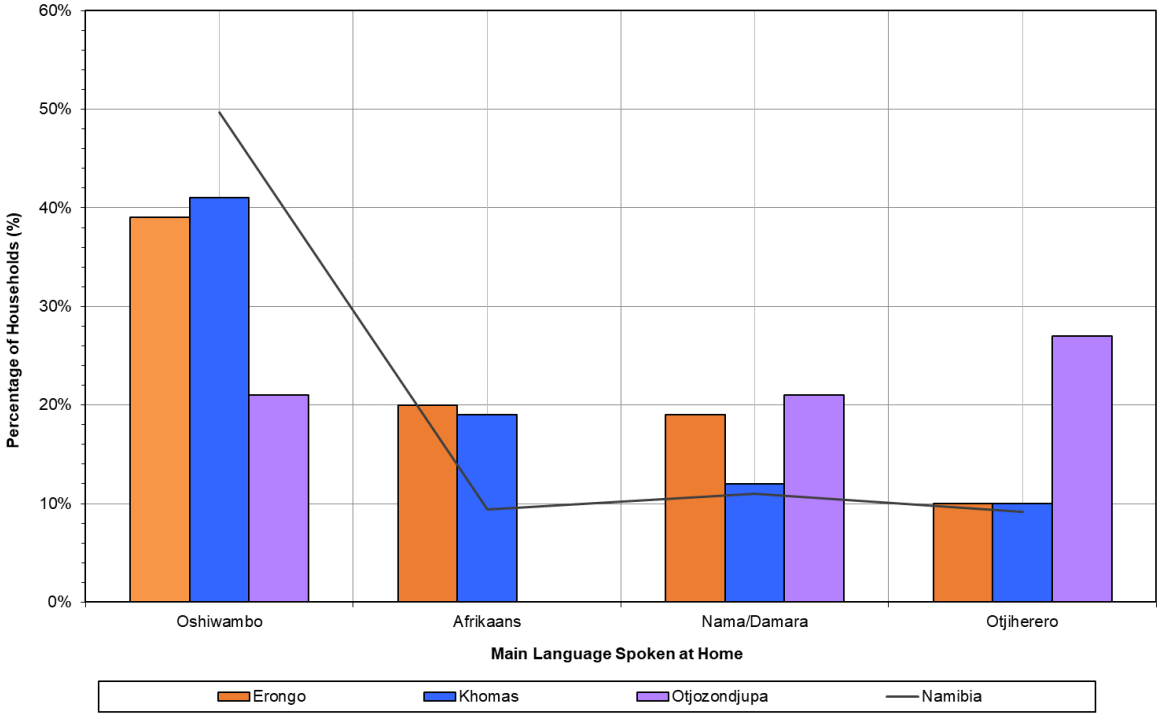

Figure 2.21: Four Most Widely Spoken Home Languages in Selected Regions in Namibia (NSA, 2017b)

Refer to the earlier notes from NSA, 2017b regarding the grouping of language types.

2.2.15 Community Organisations

The community organisations which exist in the Project Area and which may have a bearing on water-related matters include:

4. The Windhoek Residents & Ratepayers Association;
5. The Swakopmund Residents Association;
6. The Walvis Bay Port Users Association;
7. The Erongo Water Forum (refer to **Section 5.9.1** for more details);
8. The Omaruru Basin Management Committee;
9. The Upper Swakop Basin Management Committee.

Membership of the residents and ratepayers associations is typically open to residents of the relevant local authority who are over 18 years of age. These associations aim to facilitate in municipal matters, maintain communication channels between the local authority and residents, represent their members in public debates and inform them about and safeguard their rights and interests.

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The Basin Management Committees are established in accordance with Section 20 of the Water Resources Management Act, No. 11 of 2013 in order to represent those who are associated for the purpose of organising, planning or dealing with matters related to the development, management, protection and enhancement of water resources in a basin or part of a basin. These matters typically relate to water quantities and quality, conservation, the prevention of pollution, awareness of water-related matters, monitoring, implementing sustainable water resources management practices, advising the Minister on matters related to the basin and providing information to stakeholders on water-related matters in the basin.

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3 LEGAL AND POLICY FRAMEWORK OF THE NAMIBIAN WATER SECTOR

Namibia is a constitutional democracy based on the Constitution of the Republic of Namibia[9]. The president of the Republic appoints members of the National Assembly as Cabinet Ministers responsible for particular portfolios of the national administration[10]. The Constitution of the Republic of Namibia, adopted in February 1990, enjoys hierarchical primacy (supremacy) amongst the sources of law by virtue of its Article 1(6) which states that the Constitution shall be the Supreme Law of Namibia (Geraldo and Skeffers, 2007*).*

The water sector falls under the portfolio of the Ministry of Agriculture, Water and Land Reform (**MAWLR**). The implementation of an envisaged desalination plant and a water carriage system from the coast to the central areas of Namibia will involve other ministries, most notably the Ministry of Fisheries and Marine Resources, the Ministry of Works and Transport, the Ministry of Environment & Tourism, the Ministry of Land Reform as well as the Ministry of Urban and Rural Development.

3.1 Environmental Management Act 7 of 2007

The overarching piece of legislation relevant for this Feasibility Study, as well as for the subsequent scoping study and then later for the implementation of the Project, namely the envisaged construction of the desalination plant and the water pipeline and electricity supply stations, is the Environmental Management Act 7 of 2007. The entire project planning and implementation will have to comply with the provisions of this law.

The objects of this Act are to prevent and mitigate, on the basis of the environmental management principles contained in Section 3, the significant effects of activities on the environment by:

(a) ensuring that the significant effects of activities on the environment are considered in time and carefully;

(b) ensuring that there are opportunities for timeous participation of interested and affected parties throughout the assessment process; and

(c) ensuring that the findings of an assessment are taken into account before any decision is made in respect of activities.[11]

3.1.1 Principles of Environmental Management

The principles of environmental management in terms of the Act include that:

(a) renewable resources must be used on a sustainable basis for the benefit of pre-

[9] Article 1, Establishment of the Republic of Namibia and identification of its Territory.
[10] Article 35, Composition [of Cabinet].
[11] Section 2.

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sent and future generations;

(c) the participation of all interested and affected parties must be promoted and decisions must take into account the interest, needs and values of interested and affected parties;

(d) equitable access to environmental resources must be promoted and the functional integrity of ecological systems must be taken into account to ensure the sustainability of the systems and to prevent harmful effects;

(e) assessments must be undertaken for activities which may have a significant effects on the environment or the use of natural resources;

(f) sustainable development must be promoted in all aspects relating to the environment;

(g) Namibia's cultural and natural heritage including, its biological diversity, must be protected and respected for the benefit of present and future generations;

(h) the option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as in the short term must be adopted to reduce the generation of waste and polluting substances at source;

(j) a person who causes damage to the environment must pay the costs associated with rehabilitation of damage to the environment and to human health caused by pollution, including costs for measures as are reasonably required to be implemented to prevent further environmental damage;

(l) damage to the environment must be prevented and activities which cause such damage must be reduced, limited or controlled.[12]

[12] Section 3.

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3.1.2 Environmental Commissioner

The Act creates the office of the Environmental Commissioner, whose functions include to:

(a) advise organs of state on the preparation of environmental plans;

(b) receive and record applications for environmental clearance certificates;

(c) determine whether a listed activity requires an assessment;

(d) determine the scope, procedure and methods of an assessment;

(e) review the assessment report in accordance with the Act;

(f) issue environmental clearance certificates in terms of the Act;

(i) conduct inspections for monitoring compliance with this Act; and

(j) perform any other duty or function which the Minister may assign or prescribe.[13]

3.1.3 Environmental Assessment

The Government Notice 29 of 2012 stipulates that the abstraction of ground or surface water for industrial or commercial purposes[14], the release of brine back into the ocean by desalination plants[15] and the construction of water and other bulk supply pipelines[16] are all activities which may not be undertaken without an environmental clearance certificate issued by the Environmental Commissioner. All of the above aspects of the Project will therefore have to be subjected to an environmental impact assessment in accordance with the Act and regulations.

3.2 Water Resources Management Acts

The adoption of water, sanitation and environmental policies is facilitated by the provisions of Article 95(l) of the Constitution, which states that the Government must actively promote and maintain the welfare of the people by adopting policies aimed at maintaining ecosystems, essential ecological processes and biological diversity of Namibia and the utilisation of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future (IWRMJV, 2010a and Constitution).

[13] Section 17(2).
[14] Regulation 8.1.
[15] Regulation 8.12.
[16] Regulation 10.1(a).

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3.2.1 Water Resources Management Act of 2004

The Water Resources Management Act, Act No. 24 of 2004 provided for the management, development, protection, conservation and use of water resources, among other matters. Although this Act was signed by the President on 8 December 2004 and published in the Government Gazette No. 3357 of 23 December 2004, there was no publication of an effective date for the coming into force of this Act (LAC, 2009).

This act has been repealed as a whole by the Water Resources Management Act, No. 11 of 2013.

3.2.2 Water Resources Management Act 11 of 2013

Water resources in Namibia are governed by the Water Resources Management Act (**WRMA**), Act No. 11 of 2013, which was signed by the President on 02 December 2013 and published in Government Gazette Number 5367, Notice No. 332 of 19 December 2013. This “new” WRMA is to repeal both the previous Water Act No. 54 of 1956 and the previous Water Resources Management Act No. 24 of 2004, and is to amend portions of Sections 6, 7 and 14 of the Namibia Water Corporation Act, Act No. 12 of 1997.

3.2.2.1 Validity of the Water Resources Management Act 11 of 2013

The Water Resources Management Act of 2013 was published in the Government Gazette, but it has not yet come into force because its commencement has not been gazetted by the Minister. Therefore, legally speaking, this Act is not yet applicable law, and the old 1956 Act is still applicable law because the intervening Water Resources Management Act 24 of 2004 was also never implemented by way of gazettement of its commencement. Many provisions of the 2013 WRMA are treated by many stakeholders as if they are applicable law. For example, the institutions created by the Act like the basin management committees (Section 20) are in place, and the Minister of Agriculture Water and Land Reform has appointed members of the Water Advisory Council established in terms of Section 7 of the Act. This appointment was however not done by way of a notice in the Government Gazette, but only by a public speech and presumably by appointment letters sent to the council members.

Should at any stage any litigation be instituted which may involve or impact the Project, the 2013 Act will however be treated by the Courts as not applicable in law. A good case to demonstrate this with is the case of *Namib Plains Farming and Tourism CC v Valencia Uranium (Pty) Ltd & Five Others* SA 25/2008. This Supreme Court appeal against a decision of the High Court, was decided on 19 May 2011, i.e. after the Water Resources Act 24 of 2004 was gazetted and before it was repealed by the Water Resources Act 11 of 2013. However, just as is the case with the 2013 WRMA, the commencement of 2004 Act was never gazetted. Therefore the provisions of the 2004 Act were not considered by the High Court and later the Supreme Court.

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It is reported in that judgement that in terms of Section 28(1) of the Water Act 54 of 1956, it is the president who is the authority with the power to declare an area as a subterranean water control area.

In paragraph 31 of the Supreme Court judgement, it is reported that:

> [31] At the hearing of the application in the High Court, the parties were directed to search for a Proclamation, if any, in terms of which the area might have been declared to be a subterranean water control area. It became apparent that no such Proclamation existed and that the permits had been issued on an erroneous assumption that the area where the bore holes were to be drilled and from which underground water was to be extracted had been declared a subterranean water control area as contemplated in section 28(1) of the Act.

The case revolved around an application which the appellant had brought to the Ministry of Water, Agriculture and Forestry (as at the time) for a permit to drill boreholes and abstract water in the Khan River. The application to Court was therefore anchored on the contention that the permits were issued in respect of a declared subterranean water control area within the meaning of Sections 27, 28 and 30(2) of the Act. However, as the area was never proclaimed as a subterranean water control area, the judge in the High Court held that:

> "I find that no such Proclamation or Proclamations are before me, and the onus is on the applicant to disclose it or them. The fact that the permits were issued by the Minister through his officials, who must know, is of no legal consequence: the simple fact that remains is that there is no Proclamation before this Court".
>
> He concluded as follows:
>
> "For all the above reasons, I am of the view that if this Court determined this matter – even the points *in limine* – that would be tantamount to the Court perpetuating a legal lie, so to speak; something which this Court must not do under any circumstances. As I say, as far as this Court is concerned, the legal reality is that the aforementioned Permits do not exist: it is as if they had not been issued at all. If that is the case, as I hold it is so established, then logically there is nothing in respect of which an application in the nature of the present application can be brought in this Court for the Court to hear and determine it. It follows inexorably that the present application stands to be dismissed"

The Supreme Court however held that the High Court should not have decided the merits of the case as there were points *in limine* (preliminary points) which needed to be decided. The Supreme Court also differed with the High Court's approach of declaring the permits as nullities without them having been set aside by a Court:

> In any event, in concluding that because the act of issuing the permits was a nullity (given the non-existence of a Proclamation in terms of which the area in question might have been declared a water control area) it followed that logically there was "nothing in respect of which an application in the nature of the present application

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(could) be brought in this Court for the Court to hear and determine", the Court a quo committed a serious misdirection. However anomalous it may seem, it is a settled principle of law that even an unlawful administrative act is capable of producing legally valid consequences for as long as the unlawful act is not set aside by a court of law. See, for example, the South African Supreme Court of Appeal decision of Oudekraal Estates (Pty) Ltd v City of Cape Town and Others 2004 (6) SA 222 (SCA) at 242B-C where that Court (per Howie P and Nugent JA) observed as follows:

"The proper functioning of a modern State would be considerably compromised if all administrative acts could be given effect to or ignored depending upon the view the subject takes of the validity of the act in question. No doubt it is for this reason that our law has always recognised that even an unlawful administrative act is capable of producing legally valid consequences for so long as the unlawful act is not set aside."

The above discussion of the Supreme Court shows the level of confusion that can be caused when necessary steps are not taken with regard to legislation. In the case of the Water Resource Management Act 11 of 2013, it means that any administrative action taken under it, can subsequently be set aside by any stakeholder who might approach the Court to set it aside, as the Act never came into force, because its commencement was never gazetted. If therefore NamWater and all other stakeholders want to secure all administrative actions taken under the Water Resources Management Act 11 of 2013 and the legal status of any agreements which will be entered into and permits which will be issued ostensibly under that Act, then NamWater must, for the implementation of this project, insist that the Minister of Water Agriculture Water and Land Reform determines by Government Notice in the Government Gazette the commencement of the Act. This should be done even if the Regulations are not yet finalised.

Until the determination of the commencement of Water Resources Management Act, it is not valid applicable law, and we must advise accordingly. For this reason the Water Act 54 of 1956 is still the applicable law and its relevant provisions will be discussed in a following section.

3.2.2.2 Objectives of the Water Resources Management Act 11 of 2013

The WRMA recognises the fundamental principle that "*equitable access for all people to safe drinking water is an essential basic human right to support a healthy productive life*" (Section 3(a)) and specifies that ownership of the water resources in Namibia is vested in the State and that the State must ensure that water resources are managed and used to the benefit of all people (Section 4).

The WRMA has the object that water resources are managed, developed, used, conserved and protected in a manner consistent with, or conducive to, the fundamental principles set out in Section 3, which include the promotion of the sustainable development

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of water resources based on an integrated water resources management plan which incorporates social, technical, economic, and environmental issues (Section 3(d)) and the prevention of water pollution and implementation of the principle that a person disposing of effluent or waste has a duty of care to prevent pollution (Section 3(k)). This law is therefore relevant because the desalination plant will abstract seawater from the sea which is a water resource in terms of the Act. Water abstraction can only be done after obtaining an abstraction licence in terms of Section 44. As the desalination plant will discharge effluent back into the ocean (after desalination), the operator will have to apply for a licence issued by the Minister to discharge effluent, and possibly also a licence to construct or operate a wastewater treatment facility or a waste disposal site; the discharging of the effluent will further have to be conducted in accordance with the conditions to which the licence is subject (Section 69(2)).

The Act defines a water services provider as a person or an entity that provides or manages water services to end consumers. This means that NamWater is a water services provider. The Act also creates the Water Regulator in Section 11.

3.2.2.3 Water Regulator

Part 4 (Sections 11 to 19) of the WRMA allow establishment of a Water Regulator to determine tariffs, set operational targets for water service providers, to monitor the performance of water service providers, to advise the Minister on matters related to compliance by water service providers and to perform other functions required by law (Section 12). The Water Regulator is to consist of five members appointed by the Minister who must be Namibian citizens, appropriately skilled and experienced and who are to serve for a period not exceeding five years, and who may be re-appointed thereafter (Sections 13 and 14). The meetings and administration of the Water Regulator are governed by Section 16.

The functions of the Water Regulator are

(a) to determine the tariffs of fees and charges, or the maximum tariffs of fees and charges -

(i) that may be levied by a water services provider or other supplier of water, including the State, for the supply or distribution of water and the provision of wastewater services and other associated services;

(ii) that are payable by licence holders for the abstraction of water or the discharge of effluent or the supply or re-use of effluent; and

(b) and to set, after negotiation and by agreement with a water services provider or other water supplier, the operational targets to be achieved by the water services provider or supplier during a specified period, including targets as to the level and standard of services (Section 12(1)).

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Therefore, when planning for the fees and levies which NamWater will charge over the project period to recoup their investment, it must be kept in mind that the Water Regulator might influence the fees and levies chargeable. This will especially be relevant if NamWater plans to realise the project with a private sector partner.

3.2.2.4 Water Advisory Council

Part 3 (Sections 7 to 10) of the WRMA allow establishment of a Water Advisory Council to advise the Minister on water policy and review, water resources management, water abstraction and use and other matters relating to the administration of the WRMA (Section 7). Section 8 sets out the membership of the Water Advisory Council whose members are to be appointed by the Minister, upon nomination, who are to hold office for a period of five years and who may be reappointed thereafter (Section 9). Section 10 governs the meetings and administration of the Water Advisory Council.

The Water Advisory Council was launched by the Minister of the MAWLR, the Hon. J. Mutorwa, on 19 September 2016, with the first meeting of the Council scheduled for 05 October 2016, during which the Minister would announce the chairperson (Shapwanale, 2016).

The Water Advisory Council is however not currently functional.

3.2.2.5 Regulations

Section 129 of the WRMA allows the Minister to make regulations for a variety of purposes, including "*any matter required or permitted to be prescribed by regulation under this Act*". These include the quality standards for drinking water quality (Section 35(a)), recycled water (Section 35(d)), artificial recharge (Section 66(1)(f)) and effluent discharges (Section 76(1)(a)), among others. At present, no regulations have yet been published for any these various standards.

In practice, draft quality standards for drinking water quality and effluent discharges have been in development by the MAWLR for some time and have been workshopped with stakeholders. The most recent or current draft versions of these standards were provided to the Consultant by the MAWLR under this Project (dated July 2019 by the MAWLR). These "draft water quality regulations" provide two guidelines or standards for the physical, organoleptic, inorganic, organic, disinfection, biological and other determinants in water which is to be of potable quality:

- The Namibia Water Quality Standards (**NWQS**) which are the Acceptable Standards (minimum requirements) for water quality;
- The Namibia Water Quality Guidelines (**NWQG**) which are the Ideal Guidelines for water quality;

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Many stakeholders in the water sector refer to these draft quality standards for drinking water quality and effluent discharges in terms of the assessment of current facilities and the design of new facilities, in the expectation that these are to come in to force at some point in future following the commencement of the Water Resources Management Act 11 of 2013 and the gazetting of the appropriate regulations.

3.2.3 Water Act 54 of 1956

3.2.3.1 Application and Provisions

The Water Act 54 of 1956 is a South African piece of legislation, and in terms of Section 180 thereof, the State President of South Africa can make the Act or certain provisions thereof applicable to South West Africa, as Namibia was at the time. The Act applied to South West Africa as from 25 June 1969, but only certain sections thereof. Unfortunately the definition section was not made applicable to South West Africa / Namibia, which leaves certain expressions such as ‘public water’ or ‘water works’ or ‘government water works’ undefined.

With regard to government water works, it must be noted however that the Namibia Water Corporation Act 12 of 1997 does contain a definition for ‘waterwork’ as well as a definition for ‘assets’ as property of the Namibia Water Corporation.

Furthermore, the Namibia Water Corporation Act establishes the Corporation in Section 3 as a public company with only the state as member and shareholder, and the Minister of Agriculture, Water and Land Reform is empowered to exercise the rights and powers and perform the duties and functions of member and shareholder of the Corporation, on behalf of the State. There should therefore be no disputes about NamWater’s rights and powers to exercise the powers of the State contained in the Water Act 54 of 1956. The Namibia Water Corporation Act in fact expressly states in Section 6(1)(c) that the Corporation shall exercise the functions in pursuit of its objects under the Act, which include, notwithstanding any provisions of the Water Act 54 of 1956 to the contrary, the supply water to customers within and outside the borders of the Republic of Namibia;

One important distinguishing feature of the 1956 Water Act is that it establishes the Water Court as a court of first instance, where inter alia servitudes for waterworks over third party land are claimed and determined, whereas in the Water Resources Act 11 of 2013, such issues are in the jurisdiction of the High Court of Namibia. The Water Tribunal established by the Water Resources Act 11 of 2013 is an appeal body to hear appeals against decisions by the Minister.

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The Water Court established by Section 34 of the Water Act 54 of 1956 consists of a High Court Judge sitting as the Water Court and assessors, if the judge chooses to appoint any. In practice therefore, any disputes surrounding the desalination project will end up before the High Court of Namibia. The Water Act 54 of 1956 does not contain an appeal provision against decisions of the Minister, therefore any person aggrieved by a decision of the Minister will have to take the decision on review in terms of administrative law provisions, as was done in the above mentioned case of *Namib Plains Farming and Tourism CC v Valencia Uranium (Pty) Ltd & Five Others* SA 25/2008. Article 18 of the Constitution of Namibia contains the relevant legal provision:

> **Article 18 Administrative Justice**
>
> Administrative bodies and administrative officials shall act fairly and reasonably and comply with the requirements imposed upon such bodies and officials by common law and any relevant legislation, and persons aggrieved by the exercise of such acts and decisions shall have the right to seek redress before a competent Court or Tribunal.

The South African National Water Act No. 36 of 1998 repeals the whole of the Water Act 54 of 1956 in South Africa. This means that the Water Act 54 of 1956 is no longer applicable in South Africa, although it remains in force in Namibia.

3.2.3.2 Considerations Regarding the Water Act 54 of 1956

A review of the Water Act 54 of 1956 by the Legal Assistance Centre (**LAC**) highlighted a number of shortcomings of this Act, including, but not limited to (LAC, 2009):

- A central flaw that the Act ignores the hydrological reality of Namibia , being based on a model which applied the rules of well-watered countries of Europe to the arid climate conditions of Namibia. These rules are inconsistent with Article 100 of the Constitution;
- The Act fails to account for the natural environment's status under the Namibian Constitution, which under Articles 91, 95 and 100 of the Constitution is recognised as a stakeholder in the formulation of resource management policy. The Act fails to recognise the downstream environment as a user by allocating water rights only in the context of a land owner and not in regard to the natural environment;
- One of the most important questions the MAWLR must answer before a permit for water abstraction is granted, is whether the resource in question has been properly classified and proclaimed a "subterranean water control area" in terms of Section 28;
- The Act does not delineate any specific qualifications that applicants must meet before the Minister can issue a water abstraction license as Section 30(5) merely states that the Minister may issue a permit subject to such conditions as he may deem fit.

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3.2.3.3 Water Quality Standards

A document of the MAWLR (undated; MAWF, n.d.) refers to the Cabinet of the Transitional Government for National Unity adopting the existing South African water quality guidelines (461/85) at the time, which took effect from 01 April 1988 under the signature of the then Secretary for Water Affairs (as it was then). This document of the MAWLR, marked for signature of the Permanent Secretary, is titled: "*The Water Act, 1956 (Act 54 of 1956) and its Requirements in Terms of Water Supplies for Drinking Water and for Waste Water Treatment and Discharge into the Environment*".

These guidelines by the MAWLR (n.d.) correspond with the "*Guidelines for the Evaluation of Drinking-Water for Human Consumption with Regard to Chemical, Physical and Bacteriological Quality*" of the DWA (1991), which also correspond with the "*Guidelines for the Evaluation of Drinking-Water for Human Consumption with Regard to Chemical, Physical and Bacteriological Quality*" of NamWater (1998).

Since the WRMA, 11 of 2013, is not applicable in law, the NWQS and NWQG are not legally binding in terms of potable water quality standards. In practice however, NamWater has adopted the NWQS in their water resources and infrastructure plans.

3.2.3.4 Abstraction Permits

The permits for groundwater abstraction from the Omdel and Kuiseb Aquifers issued to NamWater[17] by the MAWLR are in terms of Regulations 5 and 9 of Government Notice R1278 of 23 July 1971, as promulgated under Section 30(2) of the Water Act, 54 of 1956, as amended – indicating that abstraction permits are issued under the 1956 Act by the MAWLR.

3.3 Water Supply and Sanitation Policies

3.3.1 Water Supply and Sanitation Policies

The first Water Supply Policy (**WASP**) was adopted by the Government of Namibia in 1993. As recommended in the 1993 WASP document, the Namibian Water Corporation Limited (**NamWater**), a State Owned Enterprise, was established by statute as the major bulk water supplier. Also, as recommended in the WASP, the Directorate of Rural Water Supply (**DRWS**) was established in the Ministry of Agriculture, Water and Rural Development (as it was at the time), to improve access to safe water for communities in rural, communal areas.

The Water Supply and Sanitation Policy (**WSASP**) of 2008 replaced the Water Supply Policy of 1993. Its principles are in line with Integrated Water Resources Management (**IWRM**), including a strong focus on Water Demand Management (**WDM**). The Ministry of Agriculture, Water and Land Reform (**MAWLR**) has been given the tasks of managing

[17] Copies of the permits made available by NamWater.

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and regulating the activities within the water sector, with the objective of ensuring that this natural resource is thoroughly investigated and made available to all consumers on a sustainable basis, to ensure that value addition is optimised and that environmental requirements are accommodated. The WSASP also recommends that the responsibility for sanitation services be transferred from the Ministry of Health and Social Services (**MoHSS**) to the MAWLR, so that both the management of water as well as sanitation is under one umbrella.

The MAWLR is responsible for the control, conservation and use of water for domestic, agricultural, urban and industrial purposes. Within the MAWLR, the Department of Water Affairs (DWA) is responsible for administration of water affairs. The DWA has two directorates, namely the Directorate of Resource Management and the Directorate of Rural Water Supply, which was renamed to the Directorate of Water Supply and Sanitation Coordination (**DWSSC**) following the adoption of the WSASP (2008) document.

3.3.2 The Integrated Water Resources Management Plan

The call for Integrated Water Resources Management (**IWRM**) worldwide was made at the World Summit on Sustainable development in Johannesburg in 2002. The importance of IWRM was one of the main points of discussion at a April 2006 meeting of the African Minister's Council of Water, where Namibia was represented (IWRMPJVN, 2010a). With funding from the African Development Bank, the MAWLR in early 2009 commenced with the development of the Namibian IWRM Plan. In order to embody the accepted principles of IWRM and to prepare a comprehensive Integrated Water Resources Management Plan (**IWRMP**) for the future, eight thematic reports were prepared to lay the foundation of the IWRMP (IWRMPJVN, 2010a):

- Theme Report 1: Review and assessment of the existing situation;
- Theme Report 2: The assessment of resources potential and development needs;
- Theme Report 3: Formulation of a water demand management strategy;
- Theme Report 4: The formulation of information and knowledge systems;
- Theme Report 5: Long term monitoring and evaluation framework
- Theme Report 6: Integrated framework for institutional development and human resources capacity building;
- Theme Report 7: Strategy for funding the implementation of the IWRMP;
- Theme Report 8: National Water Development Strategy and Action Plan.

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In terms of implementing WDM successfully, the IWRMP noted the importance of the implementation of the WRMA (2013), the accompanying Regulations and the performance indicators or water efficiency regulations required of the different water use sectors and service providers. Unfortunately, some 9 years after the completion of the IWRMP, these aspects still remain outstanding.

The IWRMP further notes that "*capacity building and institutional development are the key elements for the implementation of an IWRMP in Namibia*" (IWRMPJVN, 2010e). The IWRMP proposed a national development strategy and action plan for adoption, and numerous recommendations, including that managerial and technical capacity building be seen as pivotal goals, that various water governance structures be brought into force (including the WRMA and Regulations, the Water Advisory Council, the Water Regulator, a Water Research Council and others), that various enabling strategy and management plans be put in place, and that the Polytechnic of Namibia, now the Namibia University of Science and Technology (**NUST**), be used for capacity building and support, among other recommendations (IWRMPJVN, 2010e). In terms of capacity in water governance, four levels were identified; the system level, organisation level, individual level and technical level (IWRMPJVN, 2010e), across which interventions are required.

Some of the recommended governance structures are nominally in place (the Water Advisory Council and the Water Regulator), but these are not fully functioning, in part due to the lack of regulations which are to accompany the 2013 WRMA. It could also be argued that capacity in the water sector, both public and private, is lower than it was at the time of completion of the IWRMP in 2010, following retirements in the public sector (mainly the MAWLR, NamWater and CoW) and retrenchments and emigration in/from the private sector.

3.4 NamWater and the Namibia Water Corporation Act

3.4.1 The Namibia Water Corporation Act

The Namibia Water Corporation Act (**NWCA**), Act No. 12 of 1997 was enacted in order "*to establish the Namibia Water Corporation Limited* (**NamWater**); *to regulate its powers, duties and functions; to provide for a more efficient use and control of water resources; and to provide for incidental matters*".

The Namibia Water Corporation Amendment Act, Act No. 17 of 2001, which was signed by the President on 11 December 2001, amends the Namibia Water Corporation Act, Act No. 12 of 1997, to reduce the number of members of the board of directors of the Corporation and to provide for matters incidental thereto.

Small portions of Sections 6, 7 and 14 of the NWCA have most recently been amended by the 2013 WRMA.

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Sections 5 and 6 of this Act set out the Objects and Functions of the Corporation respectively. Section 5 requires the Corporation to act "*in the best interests of the Republic of Namibia*", with the primary business of bulk water supply "*in sufficient quantities, of a quality suitable for the customer's purposes, and by cost-effective, environmentally sound and sustainable means*" and the secondary business of rendering water-related services.

Section 6(2) of this Act requires that NamWater "*shall give effect to the relevant policies of the Government relating to water supply as communicated to the Corporation from time to time by the Minister*".

Section 9 of this Act specifies the duty of the Corporation to supply water, including to consider each application of bulk water supply, subject to the availability of water [9(2)], and to supply bulk water to the Corporation's customers in terms of a written agreement between the Corporation and each customer [9(2)].

Whilst bulk water supply to NamWater's customers has to take place in terms of a written agreement, according to Section 9(2) of the NWCA, NamWater also uses a (short form of) written agreement for the supply of water to small consumers.

NamWater mostly supplies water in bulk to local authorities, mines and large customers, but has increasingly also supplied water to small consumers, including individuals, particularly where "rural" water supply schemes constructed by the Ministry of Agriculture, Water and Land Reform (**MAWLR**) have been handed over to NamWater to operate. At present, NamWater is responsible for the supply of water to:

1. Local Authorities, including municipalities, regional, town and village councils;
2. Mines;
3. Large scale agricultural consumers;
4. Large scale industrial / business / manufacturing consumers;
5. Feederline committees;
6. Local water committees;
7. Water point association;
8. Individual private consumers.

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3.4.2 Demarcation of NamWater Supply

The delineation of responsibility between NamWater (upstream), the DWSSC and / or a local authority (downstream) normally occurs at a water meter installation, which is typically located as follows (varying for specific scheme configurations):

1. At an off-take from a bulk pipeline, which installation marks the start of the rural pipeline scheme or the supply to a customer;
2. At the outlet of a reservoir (either at ground level or elevated), typically termed a “terminal reservoir”;
3. At the delivery side of a pump station.

3.4.3 Delineation of NamWater’s Operational Areas

NamWater’s schemes and operations are grouped into four business units or divisions; Central, Karas, Namib and North. Each business unit, headed by a Business Unit Chief, is responsible for water supply in its area, interfacing with local authorities and other NamWater customers (for example the mines, as in the CCA), as well as the operation and maintenance of the schemes in that area.

A key challenge, among the many faced by NamWater, is the very extensive geographical extent of their schemes, business units and operations and thus the vast distances across which resources, infrastructure, personnel and operations must be monitored. Another difficulty is that the different business unit areas span across political boundaries (regions and constituencies) and thus NamWater needs to interface with diverse stakeholders within each business unit.

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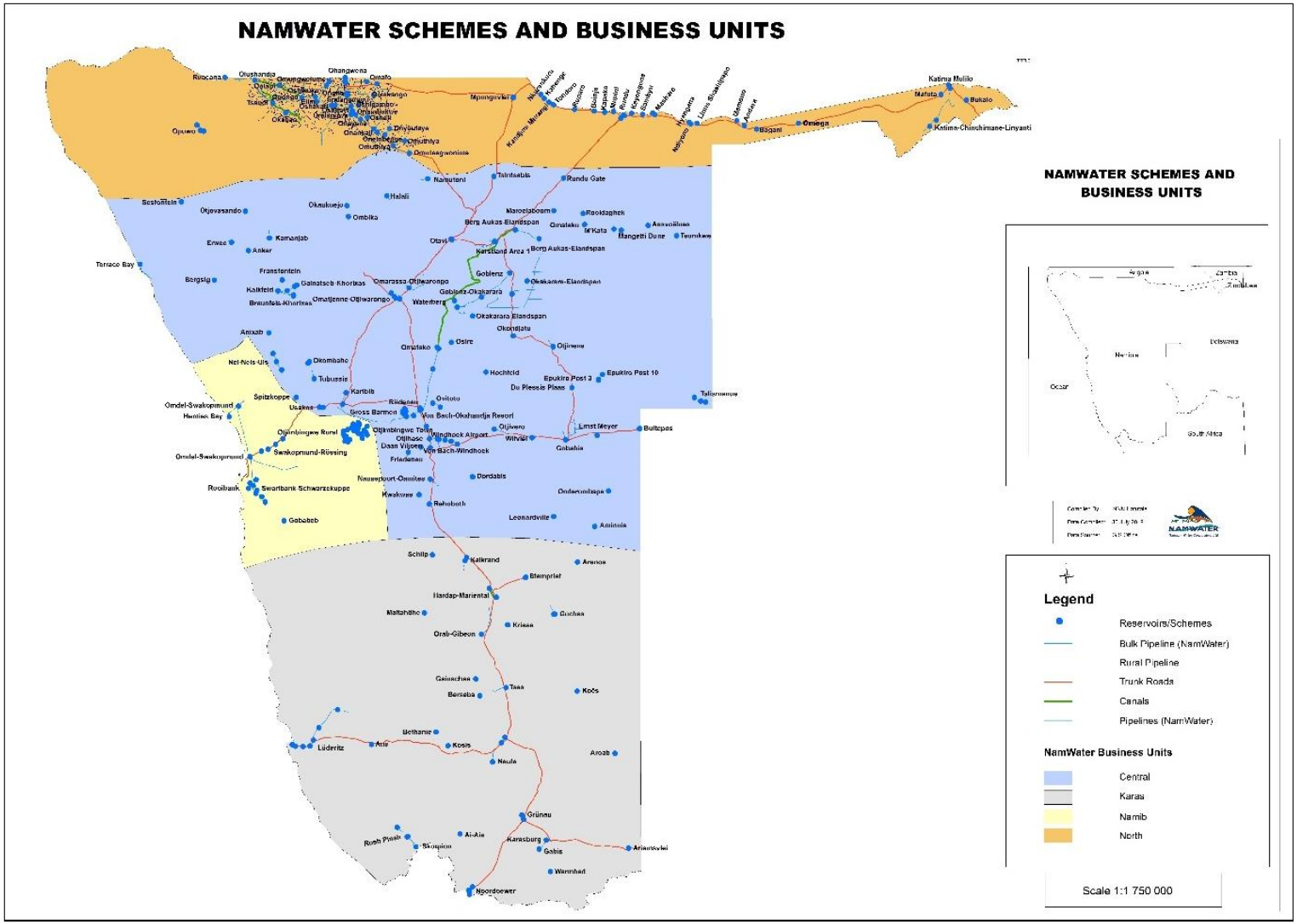

Figure 3.1: NamWater Schemes and Business Units (NamWater).

3.5 Public Enterprises Governance Act 2 of 2006

NamWater as a Public Enterprise must be viewed with reference to the Public Enterprises Governance Act 2 of 2006, as amended. In terms of Section 4 of this Act, the functions of the Minister of Public Enterprises are *inter alia*:

(a) to establish generally accepted common principles of corporate governance and good practice governing State-owned enterprises; and

(b) to develop common policy frameworks for the operations of State-owned enterprises, including policy on issues relating to human resources, assets and finance;

(f) to furnish a portfolio Minister with any comments it may wish to make in relation to an annual budget of a State-owned enterprise submitted to that Minister for approval and provided to the Minister for its information and comment.

From the above it is clear that the decisions which NamWater will make to ensure cost recovery of the investment into the desalination plant, and about pricing of water service delivery will be subject to the scrutiny of the Minister of Public Enterprises. Subsection 4(2) creates different categories of public enterprises, namely (i) regulatory enterprises (ii) service rendering enterprises (iii) economic and productive enterprises and (iv) general enterprises. In Government Notice 141 of 31 May 2013 (Government Gazette 5213 of 2013), the Public Enterprises Governance Council classified NamWater as an economic and productive enterprise.

The influence which the Public Enterprises Minister will have on NamWater is made even clearer by the provisions of Section 19 of the Act, dealing with business plans and financial plans, which states *inter alia* that:

(1) Every State-owned enterprise must annually, at least 90 days before the commencement of its next financial year, submit a business and financial plan to the portfolio Minister.

(2) The business and financial plan of a State-owned enterprise must encompass all the businesses and activities, including investments, of the State-owned enterprise and its wholly-owned subsidiaries, if any.

(3) The business and financial plan of a State-owned enterprise must include -

(b) the operating budget and the capital budget of the State-owned enterprise for the next financial year, with a description of the nature and scope of the activities to be undertaken, including commercial strategies, pricing of products or services and personnel requirements;

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(c) a statement with particulars of any expenditure included in the budget in respect of any project to be funded from any subsidy or grant awarded or given to the State-owned enterprise, from whatever source, for that purpose, the conditions attaching to the subsidy or grant and the control measures to be applied for monitoring such expenditure and the application of the funds received in respect of the subsidy or grant;

(d) if the State-owned enterprise intends to borrow money in the next financial year, a general indication of the borrowing plans and strategies of the State-owned enterprise for that year;

(4) The portfolio Minister must provide a copy of an annual business and financial plan received in terms of subsection (1) to the Minister [of Public Enterprises] for the Council's information and comment, if any.

(5) A State-owned enterprise must act only in accordance with its business plan, unless it has first obtained the written approval of the portfolio Minister to do otherwise.

(6) Nothing done by a State-owned enterprise is void or unenforceable merely because it has failed to comply with subsection (5).

Although the Public Enterprise Minister can only comment on the business plan and financial plan, the effect of the Public Enterprises Governance Act are more far-reaching than that for the operations of a public enterprise like NamWater. From the provisions of Section 19, it emerges that NamWater will only be able to divert from its approved business plan and budget after obtaining written approval from the Minister of Agriculture Water and Land Reform. Such approval, if granted, will be given with the provisions of Section 26 in mind, in terms of which the board of a public enterprise must submit the annual financial statements to the portfolio minister. The financial statements must include

(c) a statement on the extent to which the State-owned enterprise has met its objectives for the financial year; and

(d) quantitative information respecting the performance of the State-owned enterprise, including its wholly-owned subsidiaries, if any, relative to the State-owned enterprise's objectives.

If the project is to be realised in the form of a public private partnership with a private sector joint venture partner, the speed with which approvals for diversions from pre-set business plans and budgets can be obtained will be a prime consideration. Even more important will be to what extent the expected returns on the investment, which are to be gained through revenue can be secured, in other words, protected against influence from the Public Enterprises Ministry to accommodate possible future financial constraints on local authorities unable to pay for the service delivery from NamWater. These are in fact

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considerations of high importance for NamWater itself, not only for a potential private sector partner.

The provisions of paragraph 2.6.2 of the Water Supply and Sanitation Policy (2008) come to bear:

> "*Temporary termination of water supply to an entire Local Authority or proclaimed settlement by a bulk supply service provider should not be used to enforce cost or debt recovery provided that the Local Authority terminate or restrict provision of services to individual non-paying consumers. Local Authorities are advised to use trickle flow valves, similar devices or other control measures for the specific individual residential or institutional offenders. Alternative methods for credit control, should be included in the implementation strategy for the several levels of service providers*."

Section 28 of the Act contains provisions about the Minister's powers regarding subsidiaries of public enterprises, which provisions must be considered for the eventuality that any joint venture arrangement between NamWater and a private sector company will establish a separate company which may be construed as a subsidiary of NamWater in terms of the Act. Any agreement about the composition of the board of such a single purpose company for the project will need to be subject to the directives or regulations of the Minister of Public Enterprises. Any provisions of the memorandum of association or articles of association of a subsidiary of a State-owned enterprise which is contrary to this section must be interpreted as if it were in accordance with the section. This puts further limitations on the mechanisms which any private sector joint venture partners can use to protect their interests in a possible joint venture arrangement:

Section 28 of the act contains the following obligations concerning subsidiaries:

(1) The Minister may by regulation impose obligations in relation to any subsidiary of any State-owned enterprise in relation to any matter with a view to achieving the efficient governance of the subsidiary and the monitoring of its performance and the performance of the board and senior management of the subsidiary.

(2) In terms of subsection (1), obligations may be imposed either on the board of the State-owned enterprise or the board or senior management of the subsidiary and may include requirements with regard to –

(a) the manner of composition of the governing board of a subsidiary and the appointment process;

(b) the conclusion of performance agreements with the board members and senior management staff of the subsidiary and the matters to be provided for in such agreements; and

(c) any other matter provided for in this Part in relation to a State-owned enterprise.

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(3) A provision contained in the memorandum of association or articles of association of a subsidiary of a State-owned enterprise which is contrary to a provision of any regulation made under subsection (1) must be construed as if it had been amended correspondingly with the provisions of the regulation.

(4) For the purposes of this Part –

(a) the question whether a body corporate is a subsidiary of any State-owned enterprise which is not a State-owned company, must be determined in the same manner as the question would be determined under the Companies Act, 2004 (Act 28 of 2004) if the State-owned enterprise and the body corporate were companies within the meaning of that Act; and

(b) the question whether a body corporate is a subsidiary of a State-owned company must be determined in accordance with the Companies Act, 2004.

3.6 Public Enterprises Governance Act 1 of 2019

The currently applicable Public Enterprises Governance Act 2 of 2006 Act may soon be replaced by the 2019 Act with the same name. The Public Enterprises Governance Act 1 of 2019 was published in the Government Gazette on 17 May 2019. The commencement of the Act as well as the regulations however still need to be gazetted. From that point on, the 2019 Act will repeal and replace the 2006 Act as a whole.

The powers of the Minister of Public Enterprises have been expanded in the new Act, as appears for example in Section 4(1)(j) which contains the function of the Minster of Public Enterprises to receive and consider for approval submissions made by public enterprises on the annual distribution of profits and the declaration of dividends in terms of Section 21; The Minister's powers have been upgraded from merely commenting on to approving intended profit distributions and dividend declarations.

Section 13 of the 2019 Act requires commercial public enterprises to submit five year integrated strategic business plans to the Public Enterprises Minister for approval. Should the Minister fail to approve the plan, he or she must refer it back to the board of the public enterprise together with comments and instructions for amendments thereto.

Section 14 deals with annual business plans and financial plans of public enterprises and contains the same provisions as in Section 13 for the submission of the plans to the Public Enterprises Minister for approval or referral back to the board of the public enterprise with comments and instructions for amendments.

Section 21 stipulates that the board of a commercial public enterprise must -

(a) annually, at such time as the Minister may determine, submit to the Minister (which in the case of commercial public enterprises is the Minister of Public Enterprises) a proposal on the distribution of its profits for the past financial year and the declaration of dividends; and

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(b) declare and pay such dividends –

(i) as is agreed to between the board and the Minister: Provided that the Minister responsible for Finance concurs with the agreement in question; or

(ii) as is directed in writing by the Minister with the concurrence of the Minister responsible for Finance, if an agreement referred to in subparagraph (i) has not been reached.

Section 24 of the 2019 Act also gives the Minister of Public Enterprises the power to impose by regulations, obligations in relation to any subsidiary of any public enterprise, and such obligations may be with regard to the composition of the governing board of the subsidiary and the appointment process of the board. As is the case in the 2006 Act, any provision in the Memorandum or articles of a subsidiary of a public enterprise, which is contrary to the provisions of the regulations must be construed as if they had been amended and made to comply with the regulations.

All of the above are considerations of importance to NamWater and any possible private sector investors or partners when deciding on the legal and commercial structure to realise the desalination plant project.

3.7 Responsibilities of the Directorate of Water Supply and Sanitation Policy

Under the WSASP (2008) and in line with the Decentralisation Policy of 1997, the supply of water and the provision of sanitation services to the communal rural communities will become the responsibility of the Regional Councils, Division of Rural Services, and is then only to be coordinated by the Directorate of Water Supply and Sanitation Coordination (DWSSC) in the Ministry of Agriculture, Water and Land Reform.

At present however, not all the Regional Councils in the country have the capacity to accommodate the supply of water and the provision of sanitation services and for the time being therefore, the DWSSC is assisting these Regional Councils and coordinating the planning, investigation, design and implementation of water supply and sanitation schemes, as well as providing support, including extension services, for the operation of water point associations, water point committees, local water associations and committees and feederline committees.

The DWSSC still maintains ownership and operational responsibility for “rural” water supply schemes implemented by them, whilst others have been transferred to NamWater, some in terms of outright ownership (and therefore also operational responsibility) and others in terms of operational responsibility only. The matter of the transfer of schemes from the DWSSC to NamWater is an ongoing process.

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3.8 Water Supply in Local Authority Areas

Water supply for household, business or industrial purposes within local authority areas is the responsibility of local authority councils under Parts V and VI of the Local Authorities Act, No. 23 of 1992. This includes the power to "*establish, acquire or construct and maintain and carry on, any waterworks or water-main whether within or outside its area*" (Section (Part VI, Section 34(1) (a)). For the purposes of local government, local authority councils are required for municipalities, towns and villages so declared (Part I).

Local authorities are also required to provide and maintain sewerage and drainage systems as well as refuse removal facilities (Section (Part V, Section 30(1) (c)).

3.9 Water Supply outside of Local Authority Areas

Water supply to Regional Councils and settlements, being those smaller than proclaimed local authorities and not governed by local authority councils, falls under the jurisdiction of the Ministry of Urban and Rural Development. The main mandate of this ministry is to coordinate and manage decentralisation in Namibia and other aspects include the coordination of legislation, policies and standards for sub-national structures, the coordination and facilitation of rural development activities and ensuring appropriate town planning and establishment, infrastructural development and land use management, among others.

3.10 Basin Management Committees

Following a review of the Namibian water sector in the 1990s, an IWRM approach was recommended, including the idea of managing water resources at a basin level. A basin management approach was subsequently adopted as policy in the National Water Policy White Paper of 2000 (MAWLR, 2013). Functional responsibilities for the IWRM of water resources are vested in Basin Management Committees (MAWLR, 2013) which are legislated under Section 20 of the WRMA, 2013.

The composition (Section 21), support (Section 22), functions (Section 23), directives to(wards) (Section 24), requirements to coordinate with others (Section 25), ability to establish subcommittees (Section 26) and dissolution (section 27) of Basin Management Committees (**BMC**s) are governed by the WRMA, 2013.

The Omaruru Basin Management Committee and the Upper Swakop Basin Management Committee are the two BMCs which are relevant to this Project. These are "properly constituted" BMCs under Section 20 of the WRMA, 2013 which is problematic since the WRMA, 11 of 2013, is not a valid piece of legislation.

3.11 Cabinet Committee on Water Supply Security

On 06 July 2016, the President appointed a Cabinet Committee on Water Supply Security (**CCWSS**) with the (initial) brief to avert the looming water crisis (Shapwanale, 2016).

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The establishment of this committee is an identified action and strategy under the Harambee Prosperity Plan, which is the Namibian Government's Action Plan towards Prosperity for All, which was announced during the President's State of the Nation Address on 05 April 2016. This plan was developed to complement the NDPs and Vision 2030, and is based on five pillars; namely effective governance, economic advancement, social progression, infrastructure development and international relations and cooperation (after OOTP, n.d.[2]).

The CCWSS consists of cabinet ministers and is assisted by the Technical Committee of Experts (**TCE**) which consists of "*government technocrats and experts*" appointed by the President (New Era Live, 2016).

At the time of the launch of the CCWSS, it was noted that the function of the committee, was among others "*to review all existing proposed water supply solutions by various stakeholders, including proposals by the water ministry and the Windhoek Municipality*" (New Era Live, 2016).

The CCWSS and the TCE were established in the midst of the 2015-17 drought when the water supply situation in Namibia, and in the CAN in particular was critical. The CCWSS was tasked "*to fast track solutions to the water supply shortages, commencing with Windhoek*", (Maritz, 2019). The process was to have a phased approach, as follows (Maritz, 2019):

- Phase 1: To address the water supply situation in Windhoek, and the CAN between 01 July 2016 and the end of December 2017;
- Phase 2: To extend the evaluation and measures recommended for water security in the CAN for another two years up to the end of 2019;
- Phase 3: Following the preparation and costing of a clear implementation plan to address the water crisis in the CAN, to look at the long-term water requirements of the entire country in a further phased approach.

The CCWSS and the TCE undoubtedly averted a potentially very serious water supply crisis in the CAN towards the end of 2016, which neither NamWater nor the CoW would have been able to accomplish on their own. The CCWSS and the TCE have been able to get the various stakeholders in the water supply sector to work together for the greater (national) good and have been able to access funding from the treasury which none of the individual stakeholders had to that point accomplished on their own.

Although established following formal Government policy (the Harambee Prosperity Plan), the CCWSS and the TCE are not legally constituted within the framework of any water act (either the 1956 or the 2013 Acts). The de facto context in the water sector at present is that the CCWSS and the TCE have supplanted the Water Advisory Council, which has become dormant.

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3.12 Marine Resources Act 27 of 2000

The Marine Resources Act regulates the management, protection and utilisation of marine resources in Namibia and Namibian waters. The Act applies to the desalination project in so far as the definition of marine resources includes all marine organisms, including, but not limited, to, plants, vertebrate and invertebrate animals, monerans, protists (including seaweeds), fungi and viruses, and also includes guano and anything naturally derived from or produced by such organisms.

Furthermore, "harvest" is defined as meaning

(a) searching for, catching, taking or attempting to catch or take any marine resource;

(b) placing, or having, fishing gear in the sea or using it on the sea shore or on an island;

(c) engaging in any other activity that can reasonably be expected to result in the locating, catching or taking of marine resources;

(d) undertaking any operations at sea or on an island in preparation for any activity mentioned in sub-paragraph (a), (b), or (c);

The activities of the desalination plant will, at the inlet of the sea water, fall under the definition of harvest, and therefore this Act will apply. A licence or permit will have to be obtained for the intake of sea water, because Section 32(1) of the Act stipulates that no person shall in Namibia or in Namibian waters harvest any marine resource for commercial purposes, except under a right, an exploratory right or a fisheries agreement.

Similarly, the Act is relevant insofar as the brine from the desalinated water will presumably be discharged back into the sea. Section 52(4)(e) of the Act stipulates that it is a crime to discharge in or allow to enter or to permit to be discharged in Namibian waters anything which is or may be injurious to marine resources or which may disturb or change the ecological balance in any area of the sea, or which may detrimentally affect the marketability of marine resources, or which may hinder their harvesting. The discharge of the brine will have to be conducted under the auspices of a relevant permit from the Ministry of Fisheries and Marine Resources and subject further to the conditions which an environmental management plan approved by the Environmental Commissioner may determine.

3.13 Public Private Partnership Act 4 of 2017

The Public Private Partnership Act 4 of 2007 seeks to regulate Public Private Partnership (**PPP**) projects through the stages of initiation, preparation, procurement, conclusion of public private partnership agreements and project implementation. The main purpose of the Act is to protect government's financial interests when entering into public private partnership agreements. For this reason there are a number of requirements that must be fulfilled at the beginning, after a public entity has decided to execute a project through a public private partnership, and before the public entity may enter into the agreement.

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All the requirements increase the transaction costs on any potential private sector partners, such that one must wonder whether at times ideal partners may not be lost.

The objects of the Act to create frameworks and ensure oversight and governance on projects selected for development through the public private partnership mode, and to enable the creation of adequate institutional capacity for processing and regulating public private partnership projects, and to ensure fairness, transparency, equity and competition in the process of awarding public private partnerships are all well understood. The recognition of the challenges that may arise when the Act is followed to the letter in each instance is incorporated in Section 39 which provides for public entities to apply to the Minister of Finance to grant an exemption with or without conditions from any provision of the Act.

Section 3 of the Act stipulates that it applies to the initiation, preparation, procurement management and implementation of public private partnership projects. Subsection 3(2) states that the Act does not apply to the procurement of goods, works or services contemplated in the Procurement Act.

The Public Private Partnership Act establishes the Public Private Partnership Committee which reports to the Minister of Finance, and the powers and functions of the Committee are to provide for transaction approvals in respect of public private partnership projects, and even to provide, in consultation with the Attorney General, final and binding clarifications to interpretation queries raised by a public entity (Section 6).

Section 16 of the Act provides that as soon as a public entity has identified a project it intends to implement as a public private partnership project, the accounting officer must register the project with the Committee and inform the Committee of the expertise available within the public entity to execute the project. After the registration of the project with the Committee the public entity must undertake or cause to be undertaken a feasibility assessment to determine whether the public private partnership project is in the public interest. It is worth quoting the requirements for the assessment in Section 17(2) in full:

(2) In carrying out a feasibility assessment for a proposed public private partnership project, the public entity must –

(a) consider all options to optimise capital and operating costs and must establish a strong case for the project's efficiency and cost effectiveness;

(b) undertake an independent assessment of market demand, including a comprehensive justification of major assumptions and key findings and to ensure that the estimated project revenues are realistic and viable for the potential private entity;

(c) ensure that the user fees, if applicable, from the public private partnership project are affordable to the end users and is socially and economically acceptable to the government;

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(d) ensure that the setting and revision of user fees, if applicable, is predictable and transparent and that the user fee setting and revision methodology is –

(i) established by the relevant sector regulator;

(ii) is periodically fixed through a duly recognised process;

(iii) is based on a formula agreed to in the public private partnership agreement; or

(iv) is based on such other methods and processes that ensures transparency and accountability in the user fee setting process;

(e) ensure that the direct financial commitments of the public entity or government has been quantified and reasonably estimated for the entire duration of the public private partnership project and are within estimated budgetary limits of the public entity or government;

(f) must assess the contingent liabilities on account of the public private partnership project, if any, and must ensure that such liabilities are acceptable to the public entity; and

(g) ensure that the public private partnership project does not pass on unreasonably high risk on the public entity in terms of direct financial commitments, indirect or contingent liabilities.

The public entity must submit the results of the Section 17 feasibility assessment to the Public Private Partnership Committee for Approval in terms of Section 18. That is Transaction Approval 1 of 4 transaction approvals required in terms of the Act. The Committee must submit the feasibility assessment to Treasury for their clearance on the acceptability of government funding commitments before approving the feasibility assessment. After Treasury clearance is obtained, the Committee may, in consultation with the Minister approve or decline to approve the feasibility study.

Although the Public Procurement Act does not apply to Public Private Partnership projects, the Public Private Partnership Act has its own procurement provisions in Section 20, which involve a two stage competitive bidding process, comprising of the request for qualification stage and the request for proposal stage. The procurement committee of the public entity may with the concurrence the Public Private Partnership Committee adopt a single stage process for the procurement of public private partnership projects with a low project value. In such instances, the single request for proposal state will include the particulars of the request for qualification stage (Section 20(2)). The Act does not define low project value, but it can be assumed that a desalination plant development and the water pipeline project will not be regarded as of low project value by any definition.

Next, is the Request for Qualification procedure in terms of Section 21. During this stage, the public entity undertakes to make public the information on the public private partnership project and communicates the proposed timeframes and qualification criteria for po-

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tential applicants for the procurement. The public entity also ascertains the level of interest in the project and provides an avenue for bidders to comment on the proposed project. Finally, the public entity then qualifies the most capable applicants (to meet project objectives) for the next stage, the proposal stage.

If NamWater has not yet decided whether to implement the project as a public private partnership project, then some of the work being done now might have to be duplicated again after NamWater so decides. If NamWater wants to use this Feasibility Study to decide whether to implement the project as a public private partnership project, then it should register the project now with the Public Private Partnership Committee in terms of Section 16, so that the Committee's input into the parameters of the feasibility assessment can be obtained. Section 17(2) does not make provision for the Committee to give its input, but as the feasibility assessment needs to be approved by the Committee in terms of Section 18, it would be advisable to obtain its's input at as early a stage as possible.

After the public entity has selected the potential bidders for the request for qualification stage, it must develop the request for qualification and submit it to the Public Private Partnership Committee for approval. This is Transaction Approval 2A. After the approval and issuing of the request for qualification, the public entity will evaluate the applications. A successful qualification does not create any entitlement or obligations by the public entity in favour of the applicants that are successful during the pre-qualification stage (Section 24(4)).

The pre-qualification only allows the pre-qualified applicants to submit proposals during the request for proposal stage. This stage is undertaken to formally solicit bids for the project, including financial offers, to prepare and disseminate criteria and the method to be used for evaluation of bids and to prepare and disseminate the draft public private partnership agreement, including clearly articulated roles and responsibilities, penalties for non-performance and risk-sharing provisions between the public entity and the private entity (Section 25).

The request for proposal document, together with the draft public private partnership agreement must be submitted to the Public Private Partnership Committee for approval, which is Transaction Approval 2B (Section 26). The Attorney General's approval of the public private partnership agreement must also be obtained before issuing the request for proposal.

After Transaction Approval 2B, bids can be solicited and received, and after receipt they can be evaluated and ranked. The public entity's bid evaluation report must be submitted to the Public Private Partnership Committee for approval, before the bidders are informed about the outcome of the bid evaluations. This approval is Transaction Approval 3. The Committee may, in consultation with the Minister approve the evaluation report with or without changes it may consider necessary.

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The next step is entering into the public private partnership agreement with the preferred bidder. The Act is silent on whether there is an opportunity for the preferred bidder and the public entity to enter into negotiations for the final version of the public private partnership agreement, but the fact that the contract must again be approved by the Committee compels an interpretation that contract negotiations are in fact envisaged. This approval of the contract is Transaction Approval 4 (Section 31(3).

The Committee must, in terms of Section 31(1) review the contract for approval with respect to the following:

(a) that the public private partnership agreement meets the requirements of affordability, value for money and optimal risk transfer;

(b) that the public entity's management plan explains the capacity of the public entity and its proposed mechanisms and procedures, to effectively implement, manage, enforce, monitor and report on the public private partnership project;

(c) that a satisfactory due diligence including a legal due diligence has been completed in respect to the public entity and the proposed preferred bidder in relation to matters of their respective competence and capacity to enter into the public private partnership agreement; and

(d) that the public private partnership agreement has been reviewed and approved by the Attorney-General.

Upon receipt of Transaction Approval 4, the public entity may conclude the public private partnership agreement (Section 31(3)). Any material amendments to the agreement, including material variations relating to the outputs or waivers provided for in the public private partnership agreement can only be made with the approval of the Committee, and the Committee will only approve the amendment if the amended agreement will continue to provide value for money, affordability and optimum risk transfer to the private entity in terms of Section 32. 'Material amendment' is not defined in the Act.

The public private partnership agreement is managed by a management team, which the public entity must establish in terms of Section 33 of the Act. This section does not state expressly that the management team must consist of members of both partners, it only stipulates that the team must be headed by a manager, assisted by a team with financial, technical and legal expertise and the team must include the public entity's project officer until the agreement is concluded. In terms of section 34:

(1) The management team must prepare a management plan which:

    (a) defines the processes that enable the public entity and the private entity to meet their obligations in terms of the public private partnership agreement;

    (b) includes mechanisms to monitor performance by the public entity and the private entity in respect of their obligations in terms of the public private partnership agreement;

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(c) includes mechanisms to manage unanticipated developments and mitigating risks through efficient risk management; and

(d) provides procedures to resolve disputes in an expeditious manner, with minimal impact on service delivery.

(2) The management plan serves as a repository of management procedures and resources and with respect to the public private partnership project must include -

(a) the public private partnership agreement;

(b) all financing agreements as well as financial models;

(c) the names, roles and contact details of key individuals of the public entity and the private entity; and

(d) the implementation plan in respect of the development, construction, operations and exit phases of the public private partnership project.

The Public Private Partnership Act contains a dispute resolution provision in Section 35, which requires the parties to endeavour to resolve disputes amicably, failing which the parties or one of them must submit the dispute to the Public Private Partnership Committee for mediation. In terms of subsection 34(4) the Committee must determine the merits of the dispute and must within 15 days of submission of the dispute issue its decision in writing. It is not clear what the intention of the Act is, as the next subsection, Section 34(5) states that the Committee must determine the procedures for mediation and make the procedures available to the parties to the agreement. Ideally, the Committee or the Minister should prescribe mediation procedures which apply in all disputes. It is also questionable whether the Committee will be seen as a neutral party, capable of conducting mediation procedures between the parties. The reason why the section is unclear is because in mediation procedures, the mediator only tries to assist the parties to find common ground. The mediator does not make any decisions binding on the parties. It is therefore strange that in terms of the last subsection, Section 35(6), the party which does not agree with the decision of the Committee may refer the dispute to arbitration in terms of the Arbitration Act 42 of 1965.

The Public Private Partnership Act contains an audit provision in Section 36 in terms of which the Minister or the Committee may instruct an audit of a public private partnership project to be undertaken by a person or institution designated by the Minister. The scope of the audit must be as follows:

(a) the process compliance during procurement stage;

(b) the procedures observed in releasing payments from the public sector from time to time, provision of guarantees from the public sector or managing contingent liabilities;

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(c) adherence to the public private partnership agreement in terms of fulfilment of conditions precedent, performance assessments, imposition of penalties for non-performance and administration of termination payments;

(d) exercise of its rights by the public entity under the public private partnership agreement;

(e) fulfilment of obligations by the private entity under the public private partnership agreement; and

(f) adherence to the provisions of this Act, in making any change or modification in the public private partnership agreement.

This section provides for the audit report to be submitted to the Minister or the Public Private Partnership Committee but it does not state that the Minister or the Committee can order the public entity to take particular remedial steps in the event that the audit report reveals non-compliance with the Act or with the parameters, aims and objectives of the public private partnership project itself. The section containing the powers and functions of the Committee (Section 6) does also not contain a provision which expressly empowers the Committee to order a public entity (or the private entity) to take some specific steps with regard to public private partnership projects. This may have been a deliberate way of drafting the Act so as not to create conflicting jurisdictions and powers between the Minister of Finance and the Minister of Public Enterprises who acts under the powers granted by the Public Enterprises Governance Act 2 of 2006, which is discussed above.

Finally, in keeping with the object of ensuring fairness, transparency, equity and competition in the process of awarding public private partnership projects, as stipulated in Section 2(e) of the Act, Section 37 requires that public entities make available information about public private partnerships projects to the general public. For this purpose public entities must:

(a) document all the information in relation to the public private partnership agreement, construction, project operation and maintenance and termination;

(b) document and maintain on an on-going basis all information relating to performance of the private entity with respect to the provisions of the public private partnership agreement;

(c) document the reasons for declaring information as commercially sensitive and not subject to disclosure; and

(d) comply with any additional requirements for information disclosure in accordance with applicable legislation.

Public entities must further specify in their public private partnership agreements a list of documents which the private entity must periodically submit to the public for disclosure to the Public (Section 37(6)).

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Public entities must include in public private partnership agreements, effective norms for disclosure and information sharing by the private entity, which is not detrimental to the interests of the private entity. Public entities may in terms of Section 37(3) voluntarily disclose the following information regarding public private partnership agreements:

(a) feasibility assessment;

(b) procurement plan;

(c) all procurement documents and minutes of pre-submission meetings;

(d) reports of the management team, related to progress of the public private partnership project;

(e) documents relating to external quality inspectors, if appointed;

(f) audited annual report of the public private partnership project party;

(g) variations and amendments to the public private partnership agreement;

(h) the executed public private partnership agreement, along with any annexure and schedules; and

(i) other project agreements that have been signed by the preferred bidder and a public entity in relation to the public private partnership project, as applicable, such as the state support agreement, substitution agreement, any agreement related to operations, maintenance and development agreement, technical operations agreement, if applicable, and land lease agreement, if any.

NamWater should therefore shift the decision about how to implement the project to as early as possible, rather than delay it further.

3.14 Summary

A number of pieces of legislation have a bearing on the various components envisaged by this Feasibility Study and important recommendations are provided should NamWater wish to pursue this project as a public private partnership project under the Public Private Partnership Act 4 of 2007.

However, an important concern regarding the wider water sector in Namibia is the fact that the Water Act from 1956 is still the legally valid legislation, despite being badly outdated. The appointment of the Water Advisory Council and the Water Regulator, even though these bodies are not functioning, and the distribution of the “draft” water quality regulations, the NWQS and NWQG, under the WRMA 11 of 2013 which is not yet an applicable law, creates a “grey area” in terms of day to day operations in the water sector.

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Of even greater concern is that the Omaruru Basin Management Committee and the Upper Swakop Basin Management Committee have been “properly constituted” BMCs under Section 20 of the WRMA, 11 of 2013, even though this not a valid piece of legislation. It is therefore recommended that the MAWLR determines by Government Notice in the Government Gazette the commencement of the Act. This should be done even if the Regulations are not yet finalised.

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4 WATER SUPPLY FRAMEWORK AND BOUNDARY CONDITIONS

4.1 Water Supply Costs and Tariffs

4.1.1 Legal Framework for Costs and Tariff Setting

The WRMA, 2013, under Section 3, recognises the fundamental principles that all people should have an equitable access to safe drinking water as an essential basic human right to support a healthy and productive life, and that this access should be sufficient in quantity within a reasonable distance from the place of abode. A further fundamental principle is the recognition of the economic value of water in the allocation thereof.

Section 104(1) of the WRMA, 2013, gives the Minister power to prescribe tariffs, fees or charges in accordance with a determination of a Water Regulator in respect of water services provided by the State to users of water controlled by the State.

Under the WRMA, 2013, a Water Regulator is to be established, who among other functions, is responsible for the determination of tariffs, fees and charges which may be levied by a water services provider, which tariffs are to be published by notice in the Government Gazette (Section 12).

The WSASP states that the "*The basic premise of cost recovery is that water is an economic good with a social responsibility to make water available to the poor. It is accepted that the overall sustainability of the WSS sector will depend on its ability to become self-sufficient. Without the necessary revenue, the service providers will be unable to continue providing the expected water supply and sanitation services. In all instances it will be essential to recover the full financial cost or, in low income rural and urban areas, at least the operational and maintenance costs with support from government subsidies or cross-subsidies amongst consumers. As stated in the National Water Policy, the Minister of Agriculture, Water and Forestry* [as previously] *will determine tariff policies in consultation with the service providers and the public, taking the tariff policy principles indicated below into consideration*" (MAWF, 2008a).

This policy further states that "*the following general principles should be applied with the development of such a policy within all the sectors*" (MAWF, 2008a):

1. "Money generated through domestic water use or sanitation should not be used to subsidise water to any other economic activity";
2. "Any industrial, commercial or mining activity should pay the full cost recovery tariff taking the scarcity of water and the cost of future water supply augmentation into account."

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It is further stated that "*full cost recovery and prevention of debt as part of the principle of water as an economic good should be promoted and implemented, based on equitable tariffs to improve access by poor and marginalised communities. This consolidated national tariff policy for water supply and sanitation provision including appropriate credit control measures should be compiled*" (MAWF, 2008a).

The NWCA, 1997, provides NamWater with the power to determine and levy, in consultation with the Minister, tariffs on a full cost recovery basis for water supplied (Section 7(1)(a)).

4.1.2 Costs and Tariff Setting

Water supplied by NamWater, including that distributed by the DWSSC and local authorities, is supplied against a tariff, and there is no provision of a free basic quantity of water, as is the case in South Africa. End users typically pay a monthly rate which may include a connection and / or water meter fee and a volumetric tariff based on the volume of water used in a given period.

Many local authorities supply water at a relatively low tariff for a minimum "lifeline" volume, with progressively increasing rates for increasing consumption, in what is referred to as a block tariff structure (Heyns et al., 1998).

The WRMA, 2013, envisages that the Water Regulator will examine costs and determine and guide tariff setting in a manner similar to that of the Electricity Control Board, which serves as the regulator for the power sector. In practice, whilst members of the Water Regulator have been appointed by the Minister, the necessary regulations and framework for the functioning of the body, including tariff determinations and setting, are not yet in place. In practice therefore, the Water Regulator is not yet functioning as envisaged. Therefore, the *de-facto* arrangement is that NamWater and the various local authorities prepare tariffs which are submitted to Cabinet for approval, which is provided by the relevant line ministries; MAWLR in the case of NamWater and the Ministry of Urban and Rural Development in the case of the local authorities, before being published by notice in the Government Gazette.

4.1.3 NamWater's Blended Tariff in the Central Coastal Area

In the CCA, NamWater operates under the principle that desalinated water is supplied to the uranium mines and groundwater is supplied to the local authority and small consumers (for example along the Omdel – Swakopmund Pipeline). This should be understood in the context of billing / water tariffs, as in reality, the water which reaches Swakopmund and which is thus supplied to the town and the uranium mines consists of a physical mix of groundwater from the Omdel Aquifer and desalinated water from the EDP.

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Thus, prior to FY2017, the uranium mines were charged a tariff which reflected the costs to NamWater of desalinated water and the local authorities and other small users were charged a tariff which reflected the cost to NamWater of groundwater supply and distribution.

Also prior to FY2017, the different consumers supplied from the different groundwater sources (Omdel and Kuiseb Aquifers) were charged different tariffs (for example Henties Bay and Walvis Bay were charged different tariffs). From FY2017 onwards, NamWater harmonised the groundwater tariffs for the Omdel and Kuiseb Schemes / Sources and introduced a blended tariff which is charged to the local authorities (Henties Bay, Swakopmund, Arandis and Walvis Bay). Small consumers and government institutions supplied directly by NamWater are charged the groundwater tariff whilst commercial consumers (non-mining) supplied directly by NamWater, for example NamPort and the Namibia Airports Company, are charged a “commercial tariff”. NamWater’s mining customers, whilst nominally charged a “desal tariff” are in fact charged at full cost recovery rates plus a transfer charge, as determined by NamWater’s finance division.

NamWater has allocated the safe yields of the Omdel and Kuiseb Aquifers (11.6 Mm^3/a) to the local authorities overall, and a quota to each individual local authority on a pro-rata basis (proportional allocation).

Table 4.1: Allocation of Groundwater to the Coastal Local Authorities (NamWater)

Local Authority	Allocation (m^3/m)	Allocation (m^3/a)	Portion
Walvis Bay	535 430	6 425 160	56.6%
Swakopmund	335 331	4 023 972	35.4%
Henties Bay	49 306	591 672	5.2%
Arandis	26 599	319 188	2.8%
Total	**946 666**	**11 359 992**	**100.0%**

Note: Data provided by NamWater.

As the demand of these consumers has grown, and exceeded the safe yields / permitted abstraction from the groundwater sources, NamWater has had to purchase desalinated water from the EDP to supply them, which water is more expensive to NamWater than the groundwater. NamWater has allocated the additional volumes of desalinated water to each local authority based on the proportional allocation of the groundwater yields, leading to the introduction of the blended tariff, which is made up of groundwater supply at a certain tariff and desalinated water supply at a certain tariff.

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Table 4.2: Selected NamWater Bulk Tariffs to Local Authority Areas in the Central Coastal Area (NamWater)

NamWater Financial Year	NamWater Water Tariffs (N$/m³) Per Scheme Code and for Blended Water			
	HEN: Henties Bay (groundwater)	ROB: Rooibank - Mile 7 Reservoir (groundwater)	SKD: Swakop-mund Reservoir (groundwater)	Blended Tariff
2013	6.70	6.50	6.90	N/A
2014	7.70	7.50	7.95	
2015	8.45	8.25	8.75	
2016	9.30	9.10	9.65	
2017	10.60	10.60	10.60	14.81
2018	11.75	11.75	11.75	14.75

Note: A comparison of the CCA tariffs with those in the CAN is shown in Figure 4.5.

The local authorities consulted during the Inception Phase of this Project reported that the higher blended tariff has raised concerns regarding affordability. Further concerns raised by the stakeholders consulted include:

- NamWater's CEO came to the CCA to inform the local authorities about the introduction of the blended tariff, but this was perceived by NamWater's customers to be more a matter of "dictum" than of "consultation";
- The higher blended tariff was introduced by NamWater mid-way through the local authorities' financial year (01 July – 30 June[18]) and they were unable to adjust their tariffs mid-way through their financial year, thus compromising their financial positions;
- Some local authorities experience a marked seasonal fluctuation in business and thus water demand, particularly Henties Bay and Swakopmund, who receive a large influx of holiday makers during December and January. NamWater's groundwater allocations are monthly allocations, which are exceeded by some towns during the December / January period, for which they are then charged the higher blended tariff. The local authorities report that they do not have a mechanism to recover these higher costs for a couple of months of higher water consumption from their residents, thus compromising their financial positions. The local authorities have requested a reconciliation of water use and tariffs on an annual basis, but this is not supported by NamWater;
- NamWater has decided to view the water supply system in the CCA as an integrated system, hence the harmonisation of tariffs charged to the local authorities, both for groundwater supply and for "blended" water. There may be merit to this ap-

[18] The NamWater financial years (01 April – 30 March) do not coincide with those of the local authorities (01 July – 30 June).

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proach, as there is a benefit to all local authorities of NamWater supplying cheaper groundwater (at least for a portion of their demand) and a benefit to all of receiving desalinated water if the demand exceeds the availability of the groundwater resources and of having multiple sources to provide a more robust supply. In practice however, and from an historical perspective, Henties Bay has viewed the Omdel Aquifer as "their" source and Walvis Bay has viewed the Kuiseb Aquifer as "their" source. There is thus a need for historical perspectives to change to accommodate NamWater's new approach, which is a time consuming process. Practical considerations however also hamper NamWater's new approach, as neither Henties Bay nor Walvis Bay receive desalinated water, although they are required to pay the higher blended tariff in the event that their water use exceeds the quota / allocation determined by NamWater. Particularly in the case of Walvis Bay, if their water use exceeds their quota, they are supplied by the over abstraction of the Kuiseb Aquifer, which may be to the detriment of the long-term sustainability of that resource, but are charged the blended tariff without receiving desalinated water. Overall, there is at best a grudging acceptance of NamWater's approach, given the current lack of alternatives, but this background is necessary to understanding the origin of the Erongo Water Forum (EWF) and the desire on the part of consumers and stakeholders to become independent of NamWater.

Previous studies have shown and it is clear that any further growth in water demand in the CCA will have to be met with desalinated water, which is already part of the supply mix. This will most likely come at greater cost (costs to be determined under the later phases of this Study) than current water tariffs, which will require adjustments on the part of all stakeholders and consumers. Water supply is more emotive in the CCA than in the CAN, and these aspects will need to be handled with the appropriate approach and diplomacy.

4.2 Affordability of Water, Perceptions of Cost and Other Considerations

4.2.1 Considerations of Cost and Affordability

Practically all of the local authority stakeholders consulted during the Inception Phase of this Project (refer to **Section 4.4.1** and above) noted concerns regarding the costs of water being high, and the affordability of water tariffs being problematic for at least some sections of their communities. This was particularly the case with the stakeholders located in the CCA.

Many of the Local Authorities consulted reported problems with the collection of monies charged for water supply and many residents' accounts being in arrears, which has placed constraints on their operations, activities and ability to implement projects. Some local authorities are busy considering the installation of prepaid water meters, some are busy with such installations and others already have such installations – in an effort to recover the costs of water provision.

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Unfortunately the unit cost of water and the impact on current tariffs is one of the last components of or outcomes to be generated by this feasibility study, following the consideration of alternatives, preliminary designs and cost estimates, but already an important consideration in the earlier components of the study, particularly the assessment of water demands and demand projections and in terms of stakeholder consultations, where matters of costs / affordability often feature prominently.

Unfortunately, there is no information available for Namibia on the price elasticity of demand (refer below), which is one measure which could have been used to examine affordability concerns. In the absence of this information, the Consultant has attempted to estimate the and benchmark the affordability of water based on monthly household incomes.

4.2.2 Affordability Estimates

The statistics available from the NSA only indicate annual household consumption (expenditure) for “food and beverages”, without providing more details other than that this includes “*alcoholic beverages and tobacco*” (NSA, n.d.[1]). It is for example not clear whether this category of consumption includes water consumption, though that could be presumed to be the case.

In order to gain a clearer understanding of household expenditure on water consumption, cost estimates were derived for an acceptable consumption of water in the main urban centres in the Project Area based on other statistics and data available, most of which are available for urban areas. To begin with, an estimate of “an acceptable consumption of water” is required. The World Health Organisation (**WHO**) guidelines indicate 70 ℓ/c/d for the “medium-term (maintaining)” category (WHO, 2013), which is believed to correspond with a stable supply in the urban centres in the Project Area. However, the allowance of 10 ℓ/c/d for “growing food” included in this guideline value (WHO, 2013) is not believed to be applicable to the urban areas in the Project Area and this guideline value was therefore adjusted to 60 ℓ/c/d. This is considered a fair and sustainable allocation of water which includes allowances for drinking, cooking, personal washing, washing of clothes, cleaning the home, sanitation and waste disposal (WHO, 2013).

Affordability criteria vary to a large extent between states in the United States of America (**USA**); from 1 to 1.75% of the household income in disadvantaged communities. In the USA, these criteria are used to determine the allocation of subsidies for schemes from the Drinking Water State Revolving Fund. According to the World Bank, a generally accepted guideline of affordability is that 3% of the mean household income of low income families in developing countries can be spent on water. The National Development Plan for Namibia recommends a value of 5% of mean household income spent on water as an affordability guideline (LCE, 2008).

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Whilst the estimation provided in **Table 4.3** is exactly that, being based on regional averages, it does provide an indication that in the main urban centres in the Project Area on average at least, less than 3% of household consumption is spent on water supply, which is less than the 5% guideline value for Namibia.

Table 4.3: Estimation of the Affordability of Household Water Consumption in Selected Urban Centres of the Project Area

Urban Centre or Location	Household Size[1] (Capita)	Water Consumption[2] (m^3/HH/m)	Cost of Water Consumption[3] (N$/m)	Average Household Consumption (N$/m)[4]	Cost of Water as Portion of Total Monthly Consumption (%)
Swakopmund (Erongo)	3.1	5.66	131.83	10 718	1.2%
Windhoek (Khomas)	3.5	6.39	217.99	17 463	1.2%
Okahandja (Otjozondjupa)	3.9	7.12	209.11	8 317	2.5%

Notes:
1. 2016 data for the average household size on a regional basis from the 2016 Inter-censal Demographic Survey (NSA, 2017b).
2. Water consumption derived from the average number of people in the household, each using 60 ℓ/c/d as explained in the text.
3. Cost of water consumption derived from the applicable tariffs and the volumetric estimate, plus the monthly basic charge for 2016/17 in each local authority area (municipal financial years). Local authority tariffs obtained from Government Gazettes and the Municipal rate sheets.
4. Average monthly household consumption derived from the average annual values provided in Table 2.6 (NSA, n.d.[1]).
5. Average monthly expenditure of a household on water as a portion of total average monthly expenditure.
6. HH = Household.

However, it should be noted that these estimates are based on regional averages which, based on the high Gini coefficient (at least nationally; refer to **Section 2.2.11** on inequality aspects and the Gini coefficient) may not be representative of the majority of households, specifically those residing in informal settlements.

In 2015/16, 17% of households nationally (NSA, n.d.[1]), 21.7% of those in the Otjozondjupa Region, and 7% of those in the Khomas and Erongo Regions (NSA, n.d.[1]) were classified as “poor” (refer to **Section 2.2.10**). With most migrant households in informal settlements being “*poor and food insecure*” (Olivier, 2016; refer to **Section 2.2.5**), the affordability of desalinated water, particularly in informal settlements, but elsewhere as well, is a concern. This was investigated in terms of the affordability of water relative to the poverty thresholds (refer below).

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Table 4.4: Estimation of the Affordability of Individual Water Consumption in Relation to Poverty Thresholds in Selected Urban Centres of the Project Area

Urban Centre or Location	Water Consumption[1] (m^3/capita/m)	Cost of Water Consumption[2] (N$/capita/m)	Food Poverty Line (Food Poor)	Lower Bound Poverty Line (Severely Poor)	Upper Bound Poverty Line (Poor)
			N$ / adult / month[3]		
			293.10	389.30	520.80
			Cost of Water as Portion of Monthly Poverty Threshold (%)[4]		
Swakopmund (Erongo)	1.83	42.53	15%	11%	8%
Windhoek (Khomas)	1.83	62.28	21%	16%	12%
Okahandja (Otjozondjupa)	1.83	53.62	18%	14%	10%

Notes:
1. Water consumption per individual per month using 60 ℓ/c/d as explained in the text.
2. Cost of water consumption derived from the applicable tariffs and the volumetric estimate, including the monthly basic charge for 2016/17 in each local authority area (municipal financial years) on a per capita basis – i.e. the monthly basic charge was divided by the number of people 2in the average household per the 2016 Inter-censal Demographic Survey (NSA, 2017b) to derive the per-capita cost. Local authority tariffs obtained from Government Gazettes and the Municipal rate sheets.
3. The poverty thresholds are the 2015/16 values provided in Table 2.7 (NSA, n.d.[1]).
4. Average monthly expenditure of an individual on water as a portion of the different poverty thresholds.
5. Note that these calculations are on an individual basis, whilst those shown in Table 4.3 are on a household basis.

As can be expected, water consumption forms a much greater portion of individual's expenditure/consumption at the poverty thresholds. It is however also likely that individuals at or near the poverty thresholds will use less than the indicated 60 ℓ/c/d, in which case the cost of water use will be lower than that indicated.

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4.2.3 Historical Perspective on Water Tariffs

It can be argued that historically, water tariffs have not adequately reflected the total water supply costs in a manner which makes adequate provision for capital replacement, and particularly not for the development of additional sources and schemes for supply augmentation. Some of the reasons for this include the fact that prior to Independence, the state water supply schemes (as they were called at the time) were heavily subsidised by the State; with the establishment of NamWater, these schemes were transferred to NamWater at historical costs or at already depreciated "book values"; and NamWater initially based their tariffs on the historical costs of their schemes and not on their replacement values[19]. The inability of the wider water sector to implement additional schemes and develop additional sources in the last 20 years can partially be ascribed to the fact that existing water tariffs cannot support these costs. The sharp "jump" or increase in tariffs following the implementation of new schemes such as the new Von Bach – Windhoek pump stations and the Wlotzkasbaken – Swakopmund Pipeline further supports the assertion that historical tariffs do not adequately provide for capital replacement and / or additional schemes.

This is believed to represent a real dilemma to the wider water sector and to NamWater as the bulk supplier in particular. It is clear from the analyses and motivations provided in this Report, that the supply of any further increases in water demand (and some of the existing demand) in the CCA must come from desalinated sea water and that beyond some local improvements, any further increases in water demand (and some of the existing demand) in the CAN must be supplied from sources more than 350 km away from Windhoek. In both areas, such interventions constitute the development of more "difficult" and distant sources and schemes and will therefore come at greater cost than current tariffs make provision for; an observation which was made back in 1998 already by Heyns et al. (1998). If tariffs are set according to cost recovery principles, these will be much higher than present rates, particularly so in the case of the CAN. If the cost / affordability of water is problematic at present, it will be a much greater problem in future if additional sources / schemes are implemented.

In part, at least some of the present difficulty can be ascribed to matters of public perception and the way water is thought of. Statements such as "water is life" and "water (the rain) comes from God" are commonly expressed or heard. As **Figure 4.1** shows, NamWater's bulk water tariffs are an order of magnitude lower than everyday items which are also purchased on a volumetric basis. Unfortunately, when a commodity is "cheap", it is also not appropriately valued, which would appear to contradict the view that "water is life".

19 NamWater has determined tariffs based on the revaluation of their assets since 2012 only. Thereafter, the costs of water have increased at rates well above inflation (refer to Figure 4.5).

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Despite the apparent importance given to access to water, there appears to be insufficient appreciation in the wider public domain of the costs associated with the provision, maintenance and operation of water supply infrastructure; the fact that Namibia really is a water scarce country and water is transferred over large distances, which incurs large costs; and of the fact that economic theory dictates that the relative scarcity of a commodity results in a high price thereof.

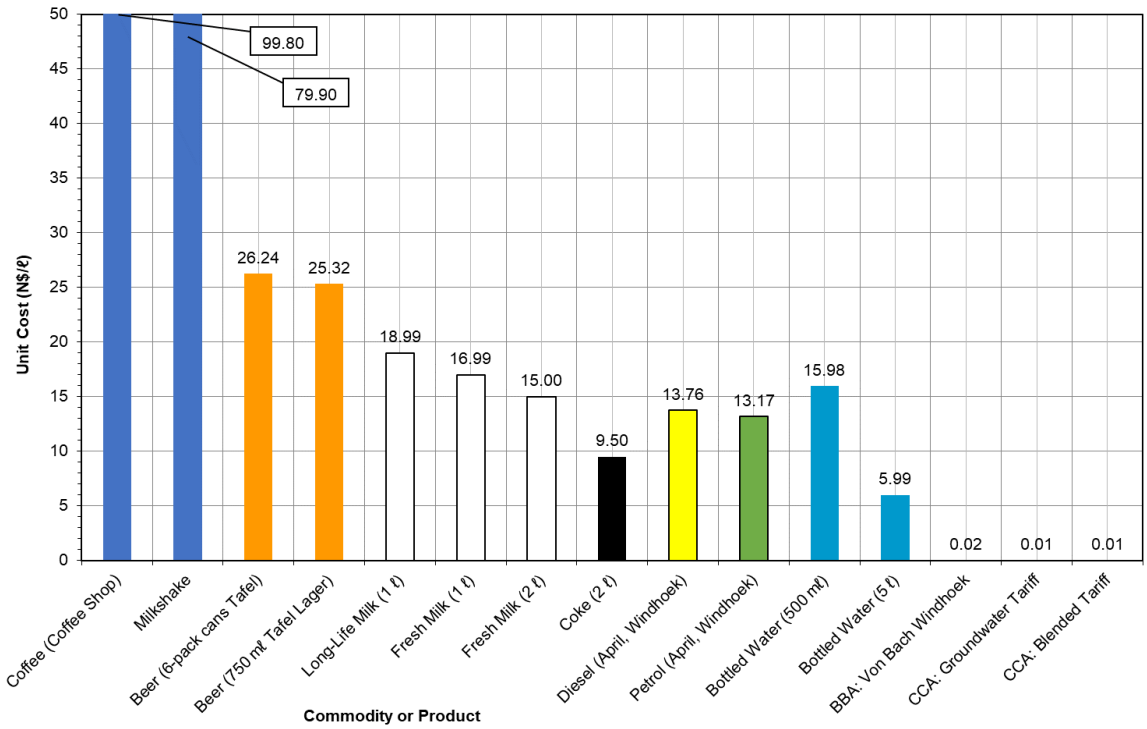

Figure 4.1: Comparison of Water Costs with Different Commodities and Products

Notes:
1. Venter (2017) is credited as the source for and inspiration for this figure, which has been updated and expanded as presented here.
2. Supermarket prices in Windhoek in April / May 2019 for most consumable products.
3. May 2019 Windhoek pump prices for diesel (50 ppm) and petrol (95 octane).
4. NamWater bulk water tariffs for FY2018 for potable water supply to Windhoek (BBA). In the CCA, all local authorities are charged the same tariffs for groundwater supplied and the supply of blended water (groundwater and desalinate sea water).

Proposals by some stakeholders to use desalinated water for irrigation, which is typically the lowest value of water use (refer to **Section 4.4.4.2**), unfortunately reflect the prevailing false notions and perceptions regarding water supply and the costs thereof. It is clear that the provision of larger volumes of desalinated water in the CCA and the introduction thereof to the CAN will come at costs much higher than can be supported by the current tariffs.

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Consideration will therefore need to be given to the following factors in the following phases of this Study:

- If these costs are to be supported by tariffs, these will increase dramatically, probably by orders of magnitude in the CAN. NamWater, in conjunction with the Local Authorities, the Water Regulator and other stakeholders, will need to implement a very effective public campaign to explain, justify and convince consumers of the rationale and need for the increase in tariffs. There is no precedent of these institutions having successfully conducted similar campaigns recently;
- If tariffs are not to increase dramatically, some portion of the costs – most likely some or all of the capital costs – of the additional infrastructure will need to be subsidised in some manner;
- Concerns regarding affordability can be addressed to a large extent via the use of rising block tariffs in the local authority areas. If the lowest block tariff is set to correspond with a “lifeline” volume of water, and priced at the same rate as the bulk tariff (i.e. no mark-up by the local authority), this could help make water more affordable to the poorest portions of the community. Blocks for higher rates of consumption would need to have higher tariffs to enable the local authorities to recover their costs. It is noted that local authorities generally all use rising block tariffs, however, there would be a need to reassess these with the introduction of supply augmentation using desalinated water, including the lowering of the first block unit to correspond more closely to a “lifeline” volume of water. The financial modelling of local authority tariffs is beyond the scope of this Study.

The costs of the infrastructure to be proposed under this Feasibility Study are such that a re-assessment of the relationship between costs and tariffs will be required on the part of NamWater and / or the owner / operator of the infrastructure proposed, possibly in the wider water sector in Namibia as well.

4.2.4 Price Elasticity of Demand

A critical distinction when considering affordability is the difference between ability to pay and willingness to pay. Willingness to pay reflects the consumer preference for purchasing a quantity of goods or services relative to prices. From the perspective of willingness to pay, responsiveness to price changes can be measured by price elasticity of demand (LCE, 2008).

The price of water is an important determinant of who uses it and how they use it. Demand for water in economic terms, varies according to a price / quantity relationship. It has been found that this relationship is an inverse one, thus as price increases, the quantity of water demanded decreases.

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The price elasticity of demand is defined as the percentage change in water demanded for any given percentage change in price (LCE, 2008). The price elasticity of demand is a measure of the sensitivity of the consumer to changes in water prices. Demand is said to be elastic when it decreases as price increases and inelastic when price increases have little influence on it. The relationship between price and water consumption is illustrated in **Figure 4.2**. The price elasticity of demand for Namibia is however unfortunately not known or defined.

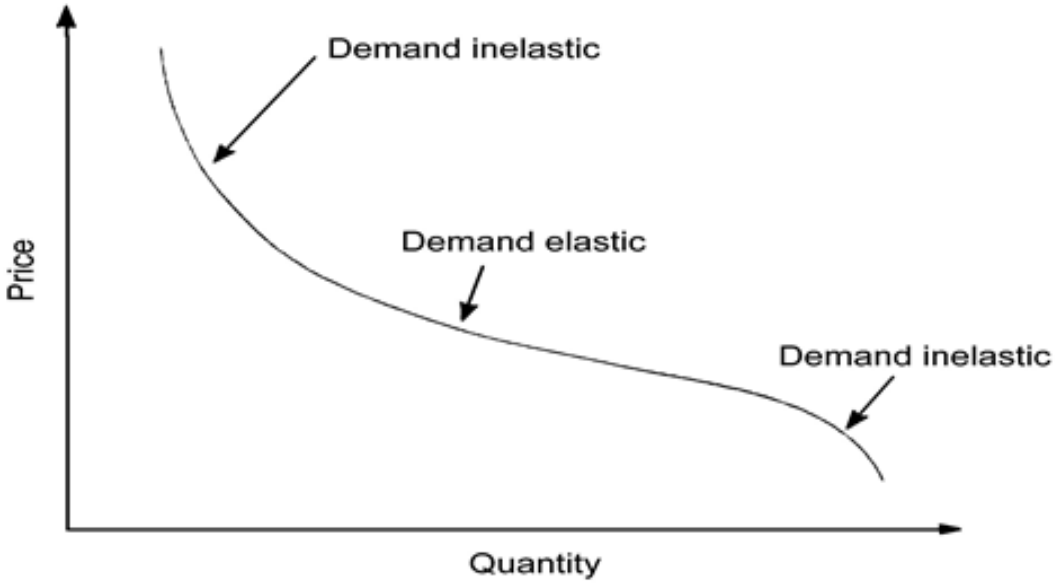

Figure 4.2: Relationship between Water Price and Volume Consumed

In NamWater's FY2017, desalinated water was introduced in the supply to local authorities in the CCA, groundwater tariffs were harmonised and a blended tariff was introduced to account for the introduction of desalinated water (**Section 4.1.3**). Water demand in Walvis Bay was marginally lower in 2017 than in 2016 (**Figure 5.24**), flat in Swakopmund (**Figure 5.25**), lower in Arandis (**Figure 5.28**) and largely unchanged in Henties Bay (**Figure 5.29**). Water use in Arandis was markedly higher in 2018 than in 2017 and also increased in Walvis Bay. On the basis of these data, it is not possible to ascertain to what extent the higher "blended tariff" in the CCA impacted on water demand/use.

It is important to take the reduction in water demand based on increased costs (price elasticity of demand) into account. In many countries, full cost recovery based on real costs for water reduced the demand to such extent that a new supply augmentation scheme may even be obsolete. If the next major supply system is identified, which in the context of this Project is expected to be a desalination plant, pipeline transfer system and power supply, it is important that water tariff increases yearly before full implementation for water suppliers to get a better understanding of the expected future water demand and for consumers to become accustomed to higher tariffs.

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It is also important to gain some *a priori* estimate of how much of the expected future water demand in the different Project Areas is to be supplied from desalinated water (which will be more expensive) and from existing sources (which will be cheaper), and thus an expectation of by how much the supply mix and hence costs will change from the current situation, before the water demand projections are prepared. According to the price elasticity of demand, the cost of water supplied in the future (with the inclusion of desalinated water) will have an influence on the demand for it.

Unfortunately the demand for water needs to be determined first, in order to size the supply infrastructure, from which the costs thereof can be determined and hence the unit costs derived, from which the impact on the demand can be estimated, leading back to the point of departure, and thus creating a “loop”. In practice, it is recommended that should further projects emanate from this Feasibility Study, or should some of the proposals proceed to a more detailed design phase, the water demands be re-assessed on the basis of the expected unit costs derived from the outcome of this Study.

4.3 Technology Selection

4.3.1 Prepaid Water Meters in the Project Area

The nature of Namibian’s access to water supply and sanitation is provided in **Section 2.2.11**. In urban areas, which are the major demand nodes in the Project Area, nearly all residents (98%; NSA, 2017b) have access to piped water either inside their houses, outside their houses (for example as a yard connection), or at a public or communal standpipe. Generally, the service level corresponds with socio-economic grouping; communal standpipes are provided in informal and very low income areas, yard connections in low income areas, with internal plumbing available in nearly all other areas.

Prepaid water meters have been installed in various centres in Namibia, mostly with mixed results. Some of the local authorities consulted who have installed such devices in the Project Area have reported operational problems with these systems. These include:

1. Prepaid systems are not always easily (or at all) accepted by the communities. In many instances, this is at least partially due to deficient consultation and engagement processes prior to implementation;

2. Prepaid systems are not available locally and are thus imported. This often leads to problems obtaining support, back-up, spare parts and replacement units. In most cases, the batteries of such units are the most problematic components. Should the supplier / agent of such units cease operations or the importation of such systems, the local authorities face serious difficulties in obtaining spare / replacement parts;

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3. Prepaid systems typically come with their own software operating systems, which run independently of the local authority's financial operating system (Finstel, SAP or similar). These systems are often not integrated, and it is for example therefore difficult to obtain a consolidated water usage figure for the local authority;

4. Prepaid systems are typically installed in areas where residents have an established poor record of payment for municipal services. Electricity is typically available on a prepaid basis, and once water is paid on a prepaid basis, residents think that they have paid what they should and local authorities then struggle to recover charges for sewerage services, refuse removal and other rates and taxes. Authorities then institute some or all of the following measures:

   a. Allocating a portion (often 50%) of any payment made by a resident in arrears towards their outstanding debt, and the remainder to their future consumption (prepaid credit);

   b. Only issuing credit for future consumption if the monthly basic charges for various services have been paid;

   c. Charging a higher volumetric tariff for water use to "work-in" or include the monthly basic charges where these are not charged separately. This can lead to problems explaining why the poorer sections of the community (those with prepaid water meter systems) are charged higher volumetric tariffs than the more affluent sections of the community which make use of conventional water meters and monthly billing / invoicing and payment.

Table 4.5: Prevalence of Prepaid Water Meters in the Local Authorities in the Project Area

Local Authority	Prepaid Water Meters (No.)
Walvis Bay	± 400
Swakopmund	± 20 communal standpipes
Henties Bay	N/A
Arandis	20 -30 households; pilot project
Usakos	N/A
Omaruru	N/A
Karibib	N/A
Otjimbingwe	N/A
Okahandja	± 800
Windhoek	N/A

Notes:
1. Data as obtained from the various local authorities during the consultations carried out during the Inception Phase.
2. N/A = Not Available.

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In essence, prepaid water meter systems are installed as a debt recovery or payment management system and not as a water management tool (Mr. Esterhuizen, 2019, pers. comm., 26 March).

There is unfortunately very little information available on the extent of pre prepaid paid water meters installed in the different local authorities in the Project Area.

4.3.2 Experience with Prepaid Water Meters Elsewhere

Heymans et al., (2014) note that the introduction of prepaid standpipes in Windhoek (first introduced in 1998) have reduced conflict around shared payment and disconnection, since residents are not penalised by disconnection if others do not pay.

Some literature which covers other's experience with prepaid water meters is available, which indicates that these systems are not a panacea for fixing underlying management issues in the delivery of urban water supply (Heymans et al., 2014).

A review of the implementation (between 1999 and 2004) of prepaid metering systems in eight municipalities throughout South Africa showed mixed results. Success (two instances) was achieved where faulty meters were replaced regularly, and failure (six instances) where maintenance and repair costs were high and not adequately budgeted for by the local authority, the meters were poorly designed and / or not robust enough, operators were not adequately trained and consumers were not willing to pay (high public resistance) (Malunga, 2016).

Often, the notion of prepaid systems obscures the fact that an overall water metering strategy needs to be developed by a local authority which depends on local conditions and needs, which may include prepaid water metering as one of several options, if appropriate (after Van Zyl, 2011 and Heymans et al., 2014).

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Table 4.6: Selected Comparative Advantages, Disadvantages and Other Aspects of Pre-paid Water Metering

Advantages	Disadvantages	Other Aspects
• Allow users to manage their accounts more directly, which benefits women who often manage the household budgets • More equitable access offered to people without their own connections • Can provide better solutions for revenue collection than conventional metering (revenue collected in advance; no arrears) • (Conventional) Meter readings, billing and collecting systems are not required • Units can dispense a free basic allowance of water (as in South Africa) or restrict flow instead of shutting it off completely • Can be programmed to provide alerts to users • Consumers cannot ignore their water use, and are reminded thereof by constantly needing to purchase credit, which can lead to more efficient water use • Losses due to leaks on a property can be limited if the meter shuts off once credit is depleted	• Higher costs than a conventional meter due to additional components, the need for a secure housing with tamper protection • More highly skilled municipal staff are needed to install, repair, maintain and operate these meters • Tracking of consumption against prepaid sales is required and prepaid sales (consumption) need to be integrated into the sales (consumption) of post-paid systems, which typically run on different operating systems • Prepaid meters are more sophisticated and prone to failure and the technology is still inconsistent • More regular inspection and maintenance of these meters is required • An electrical supply via mains or battery is required. In particular, battery units are prone to failure and may be expensive • Many systems are propriety, and once units from one supplier are installed, options for the procurement of spares, particularly batteries, may become limited or non-existent • A network of credit vendors is required, so that users can easily buy additional credit • Users often tamper with or bypass the meter when their water is shut off • Community backlash can be expected when such systems are forced on users • If rising block tariffs are used, consumers who buy credit more than once a month get less credit on subsequent purchases than on the first instance, which can be difficult to explain to users, leading to discontent • In middle income areas, prepaid water meters may result in a drop in consumption, which may be positive from a WDM perspective, but may adversely impact on revenue for the local authority • These systems can increase social and gender inequalities, and benefit local authorities more than users • Users can be without water for long periods, especially after hours, if vendors are not available / open • Interruptions in supply for whatever reason can result in unhygienic conditions and health concerns	• Prepaid systems should not be seen as a way to avoid high billing and collection inefficiencies • Prepaid meters are not considered viable in informal settlements in South Africa, where users generally rely on the free basic allowance and do not purchase enough water to recover the costs of the prepaid water meter and installation thereof • This is also true in very poor areas or those with intermittent water supply • Prepaid water meters at communal standpipes in informal areas may be an attractive option, allowing service providers to better serve poor households • It is vital that a prepaid metering system is well-managed. Experience has shown that the success and acceptance of these systems is a function of how well they are managed after installation • Prepaid systems are a technological solution and are not intrinsically anti-poor or do not intrinsically equate to the commodification of water or even privatisation

Notes:
1. Compiled from Van Zyl, 2011; Heymans et al., 2014, Malunga, 2016 and WaterFund, n.d.

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4.4 General Boundary Conditions for Water Supply

4.4.1 Consultations with Technical Stakeholders

The Consultant (engineering) conducted consultations with technical representatives of the various local authorities in the Project Area, per the methodology stated in the Technical Proposal. The purpose of these consultations was to introduce the Project to the technical departments / representatives of the various local authorities, request in person the information required to conduct the necessary analyses and obtain input, information, perspectives and concerns of these various stakeholders.

It should be noted that these consultations are separate from the consultations with interested and affected parties (stakeholders) conducted under the ESIA component of the Project, although there is information sharing and coordination between the engineering and environmental consultants working on these components of the Project.

4.4.2 Project Area Definitions

It is proposed that the CCA is to encompass the area currently supplied with water by NamWater, between Henties Bay in the north, Walvis Bay in the south and Arandis in the east.

It is proposed that the CAN portion to be considered for desalinated water supply is that area downstream of the Von Bach Water Treatment Plant (**VBWTP**), which is termed the Von Bach Node, at least for the purposes of this Feasibility Study. In terms of resource use and allocation, some of the existing resources located to the north of the Von Bach node will still be used for supply to this demand node. Further details in this regard are provided in **Section 6**.

Although Karibib and Otjimbingwe are geographically located in the area of the en-route users, they will be considered as part of the CAN, per the current supply configuration and the approach followed with previous feasibility studies for water supply to the CAN.

It is thus proposed that the en-route users to be considered for desalinated water supply encompass Usakos and Omaruru through take – off provisions. Further details in this regard are provided in **Section 7**.

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Table 4.7: Record of Consultations with Technical Stakeholders

Stakeholder Consulted	Date	Persons Consulted	Nature of Consultation
Erongo Water Forum	28 February 2019	Regional Governor, representatives of all the coastal local authorities	Meeting
City of Windhoek	08 March 2019	Mr. Husselmann	Meeting
Okahandja Municipality	25 March 2019	Ms. Mutilifa, CEO; Mr. Nunda, Finance Division	Meeting
Omaruru Municipality	25 March 2019	Mr. Tjitombo, CEO; Mr. Haipinge, Head: Planning and Technical Services; Mr. Shopati, Technical Serivces Officer	Meeting
Usakos Town Council	25 March 2019	Mr. Lombard, CEO	Meeting
Walvis Bay Municipality	26 March 2019	Mr. Esterhuizen, GM: Dep. Of Water Waste & Environmental Management; Mr. Shikongo, Dep. Engineer	Meeting
NamPort	26 March 2019	Mr. Gelderbloem, Executive: Port Authority; Mr. Kashweka: Engineer: New Infrastructure	Meeting
Arandis Town Council	26 March 2019	Mr. Makili, Technical Services Manager	Meeting
Husab Mine / Swakop Uranium	26 March 2019	Mr. Dengeinge, Head of Planning and Projects at Swakop Uranium	Meeting
Swakopmund Municipality	27 March 2019	Mr. McClune, GM: Engineering Services	Meeting
Erongo Regional Council	27 March 2019	Chief Regional Officer; Chief Accountant; Director: Development and Planning; Deputy Director: Admin; Management Committee Members and Councillors	Meeting
Henties Bay Municipality	28 March 2019	Mr. Kambatuamasa: Strategic Executive: Infrastructure, Town Planning and Technical Services	Meeting
Orano HQ Swakopmund	28 March 2019	Mr. H. Mbako: CEO; Mr. T. Gouws: Financial Manager	Meeting
Karibib Town Council	29 March 2019	Ms. Tjombumbi, Manager: Technical Services and Planning; Mr. Au-Khaob: Safety, Health and Environmental Practitioner	Meeting
Rössing Uranium	05 April 2019	Mr. van Schalkwyk: Chief Financial Officer	Email correspondence
QKR Namibia (Navachab Mine)	25 April 2019	Mr. I. Schneider: Chief Financial Officer; Mr. H. Wilhelm: Processing Manager	Meeting
City of Windhoek	19 July 2019	Various representatives of the CoW	Meeting
Municipalities of Walvis Bay, Swakopmund and Henties Bay and Arandis Town Council	24 July 2019	Mr. McClune, (Swakopmund), Mr. H. Shikongo (Municipality of Walvis Bay), Mr. D. Kambatuamasa (Henties Bay Municipality), Mr. S. Norris (Arandis Town Council)	Meeting
City of Windhoek	06 August 2019	Various representatives of the CoW	Meeting

Note: Email correspondence was sent to Rössing Uranium (and received by them) well in advance of the planned one-week trip to visit the Central Coastal Area stakeholders. However, their response was only received after the visit, following which further email correspondence was undertaken to request the information required.

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4.4.3 Configuration for the Supply of Desalinated Water Supply

4.4.3.1 Basic Supply Options

In terms of the assessments of water resources and the preparation of water demand projections, the project area can be divided into four components:

1. The Central Area of Namibia (CAN);
2. The Central Coastal Area (CCA) of Namibia (which is assumed to extend up to Arandis based on the existing configuration of supply and infrastructure);
3. The en-route (ER) users between a desalination plant at the coast and Windhoek;
4. Supply to Botswana (Bots).

In terms of water supply to Botswana, the ToR specify that the proposed scheme is to be sized to a "*water transfer volume / capacity of 20 Mm^3/a (about 54 800 m^3/d)*". In this respect, no assessments for the "fourth" demand area or component are required and therefore water demand projections will be prepared for the three areas or components within Namibia.

These four basic areas / demand nodes, are to be combined in accordance with the three supply scenarios (SS) required by the ToR:

1. Supply Scenario 1: Central Coastal Area (SS1 = CCA);
2. Supply Scenario 2: Central Coastal Area, the Central Area of Namibia and the en-route users (SS2 = CCA + CAN + ER);
3. Supply Scenario 3: Central Coastal Area, the Central Area of Namibia and the en-route users as well as Botswana (SS3 = CCA + CAN + ER + Bots).

4.4.3.2 Configuration for the Supply of Desalinated Water Supply to Local Authorities

Where desalinated water is to be supplied to local authority areas (towns and cities), it is currently proposed that desalinated water will be supplied into the same terminal groundwater reservoirs used for this purpose by NamWater, or if necessary additional reservoirs, for supply to the local authority areas within the Project Area. There is typically a water meter located on the outlet pipe of these terminal reservoirs which is that used to bill sales volumes to the local authority area in question, and which demarcates the responsibility between NamWater (upstream) and the relevant local authority (downstream).

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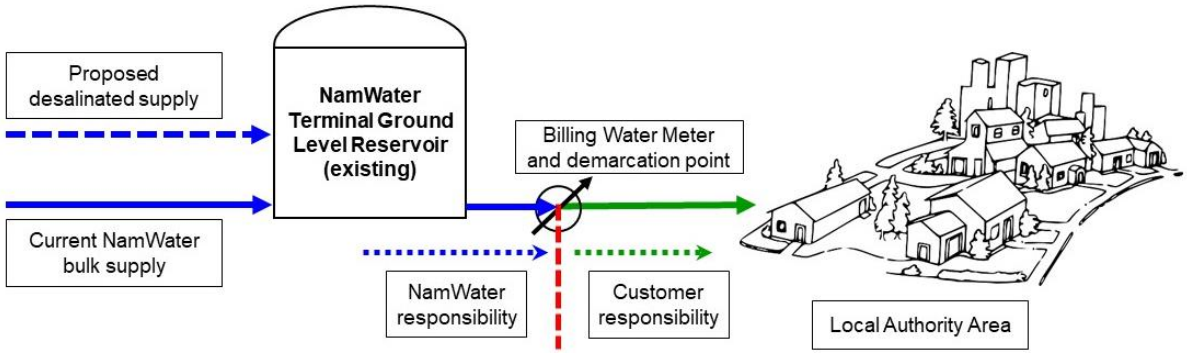

Figure 4.3: Schematic Layout of Proposed Desalinated Supply to Local Authority Areas

Further refinements of this concept can be developed once it is has been established who (NamWater or another party) will be responsible for the operation of the proposed desalinated water supply (the exact configuration of pipeline and location of billing water meters for example).

4.4.4 Supply of Desalinated Water

4.4.4.1 Supply for Domestic, Mining and other Non-Irrigation Use

When interviewed, Mr. Dengeinge indicated that Husab Mine requires potable water for their processes (Mr. Dengeinge, 2019, pers. comm., 26 March) and the same is expected to be the case with Rössing Uranium. Langer Heinrich, although not currently operational, apparently requires a higher "grade" water, which is of "*better quality than drinking water*", due to the specific production process used at the mine (Fichtner, 2011).

Water to be supplied to the uranium mines is supplied through the same infrastructure used to supply domestic demands (the Wlotzkasbaken – Swakopmund Pipeline and Swakopmund Terminal Reservoirs), and thus mixes with the water supplied to some local authority areas by NamWater. Desalinated water therefore has to be treated to potable standards for supply for domestic use and to the uranium mines in the CCA, which constitute by far the bulk of the water demand. It is therefore proposed that all desalinated water (for domestic, mining {if applicable; to the uranium mines in the CCA}, industrial and commercial use) be treated to the same standard on the basis of economy of scale, complexity and thus cost considerations and that this standard be that for potable use. The exact parameters of potable water use are discussed separately in the Design Criteria Report.

Should Langer Heinrich Mine resume operations, it is assumed that the mine treat its process water according to its requirements on site, as proposed previously by Fichtner (2011).

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It should be noted that separate proposals are provided with regard to the supply of mining water demand, per **Section 5.7.2.3** and the recommendations regarding the supply of water to the mines are to be resolved conjunctively.

In the CAN, all water to be supplied, with the exception of that to Navachab Gold Mine, shall be of potable standard. Raw water from the Swakoppoort Dam is currently supplied to Navachab Gold Mine and treated by the mine for their own use (process and domestic supply) and this arrangement can be retained.

4.4.4.2 Supply for Possible Irrigation Use

4.4.4.2.1 Proposals of the Erongo Regional Council

During a meeting with the Erongo Water Forum, which is an initiative of the Office of the Governor of the Erongo Regional Council (ERC), with the local authorities of Henties Bay, Swakopmund, Walvis Bay and Arandis as members (Louw, 2018) on 28 February 2019, the Consultant was provided with a document entitled "*Erongo Coast to Omaruru Agriculture Development Corridor"* (ERC, n.d.) for reference under this Project.

This document sets out the proposals of the ERC to develop an agricultural corridor in the Erongo Region to increase food production, and hence food security, to stimulate industrialisation and agribusiness development, provide employment opportunities and water to rural and urban areas in the Erongo Region (ERC, n.d.). This Coast to Omaruru Development Corridor proposal envisages establishing some 300 000 ha of irrigation projects growing olives, dates, grapes, fodder, tomatoes, persimmons, avocados, pomegranates, plums, peaches, butternuts and onions, as well as aquaculture projects using desalinated water (ERC, n.d.). These initiatives are estimated to cost N$ 7 billion in total, and provide employment to 20 011 people (ERC, n.d.).

NamWater, in the meeting with the ERC, on 28 February 2019, noted that the use of the expensive desalinated seawater for irrigation purposes is not defined by the ToR of this study. Therefore, only a brief assessment of the proposals of the ERC is provided.

Table 4.8: Irrigation Proposals of the Erongo Regional Council (ERC, n.d.)

Ref.	Product Type	Area (ha)
1	Olive production and oil processing	1 000
2	Date and grape production	285 600
3	Fodder production (Lucerne, sorghum, maize, etc.)	10 000
4	Tomatoes (including a pastry plant)	500
5	Persimmons (Avocados, pomegranates, plum, peaches, butternuts & onions)	280
6	Aquaculture	100
	Total	**297 480**

Notes: Product type and area (ha) per the Coast to Omaruru Development Corridor document of the Erongo Regional Council (ERC, n.d.).

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4.4.4.2.2 Water Demand of the Coast to Omaruru Development Corridor per the Estimate of the Erongo Regional Council

The proposal of the ERC indicates a water demand of 28.8 (presumably Mm^3/a as no units are provided) for the 2025 irrigation water demand in the Erongo Region (ERC, n.d.). If the proposed 300 000 ha of irrigation projects are fully developed by this date, this would imply a unit irrigation demand of some 97 $m^3/ha/a$. In the context of water demands for Green Schemes alongside the Okavango River of between 13 000 and 15 000 $m^3/ha/a$ depending on the crop mix (Liebenberg, 2009), this unit irrigation demand rate for the Erongo Region seems highly unlikely.

4.4.4.2.3 Revised Estimate of Irrigation Water Demand of the Coast to Omaruru Development Corridor

The estimate of 285 600 ha for date and grape production, per the Coast to Omaruru Development Corridor proposal of the ERC is an order of magnitude greater than the other development proposals.

This value was thus queried with the ERC (in writing), who replied (in writing also) that the revised development proposals were 30 ha for olives, 30 ha dates and 4 ha for greenhouse vegetables in lieu of the initially indicated 285 600 ha. Water demand rates per crop type were applied to the revised irrigation proposals, per Table 4.9

Table 4.9: Estimated Water Demands for the Revised Irrigation Proposals of the Erongo Regional Council

Ref.	Product Type	Area (ha)	Irrigation Demand ($m^3/ha/a$)	Estimated Water Demand (Mm^3/a)
1	Olives (Olives & Oil production)	1 000	12 500	12.500
2a	Date Plantation (Otjimbingwe)	30	15 000	0.450
2b	Olive Plantation (Okombahe)	30	12 500	0.375
2c	Greenhouse Vegetable Garden (Nama pos)	4	10 000	0.040
3a	Fodder: Lucerne	3 333	25 000	83.333
3b	Fodder: Sorghum	3 333	9 000	30.000
3c	Fodder: Maize	3 333	9 000	30.000
4	Tomatoes	500	6 000	3.000
5	Persimmons, avocados, pomegranates, plum, peaches, butternuts & onions	280	10 000	2.800
6	Aquaculture	100	22 400	2.240
		11 944	**Totals**	**164.738**

Notes:
1. Product type and area (ha) for nos. 1, 4, 5 and 6 per the Erongo Regional Council (ERC, n.d.).
2. Product type and area (ha) for nos. 2a to 2c per a letter from the Erongo Regional Council dated 16 May 2019 in reply to a query by the Consultant.
3. For no. 3, the Coast to Omaruru Development Corridor proposal of the Erongo Regional Council gives a total proposed 10 000 ha for "*Fodder production (Lucerne, sorghum and maize)*". Since these three crops have very different irrigation demands, this item was split into three per crop type, assuming an even distribution, thus one third of the total area per crop type.
4. Realistic irrigation water demands provided as average annual rates, i.e. not including peak factors for application rates during peak periods.

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The revised estimate for the irrigation developments is thus approximately 12 000 ha, which is significantly less than the nearly 300 000 ha of the initial estimate. Based on realistic water demand rates per crop type however, the estimated water demands for these proposals amount to 165 Mm^3/a, which is some 6 times the estimate of the ERC (28.8 Mm^3/a; ERC, n.d.).

This estimated irrigation water demand is also in the order of 7 times the potable water demand of the CCA (approximately 23.5 Mm^3/a sales by NamWater in FY2018).

4.4.4.2.4 Irrigation and Potable Water Tariffs in Namibia

A 20-year perspective on NamWater's irrigation water tariffs shows that prior to 2010 at the three largest irrigation schemes; Etunda (RCO[20]), Hardap (HAD) and Naute (UTE), irrigation tariffs were well below N$ 0.2/m^3 or 20 Nc/m^3. The Naute (UTE) irrigation tariff is currently the lowest of the three large schemes, at 14 c/m^3 in FY2018 (NamWater financial year). Irrigation tariffs at Hardap (HAD) and Etunda (RCO) were respectively 33 c/m^3 and 34 c/m^3 in FY2018.

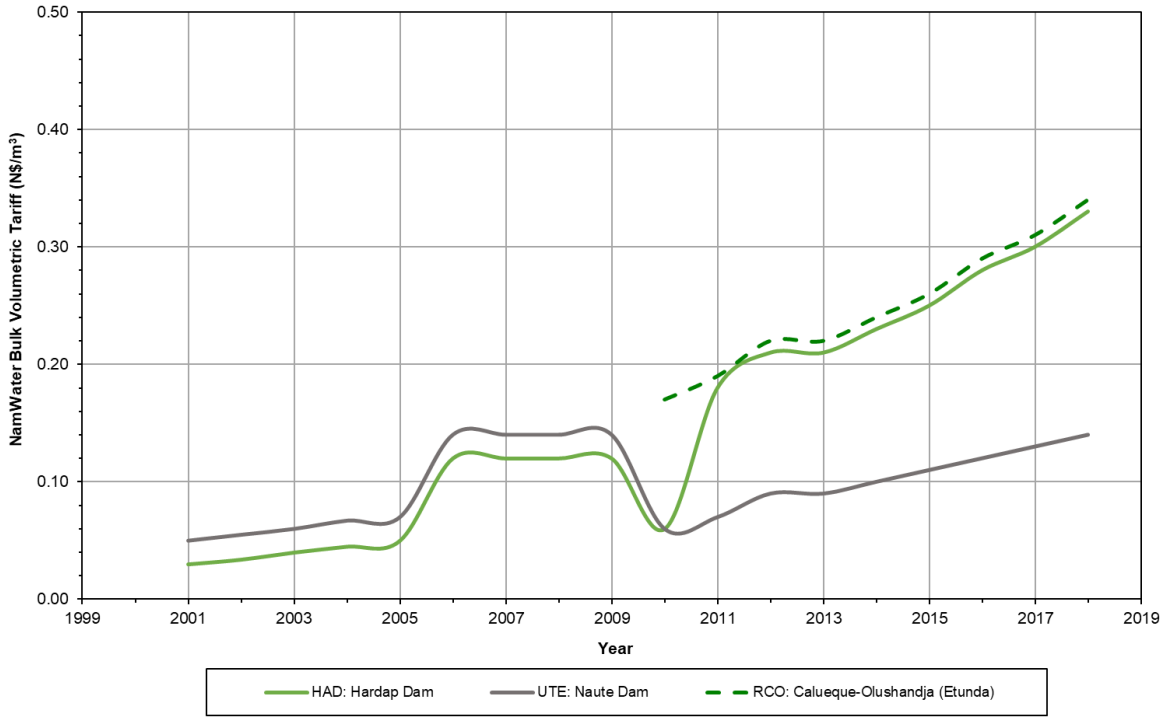

Figure 4.4: Selected NamWater Irrigation Water Tariffs

Notes: Data from various Government Gazettes in which the NamWater bulk water tariffs were published.

A comparison of these selected irrigation water tariffs (for raw water) with selected tariffs for potable (treated) water in the Project Area, shows that the irrigation tariffs are so much lower than those of potable water that they are not visible on the same scale when plotted together.

[20] NamWater cost centres indicated in parentheses.

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Some of the most expensive water in the Project Area is that from the Von Bach – Windhoek Scheme[21] (BBA), which in FY2018 was charged at N$ 21.30/m^3, which is approximately 65 times the tariff charged for irrigation water at the Hardap Scheme (HAD).

All groundwater in the CCA was charged at N$ 11.75/m^3 in FY2018, which approximately 36 times the tariff charged for irrigation water at the Hardap Scheme (HAD). The blended (groundwater and desalination) tariff charged to local authorities in the CCA in FY2018 was N$ 14.75/m^3, which is approximately 45 times the tariff charged for irrigation water at the Hardap Scheme (HAD).

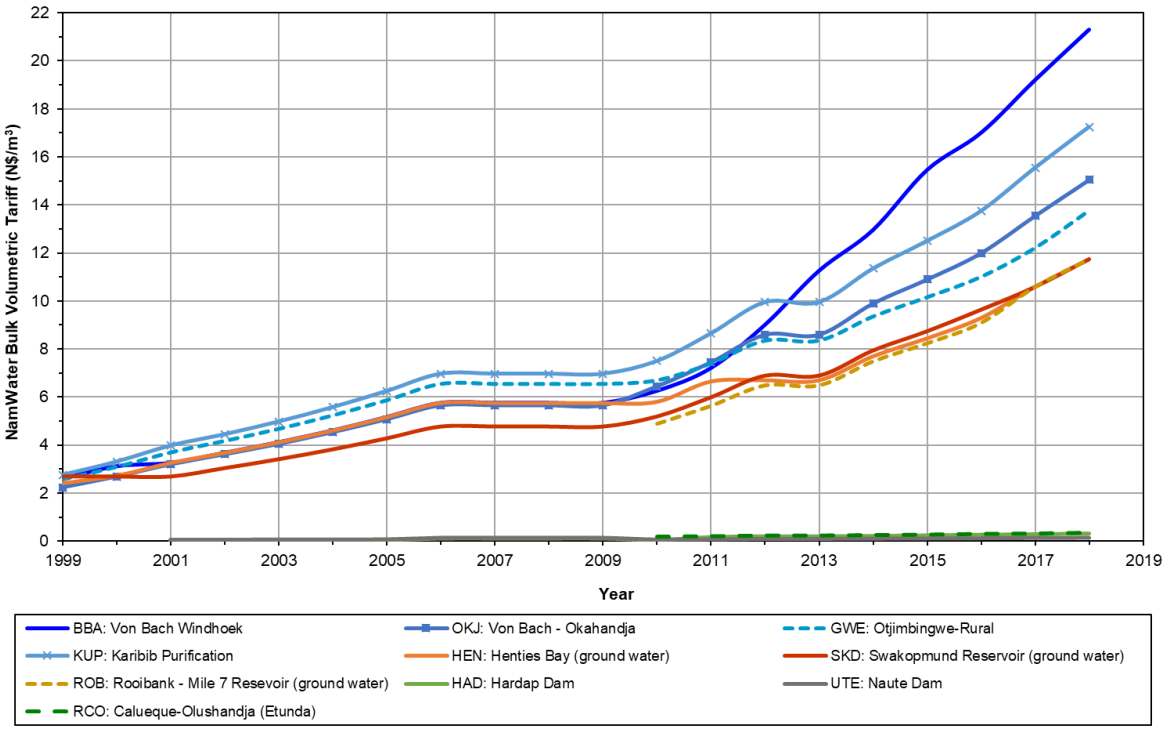

Figure 4.5: Selected NamWater Irrigation Water Tariffs and NamWater Potable Water Tariffs for Selected Schemes in the Project Area

Notes: Data from various Government Gazettes with publication of the NamWater bulk water tariffs.

These comparisons show that irrigation water in Namibia is charged at an order of magnitude lower than potable water in the Project Area. It is worth noting that in the past ("from June 1997"[22]), irrigation water at the Hardap and Naute schemes was heavily subsidised; 69% and 74% respectively, implying that at that time, at the Hardap scheme for example, the tariff charged by NamWater reflected only 31% of the full cost recovery tariff (Van der Merwe, 1999). To what extent current irrigation tariffs are subsidised (or not) is not known.

21 The most expensive water not used for mining in the Project Area is the commercial tariff charged to Namib Poultry Industries at N$ 34.40/m^3 in FY2018. The most expensive water for domestic use is that charged to Finkenstein (FKS) and Herbotsblick (HER) at N$ 25.95/m^3 in FY2018. The Von Bach – Windhoek (BBA) tariff is the most expensive charged to a local authority in the Project Area.

22 Water tariffs from 1997 were not readily available for this Study.

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In summary therefore, irrigation water is an order of magnitude or more cheaper than potable water in the Project Area, and that this water has in the past been heavily subsidised.

The last water accounts for Namibia (Natural Resource Accounting, **NRA**) covered the period from April 2001 until the end of March 2002 (MAWF, 2006). Although not a reflection of the current situation, these values provide some background on the value added to the economy of the country per cubic metre of water used by different activities.

The value added for Namibia amounted to N$ 203.76 per cubic metre of water used in 2001/02 (excluding agriculture) according to these NRA (MAWF, 2006). Agricultural activity as a whole accounted for N$ 4.54/m^3 of value addition, whilst commercial crops as a separate category accounted for N$ 0.55/m^3 of value addition. Communal crops provided a value addition of -N$ 0.49/m^3 (MAWF, 2006).

Communal crops therefore cost money on a unit water basis, whilst commercial cropping provides the lowest positive value addition per cubic metre of water of all the activities investigated by the MAWLR (2006).

A consideration of the water tariffs and the results of the NRA therefore shows that even at tariffs which are orders of magnitude lower than those for potable water, and which have in the past been heavily subsidised, commercial crops provide very little value addition on a per cubic metre basis. Therefore, and in the context of water scarcity, the NRA indicate that any other activity (of those investigated) will provide greater value addition to the Namibian economy as a whole, per unit of water used, than crop production.

The unit costs for desalinated water in the CCA and CAN are expected to be key outcomes from this Feasibility Study, however, these will only be available near the end of the Study. Under this Inception Phase, unit costs for desalinated water of US$ 2 to US$ 3/m^3 at the desalinate plant can be considered as a realistic frame of reference. If the more conservative value of US$ 3/m^3 is assumed, this would equate to nearly N$ 43[23]/m^3 at a (the) desalination plant. This is some 130 times the FY2018 tariff charged for irrigation water at the Hardap Scheme (HAD).

4.4.4.2.5 Project Recommendation

From the above considerations, it is clear that crop irrigation with desalinated water which is over 100 times more costly than current irrigation water in Namibia cannot be economically viable unless the cost of water is almost fully subsidised by the Namibian Government. In the context of a struggling economy (refer to **Section 2.1**) and the government being heavily indebted, this is unlikely to be possible, and in the context of very low value addition per cubic metre of water used, this would be economically unwise.

[23] At an exchange rate of 1 US$ = 14.256 N$ for 13 May 2019, per Reuters: https://www.reuters.com/finance/currencies

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It is therefore proposed that for the purposes of this Study, it is assumed that desalinated water will not be supplied for irrigation use. Should the ERC wish to pursue plans to develop irrigation projects in the Erongo Region, it is recommended that semi-purified water (treated domestic effluent) be used for irrigation purposes.

4.4.4.2.6 Recommendations for Reconsidering Irrigation in the Erongo Region

In the wider context of water supply and proposed irrigation in the Erongo Region, consideration should be given to following the "Israeli model" of water supply, which relies on the augmentation of conventional resources with desalinated brackish and seawater for potable supply (IWA, 2015), together with treated sewage for agricultural use. In 2014, sewage effluents formed 50% of the irrigation water allocations (IWA, 2015), whilst it has also been stated that 85% of "highly purified sewage gets reused for agriculture" (Hazony, 2015).

Agriculture in Israel uses water efficient crops (Hazony, 2015), drought-resistant seeds, efficient, drip irrigation, together with other measures such as the free-market pricing of water, cutting-edge metering and leak-detection systems and conservation education (Leichman, 2016).

An example of the use of treated domestic sewage for irrigation purposes in the Namibian context can be found in Outapi. Under the umbrella of the CuveWaters initiative, and in conjunction with the Outapi Town Council and Roediger Vacuum, a vacuum sewer system and wastewater treatment plant have been constructed to collect and treat the wastewater from three settlements in Outapi (Ombalantu). Following anaerobic and aerobic treatment, the treated but still nutrient-rich wastewater will be used under an agricultural initiative to grow crops. Residues from these crops will be co-digested (anaerobically) with the sewage sludge to enhance biogas production and stabilise the sludge, with the stabilised sludge to be used as fertilizer, thus maximising wastewater use (after CuveWaters, n.d.[1]. and ISOE, 2015).

The net size of the drip irrigation area is given as 3 ha, from which tomatoes, green peppers, maize, water melons and pumpkins are among the crops grown. The sanitation facilities serve up to 300 users in individual households and up to 360 users in cluster units, with the communal washhouse used around 200 times per day. It is stated that the irrigation site, with the plant currently operating at 30 m^3/d, produces up to 40 tonnes of fruits and vegetables per year, from which a turnover of N$ 300,000 per hectare per year can be achieved. With full utilisation of the plant's 90 m^3/d design capacity, it is envisaged that the system can operate without financial subsidies (after ISOE, 2015). Despite the aforementioned it is not clear what the capital and operating costs of this project area, and whether the costs of the vacuum sewer system are included in the overall viability of the project.

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The Outapi sanitation and reuse project clearly has many benefits, not least the productive reuse of wastewater, even though the provision of improved water and sanitation supply would have resulted in a gross increase in potable water use. There are apparently no problems with the community's acceptance of water reuse or the agricultural produce[24], though this is likely due to the involvement of the community during the planning phase of the project to obtain their interest in and acceptance thereof, as well as hygiene and health education and operator training conducted under the project (after ISOE, 2015). On this basis, the CuveWaters project at Outapi can serve as an example of the potential for water reuse in other areas of Namibia.

The very high evaporation rates and water deficit rates in the Erongo Region will require that high-value crops are grown in tunnel systems where a microclimate can be created and controlled, or at the least under some form of shade. An example of the use of tunnel systems in Namibia is the activities of Greencrisp Farming which produces vegetables, mostly in tunnel systems, near Okahandja, with raw water from the Swakoppoort – Von Bach Pipeline. It is recommended that the ERC conduct further investigations into their irrigation proposals based on the use of tunnel systems (or "greenhouse gardening per de Klerk {2019}), the shading of plants, drip- and subsurface irrigation, hydroponics (as recommended by de Klerk {2019}) and irrigation with treated wastewater, as done in Israel. This may lead to a revision of the areas suitable for such agricultural initiatives, the types of crops to be grown and hence the water demands.

4.4.5 General Approach to the Estimation of Augmentation or Deficit Volumes

4.4.5.1 Estimation of Augmentation Volumes

The same "deficit approach" as that followed with the *Rapid Assessment of Desalination Options* report (BCT and DME, 2016) has been applied for this Study, which can be represented as follows (in a simplified manner):

$$Augmentation\ Volumes = Deficit$$
$$= Future\ Supply\ Requirements - \sum Yields\ of\ Existing\ and\ Local\ Sources$$

Where:

$$Water\ Supply\ Requirements = Water\ Demands + Distribution\ \&\ Transfer\ Losses$$

In principle therefore, the volumes of desalinated water to be provided (in the context of this Study) will be those derived as the deficit between the estimated supply requirements (demands plus losses) and the total supply available from existing resources and local sources which are likely to be developed in the short- to medium-term.

[24] Personal communication with Dr. Thomas Kluge, Project Lead of the CuveWaters project, 29 July 2015 under the Pre-Feasibility Study into the Augmentation of Water Supply to the Central Area of Namibia and the Cuvelai project.

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The estimation of the deficit and thus the magnitude of the supply of desalinated water required therefore depends on the utilisation of the existing sources and the security of supply desired. It is also important to note that this “deficit approach” has been applied for / to 2050, the end of the project planning horizon, to derive the “ultimate” capacity / volume of desalinated water required. The capacities / volumes of desalinated water to be provided during the interim period, will be phased in over a period of time (refer to the separate report on the desalination options component).

For the CCA, this “deficit approach” is believed to be appropriate, as the configuration of supply is reasonably straightforward, certainly in comparison with that in the CAN, and whilst there is inherently variation in the recharge of the groundwater sources, the nature of these resources is that the variation is more “attenuated” than is the case with surface water sources (the variation is less noticeable and is spread over longer time periods due to the slower movement of water through aquifer systems).

Key features of water supply in the CAN include the reliance on surface water sources, which are highly variable and the complex, and the integrated nature of supply with inter-basin transfer schemes, aquifer recharge and abstraction and water reuse. In order to accommodate these characteristics, NamWater uses a numerical model, the CA-Model, to investigate the nature of supply and demand in the CAN. Unfortunately, due to the rigid, customised nature of this software, different options, including sizing and the timing of supply for the inclusion of desalinated water into the integrated CAN system cannot be analysed. Of necessity therefore, the “deficit approach” described above must be followed. This is also termed an “incremental approach” by Van Niekerk and Du Plessis (2013a) or the “traditional approach” by Blersch and du Plessis (2017). When surface water sources are considered, this is not the ideal approach, as outlined by Van Niekerk and Du Plessis (2013a) and it is therefore very strongly recommended that NamWater implement an appropriate yield / planning model to more accurately analyse the proposed changes to supply in the CAN with / and the provision of desalinated water, should this option be pursued beyond this Feasibility Study.

4.4.5.2 Preparation of Options

The approach requested by NamWater was that a variety of options be prepared for each of the components involved in the derivation of the deficit volumes, for them to select the most appropriate, namely:

- Demand Options:
    - *Basic Options* for the Local Authority and other Demand Nodes: In accordance with the approach typically followed by NamWater, three water demand options were prepared; *Low Likely*, *Likely* and *High Likely* options or scenarios;

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- *Additional Demand Options*: Additional options / scenarios were prepared for some categories of water demands:
  - Mining Water Demands in the CCA: Different scenarios were prepared to encompass different alternatives regarding the mining water demands in the CCA, in part due to the difficulties inherent in doing so;
  - Major Developments Near Windhoek: Following consultation with Nam-Water, different scenarios were prepared for different levels of development to be assumed for the Osona Village, Elisenheim, Brakwater, Ongos and Monte Christo developments around Windhoek;
- The different *Basic Options* and *Additional Demand Options* multiply out to a number of overall water demand options; for example for the CCA, three demand scenarios (low likely / likely / high likely) and five options for the mines, multiply out to 15 “demand options”;

- Supply Options:
  - Existing Sources: Options or scenarios were prepared according to different philosophies for the utilisation of the existing sources;
  - Local Sources: Options or scenarios were prepared according to different philosophies for the development of local sources, for example potable re-use[25] where there is currently none (Walvis Bay) or additional potable reuse (Windhoek).
- Overall Deficit Options:
  - The different demand options, when combined with the different supply options multiply out to a large number of overall options. For example, for the CCA, three demand scenarios (low likely / likely / high likely) and five options for the mines, multiply out to 15 “demand options”, which coupled with two supply options, ends with 30 options. In all instances, the options have been numbered, so that the various options and component options can be traced / tracked. The graphs provided show the lowest and highest deficit volumes, representing the envelope of the suite of options;
  - The options accepted by NamWater and / or other stakeholders (local authorities, both in the CCA and in the CAN) have been indicated as “Client’s Recommendation”;
  - Where applicable, the Consultant’s recommendations are indicated.

[25] Potable reuse was in some instances included as a demand option were linked directly with different water demand scenarios and in some instances as a supply option where its inclusion / exclusion is more clearly a matter of a supply-side intervention.

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4.4.5.3 General Definition of the Demand Scenarios

In accordance with the approach followed by NamWater, projections were prepared for three scenarios, defined as follows:

- Low: A combination of a low / negative development outlook combined with optimistic demand management targets, which will result in low water demands;
- Medium: This represents the most likely or expected scenario which factors in reasonable growth scenarios and realistic demand management targets, resulting in the expected water demands;
- High: The opposite of the low scenario, this is a combination of a very aggressive development outlook with all prospective projects and developments being completed and low expectations of water demand management, which will result in high water demands.

4.4.5.4 General Comments and Considerations Regarding Water Demand Projections

4.4.5.4.1 General Comments and Considerations Regarding Water Demand Projections

A key outcome of the water resources and demand projections component of this Project is the preparation of projections for water demands and deficits for 30 years into the future. Water demand projections over decades, as required for this Study (30 years) are typically used for sizing system capacities and raw water supply, infrastructure and capital planning (after PI, n.d.). In the context of this Study, a key application of the projections is the eventual sizing of infrastructure such as the pipeline and desalination plant (civil aspects), for which the eventual installed capacity must be implemented in the initial construction, as these cannot be phased in over time (excepting if two parallel pipelines are considered). There are however other aspects which can be phased in over time and thus the “picture” for the end of the project horizon, as currently foreseen, will not be implemented overnight, but will change over time (for example the utilisation of the CAN dams).

Multi-coefficient methods for water demand projections which are based on multiple factors influencing water demand and which include end use analyses, as used in developed countries, are unfortunately not available in Namibia[26]. Should desalinated water be introduced in larger volumes, such analytical tools or methods should be investigated for Namibia, in order to provide more accurate demand projections under consideration of the greater costs of desalinated water.

[26] The multiple regression model, Time Series Analysis model which was set up and previously used to model water demand in Windhoek is no longer usable due to the lack of suitably available and accurate data.

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The assessments of recent studies has shown that past projections seldom reflect the eventual reality of water demand / use. Developments, and whether they occur or not, and if so, to what extent, even within a year or two, can have drastic impacts on the overall water consumption outlook in any area. Potential future developments as documented in development / master plans of local authorities very rarely anticipate actual developments.

Many of the aspects which govern the eventual implementation or not of development proposals are dependent on factors which are beyond the confidence limits of engineering estimates.

4.4.5.4.2 Development Plans Underlying the Water Demand Projections

It is further important to note that the Planning Horizon for this Project, 2050, extends some years beyond the end date of the master / (spatial) development plans of the various local authorities in the Project Areas, most of which do not extend beyond 2030. The water demand projections required by this Project for the period beyond 2030 or 2040 (depending on the local authority) are therefore not “supported” by planning information at local authority level.

On a national scale, the Government in 2004 launched Vision 2030, which is an overarching framework for the development of the country. The main goals identified by this vision are that by 2030, Namibia will be an industrialised, globally competitive, food-secured, country, with a knowledge-based, highly competitive, industrialised, eco-friendly economy with sustainable economic growth and a high quality of life (OOTP, 2004). The Planning Horizon for this Project, 2050, extends some 20 years beyond the date of 2030 targeted by this an overarching framework or development plan.

Since Independence, Namibia has prepared 5-year National Development Plans (**NDP**s) to guide national priorities and development. The current such plan, Namibia’s 5th National Development Plan, NDP5, covers the 5-year period from 2017/18 to 2021/22. A further two plans, NDP6 and NDP7 are envisaged to cover the period until 2030. Again, there are currently no development plans which extend up to 2050, the Planning Horizon for this Project.

There is thus considerable uncertainty associated with water demand projections which extend 30 years into the future and which are not supported by local or national planning information, in most instances extending some 20 years beyond the end date of the available development plans.

4.4.5.4.3 Revision of Water Demand Projections

The water demand projections prepared under this Study have needed to balance the need to avoid overestimation of the future expected water demands with the need to avoid underestimation of the expected water demands. The former results in unnecessary capital expenditure on oversized infrastructure, which costs cannot be recovered from end users / tariffs.

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The latter could result in insufficient supply which disrupts economic activity, especially in areas where major variations in annual runoff and recharge of aquifers occurs, as a result of variable rainfall and intensity of rainfall.

Considering the inherent uncertainty associated with preparing demand projections for 30 years into the future, incomplete data to support such projections, the lack of multi-coefficient models to account for various influencing factors, and the uncertainty surrounding the impact of the introduction of desalinated water at higher cost than current tariffs, given the almost complete lack of information on the price elasticity of demand, it is recommended that should further projects emanate from this Feasibility Study, or should some of the proposals proceed to a more detailed design phase, the water demands be re-assessed on the basis of the expected unit costs derived from the outcome of this Study and that the water demand projections provided and the planning and implementation of augmentation schemes be reviewed and updated at least once every 4 to 5 years.

4.4.5.5 Factors Considered in the Derivation of Water Demand Projections

A recent report into water by The Economist notes that the three main factors which will drive a continued growth in water demand are "*population, prosperity and climate*" (Long, 2019). These three factors as well as others which influence water demands in Namibia have been considered in the derivation of the water demand projections, including:

- Assessments of historical water use / sales data and trends, being:
  - The growth rates and trends in historical water use (sales) for the major local authorities;
  - An assessment of previous demand projections in comparison with historical water use (sales) thereafter;
- Population growth rates, including urbanisation trends (**Section 2.2**) and how historical population growth rates compare with the growth rates in water use. A key trend which is expected to continue into the future is that of increasing urbanisation;
- Development proposals / plans and related information gathered from stakeholders during the visits conducted under the Project in March 2019 and from information obtained from stakeholders during the Project period;
- Economic growth, development and outlook (**Section 2.1**);
- Government legislation and policy;
- Improved level of services. Large numbers of urban dwellers reside in improvised or informal housing (**Section 2.2.5**). Many of these residents have water available outside the house (**Figure 2.16**) and dry or no sanitation facilities (**Figure 2.17**). There is thus a significant need to formalise and improve the provision of water and

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sanitation services in peri-urban and informal settlement areas, both of which can be expected to increase the demand for water (refer to **Section 2.2.5**). This is linked to government legislation and policy in terms of land ownership and initiatives such as the Mass Housing Program as well as to increased prosperity. However, affordability remains a major concern, both at individual / household and public sector levels. In the case of the former, the affordability of current water tariffs is already problematic in many communities (refer to **Section 4.2**), which can be expected to worsen should improved services be rolled out at cost recovery rates and the current economic conditions persist. In the case of the latter, the finances and central government and most local authorities are severely constrained, limiting their ability to address the backlog in service delivery, particularly if there is not a mechanism in place to recover at least some of the costs. In the short to medium term at least, it is unlikely that the backlog will be sufficiently addressed, but it should be acknowledged that there is a significant latent demand should the service level of water supply and sanitation be improved and the prosperity of inhabitants in the informal settlements improve;

- Climate change: The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. This term is however mostly used in connection with anthropogenic (caused by humans) global warming. The causes of climate change are many, varied and complex, and similarly the expected implications thereof. It is however expected that climate change will affect temperatures, rainfall, evaporation and runoff patterns, thereby impacting on water availability, usage and demand patterns. It is difficult to incorporate these possible effects into water demand projections, beyond noting that greater variability in weather patterns is expected and that dry periods may become more prolonged and more severe. Consequently, greater variation in water usage and demand, particularly in agriculture, can be expected.

- The costs and tariffs of water have also been considered, although the possible costs of desalinated water were not known at the time the demand projections were derived (refer to **Section 4.2**);

- Increased water use efficiency. In accordance with the ToR, and under consideration of the costs, which are likely to be high, associated with desalinated sea water, the demand projections also make provision for reductions in Non-Revenue Water (NRW). The *Rapid Assessment of Desalination Options* report concluded that there was a high potential for water demand reduction in the urban water supply systems in Namibia and recommended that NRW be systematically reduced to 15% (BCT and DME, 2016). The underlying philosophy to this recommendation is assumed to be that the high costs of desalinated water will form an imperative for local authorities to increase their efficiencies (increased billing efficiencies, reductions in physical leakages, etc.). NRW of 12% has generally been assumed for the end of the

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Project Horizon, on the basis that the high costs of desalinated water will drive higher improvements in water use efficiency.

In the main, where growth rates are provided, these decrease over successive periods to correspond with the historical trend observed in the population growth rates, which have been seen to decrease over successive 10 year periods between censuses.

4.4.5.6 Supply-Orientated vs Demand-Orientated Augmentation

The planning approach typically followed in Namibia can be characterised as demand- or deficit-driven, in that water sources and schemes are planned and sized according to estimates of the (future) deficits, which represent the difference between the capacities of existing sources and schemes and the expected future water demands. This is largely because Namibia's aridity means that water sources are limited and / or are located far away from demand centres, such that only *as much water is supplied as may be needed*.

Desalinated sea water by contrast to conventional water sources, is not source-limited from a technical or water resources perspective and offers the opportunity to provide a water supply in excess of what the demands or deficits may otherwise be (cost, environmental and other considerations aside; to be determined under later phases of the Project). Thus, if more water can be supplied than what may be deemed to be necessary, this may offer the opportunity for water demand to grow, and thus sales and revenues to water services providers to increase, and importantly, may also allow opportunities for developments and hence economic growth which are not foreseen, due to currently constrained water supply.

In order to successfully attract the large sums (N$ 15 billion) of investments proposed by the President (Nakale, 2019a), Namibia would need to be able to offer potential investors sufficient quantities of reliable power and water supplies and access (logistics), at the very least. Desalinated sea water is the only water source to which Namibia has access which is not capacity-limited. However, providing water supply capacity in excess of the foreseen demands would imply capital investments which cannot initially be recovered from water sales (since the capacity will initially exceed the demand / sales), which would require a government or other subsidy.

Such an initiative would also need to be developed in accordance with a broader national development plan under the auspices of the National Planning Commission. Water supply has historically always been developed reactively (in response to water demands and shortfalls/deficits) and there is at present no such pro-active initiative or plan for large-scale water supply. Should this Study find that the supply of desalinated water is feasible in the Namibian context, it may be possible to consider a pro-active, supply-orientated development plan under a future iteration of the national development plan(s).

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4.4.5.7 Assessment and Benchmarking of Water Use Efficiency

4.4.5.7.1 Assessment and Benchmarking of Non-Revenue Water

The estimation of Non-Revenue Water (NRW) has generally followed the standard international "best practice" water balance published by the International Water Association (**IWA**) Task Forces on Performance Indicators and Water Losses in July 2000. This water balance has since been recognised and adopted as international "best practice" by a steadily increasing number of countries and water utilities throughout the world (Mckenzie and Seago, 2005). The use of this best practice water balance has helped to standardise terminologies and methodologies between utilities and different parts of the world.

NRW is one of the "best practice" Performance Indicators (**PI**s) proposed in addition to the standardised water balance method by the IWA task force (Mckenzie and Seago, 2005).

Within the scope of this Study, the NRW for the towns in the CAN, and where possible those in the CCA, have been estimated on the basis of input volumes and revenue water. Therefore, for the purposes of this Study, and within the context of examining the NRW of a local authority area, the IWA water balance has been interpreted as shown in **Figure 4.6**.

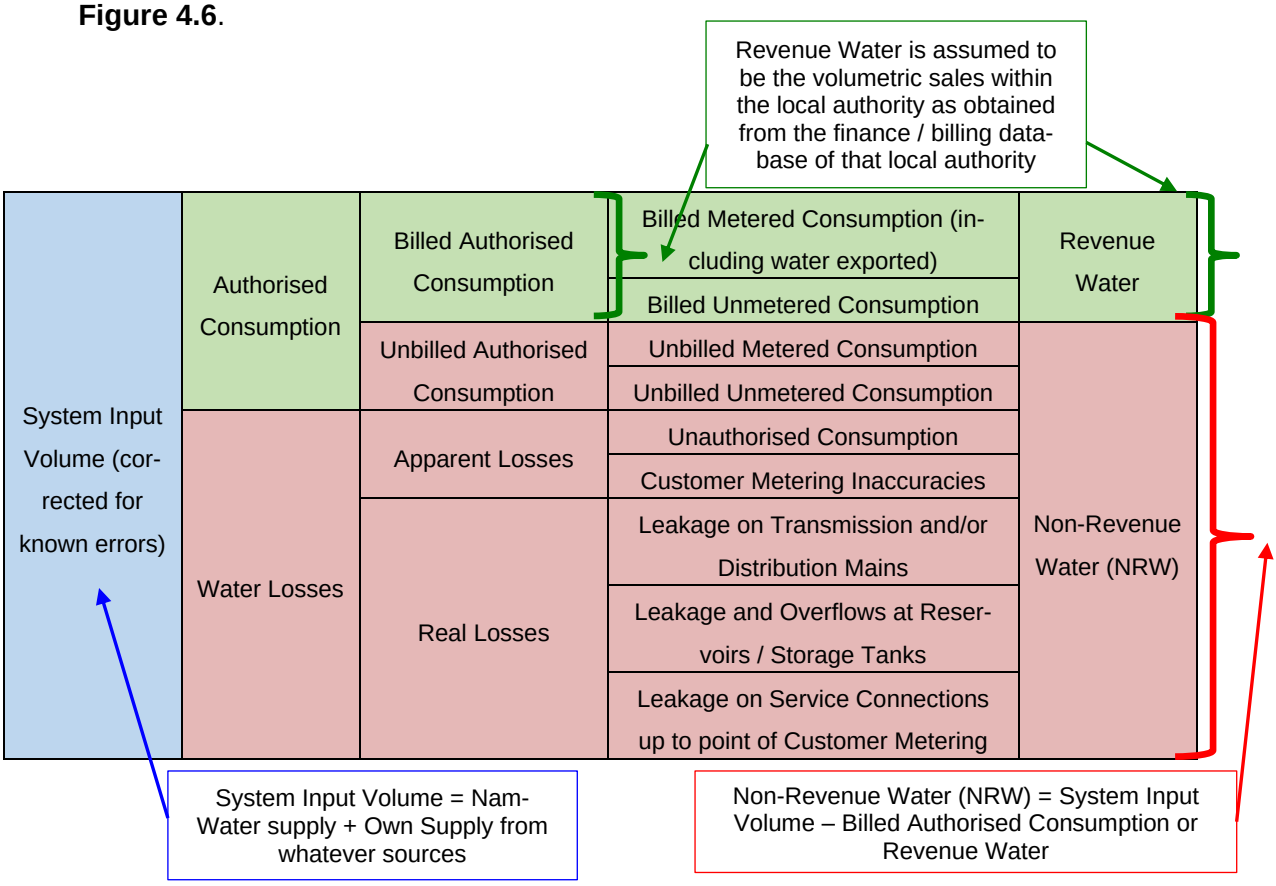

Figure 4.6: Interpretation of the IWA Best Practice Standard Water Balance

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For the various towns, the input volumes and revenue water have been defined as follows:

- System Input Volume = NamWater Supply + Own Supply
  - In the case of Karibib, Okahandja (assumed; refer to the text), Henties Bay, Swakopmund, Arandis and Walvis Bay, NamWater is the sole source of supply;
  - In the case of Windhoek, additional sources of supply include groundwater from the Windhoek Aquifer (supplied by the CoW) and reclaimed potable water (supplied by Wingoc);
  - Omaruru is responsible for their own supply;
  - Usakos is supplied partially by the Town Council and partially by NamWater;
- Revenue Water = Sales Volumes of the Local Authority
  - In the case of Karibib and Okahandja, the volumetric sales for the local authority were obtained from /AE//Gams Networks (Pty) Ltd. (**/AE//Gams**) under the CAN Medium Term Options Study. AE//Gams maintains financial and billing databases on behalf of several smaller municipalities and town councils in Namibia who are not able to do so themselves. This data was unfortunately often problematic, showing a number of anomalies and resulted in analyses to which is difficult to attach high levels of confidence to the levels of NRW indicated;
  - In the case of Windhoek, the volumetric sales data was provided by the CoW under the CAN Medium Term Options Study;
  - In the case of Walvis Bay, a summary table of volumetric sales was received from the Municipality;
  - In the case of Henties Bay, tables of volumetric sales were received from the Municipality;
  - In the case of Swakopmund, some sales data was received from the Municipality;
  - In the case of Arandis, Usakos and Omaruru, no sales data was received.

NRW for the towns in the Project Area was compared and benchmarked against the South African National and World Averages as obtained from McKenzie et al. (2012).

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4.4.5.7.2 Assessment of Night Flows

Night Flows

The minimisation of loss or waste, particularly water leakage, in the distribution network of a town, thereby maximising the efficiency of water use, is one of the key aspects or components of WC/WDM. In order to assess water leakage and therefore the potential for WC/WDM in the towns of the CAN, diurnal water demands and night flows have been analysed.

NamWater provided average hourly flow rates from the last ±12 – 18 months for the out-flow from their reservoirs supplying Okahandja, Karibib, Walvis Bay, Swakopmund, Henties Bay and Arandis, which have been analysed to estimate the night flows and leakage rates.

Night flows can be defined as those flows which occur between 00:00 and 04:00 in a water distribution system, when flows are normally at their lowest for the day. The Minimum Night Flow (**MNF**) is defined as the lowest flow in a water supply system during a 24-hour period, under the assumption that there is sufficient water available during the period to meet the demands (McKenzie et al., n.d.), which is expected to be the case in these towns.

Night flows and specifically the MNF are analysed since the MNF "*can be compared to a medical doctor taking a patient's heart-rate in that it provides a valuable indication of the health of the area*" (McKenzie et al., n.d.). The MNF is regarded as one of the, if not the most important, actions to be taken when identifying leakage problems in an area (McKenzie et al., n.d.), with leakage reduction being one of the key components of WC/WDM.

Night Flows and Leakage Estimation

The methodology proscribed in the *Water Demand Management Cookbook* (McKenzie et al., n.d.), was followed to estimate the normal domestic night time use and the small non-domestic night use in the various towns where the night flows were assessed. From this assessment, the unaccounted for leakage was assessed, being the difference between the MNF and the estimated normal night use. This unaccounted for leakage was benchmarked as a percentage of the average hourly flow rate over a day in each town.

4.4.5.7.3 Assessment and Benchmarking of Water Consumption

For the assessment of NRW in South Africa, the per capita consumption was based on the total water supplied to municipalities and the total population served in each municipality. This value therefore included all losses, as well as industrial and commercial water use supplied from the municipal systems (Mckenzie et al., 2012). A similar approach will be followed for estimating the per capita consumption in the towns in the Project Area, which will allow water consumption in these towns to be benchmarked against that in South Africa, but also because the assessment by McKenzie et al. (2012) was based on internationally accepted best practice as developed by the IWA.

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Water consumption in Local Authorities (towns in the Project Area) were therefore expressed as: litre / capita / day (ℓ/c/d) and benchmarked against the South African National and World Averages as obtained from McKenzie et al. (2012).

The per capita consumption values for the towns in the Project Area was calculated for 2001 and 2011, the years when population censuses were carried out and therefore when the population numbers are known with greater accuracy or certainty. A comparison of the per capita consumption values for the various towns, the estimated average for Namibia as a whole and the average for South Africa is provided.

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5 CENTRAL COASTAL AREA

5.1 Configuration of Supply in the Central Coastal Area of Namibia

The Central Coastal Area of Namibia or CCA, is the populated and developed portion of the central coast between Henties Bay in the north and Walvis Bay in the south, extending up to Arandis in the east. This area is supplied with groundwater from the Omdel and Kuiseb alluvial aquifers in the north, which are respectively fed by the ephemeral Omaruru River (in the north, near Henties Bay) and the Kuiseb River (in the south, near Walvis Bay).

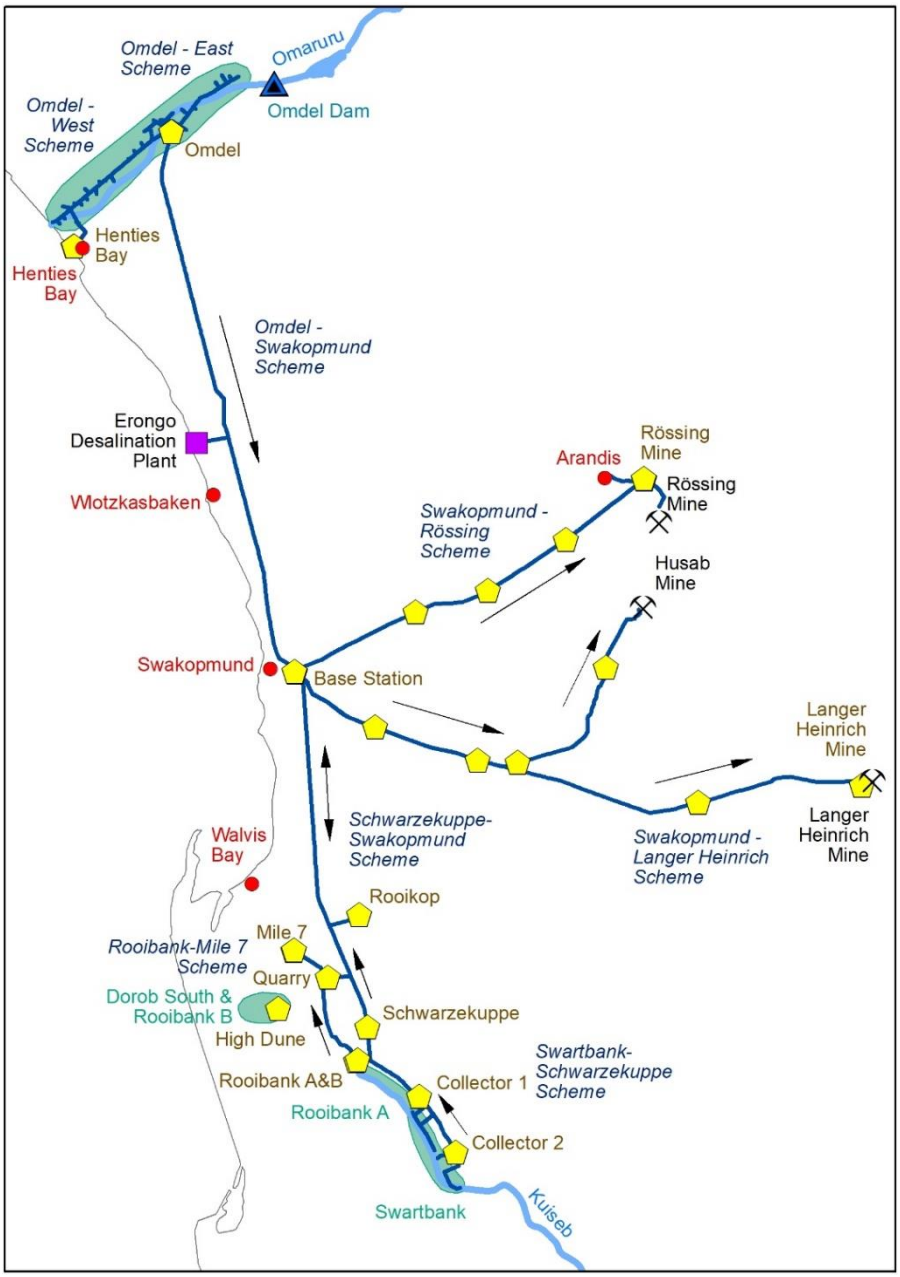

Figure 5.1: Configuration of Water Supply Infrastructure in the Central Coastal Area of Namibia

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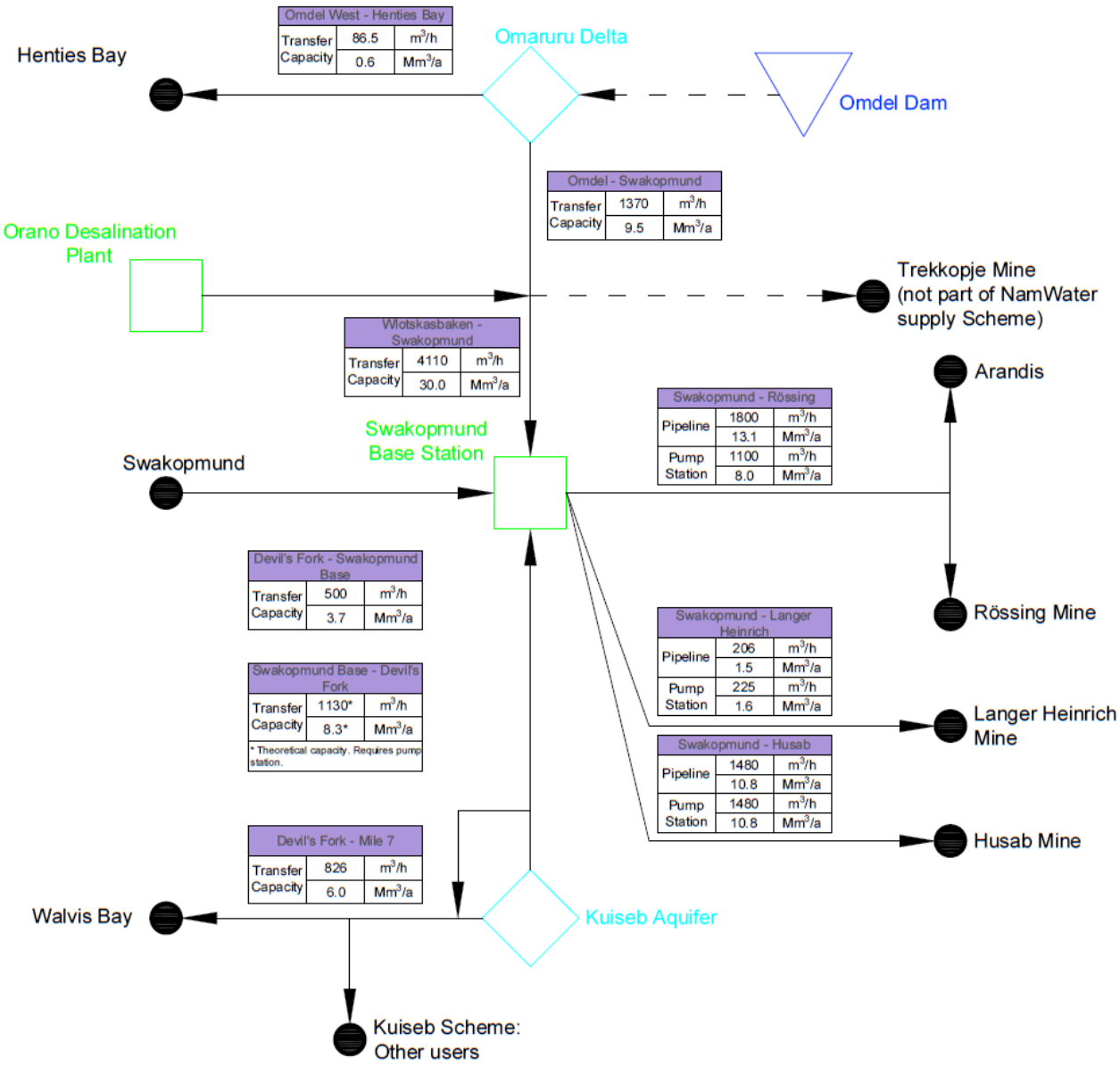

Figure 5.2: Schematic Layout of the Water Supply Infrastructure in the Central Coastal Area of Namibia

In August 2013, NamWater commenced with the purchase of desalinated water from Orano's Erongo Desalination Plant (EDP) at Wlotzkasbaken, which is introduced into the Omdel – Swakopmund Pipeline and transferred to NamWater's Swakopmund reservoirs for further distribution

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The Central Coastal Area can be viewed as two broad supply schemes:

1. The Kuiseb scheme, supplying Walvis Bay and other smaller consumers from the Kuiseb Aquifer;
2. The Omdel Scheme, supplying Swakopmund, major uranium mines, Henties Bay and other smaller consumers from the Omdel Aquifer and desalinated water from the Orano desalination plant.

The supply configuration (the Kuiseb Aquifer in the south and the Omdel Aquifer and desalinated sea water in the north) can be viewed separately but transfer pipelines between Swakopmund and Walvis Bay link these areas into a larger whole.

A schematic layout of the major supply infrastructure in the CCA is provided in **Figure 5.2**.

5.2 Historical and Current Supply and Demand

5.2.1 Historical Supply and Demand in the Central Coastal Area Overall

NamWater's sales (used as a proxy for water demand) to the CCA grew by 48% from 11.5 Mm^3/a in 1998 to 17 Mm^3/a in 2016, at a 2.1% annual growth rate. Since 2016, water use by the Husab Mine has dramatically increased consumption/demand in the area, resulting in a total consumption of 23.5 Mm^3/a in 2018 (a 104% increase since 1998 and a 38% increase since 2016).

Prior to 2014, the CCA was exclusively supplied with groundwater from the Kuiseb and Omdel Aquifers. Production from these boreholes grew at the same rate as the demands in the CCA and peaked at 17.1 Mm^3/a in 2013. Concerns over the unsustainable use of the Omdel Aquifer and the introduction of desalinated water supplied from the Erongo Desalination Plant (EDP) in 2014 has reduced the dependence on groundwater supply, where in 2018 production of groundwater stood at 14.4 Mm^3/a. Despite these reductions since 2014, production has nevertheless exceeded the sustainable yields[27] by 2.4 Mm^3 and the aquifer abstraction permit values[28] by 4.4 Mm^3 for the year 2018.

The major scheme delineations used by NamWater are summarised in **Table 5.1**. The sales data provided by NamWater have been compiled according to these scheme delineations, which excluded desalinated supply. The desalinated supply, which is theoretically estimated to only supply the Uranium mines, was provided separately.

[27] Per the data supplied by NamWater, sustainable yields for 2018 of 4.6 Mm^3/a and 7.4 Mm^3/a were used for the Omdel and Kuiseb Aquifers respectively.

28 Per the latest permit applications supplied by NamWater, permit values for 2018 of 3.0 Mm^3/a and 7.0 Mm^3/a were used for the Omdel and Kuiseb Aquifers respectively.

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Table 5.1: NamWater Supply Area Summary

Area	NamWater Scheme Code	FY 2018 Summary		Scheme Description
		Proportion of Consumption	Estimated No. active Clients	
Omdel Scheme				
Henties Bay	HEN	2%	1	Main supply node to Henties Bay Municipality
Langer Heinrich	LHU	8%	4	Main supply node to Langer Heinrich Mine
Swakopmund Reservoir	SKD	19%	13	Main supply node to Swakopmund Municipality
Omdel-Swakopmund	SOS	1%	15	Supply to smaller users between Omdel wellfields and Swakopmund Base reservoir, including Wlotzkasbaken, Salt Company and various industries.
Swakopmund Rössing	SRA	41%	22	Supply to Arandis Town Council and two active uranium mines, Rössing and Husab.
Kuiseb Scheme				
Rooibank Mile 7 Reservoir	ROB	29%	22	Main supply node to Walvis Bay Municipality
Swartbank - Swartzekuppe	SSS	1%	38	Supply to smaller users around the Kuiseb Aquifer area, including the Rooikop military base, Walvis Bay Airport and Topnaar settlements.

5.3 Scheme Water Balance

An overall scheme water balance in terms of NamWater's supply for the CCA is provided in **Figure 5.3**. By FY 2018, a total of 24.97 Mm^3/a was produced; 14.43 Mm^3/a (58%) from groundwater sources and 10.54 Mm^3/a (42%) from desalination. Total consumption / sales was 23.51 Mm^3/a, resulting in losses or non-revenue water of 1.46 Mm^3/a or 6%. Non-revenue water averaged 8% for the last five years (2014-2018).

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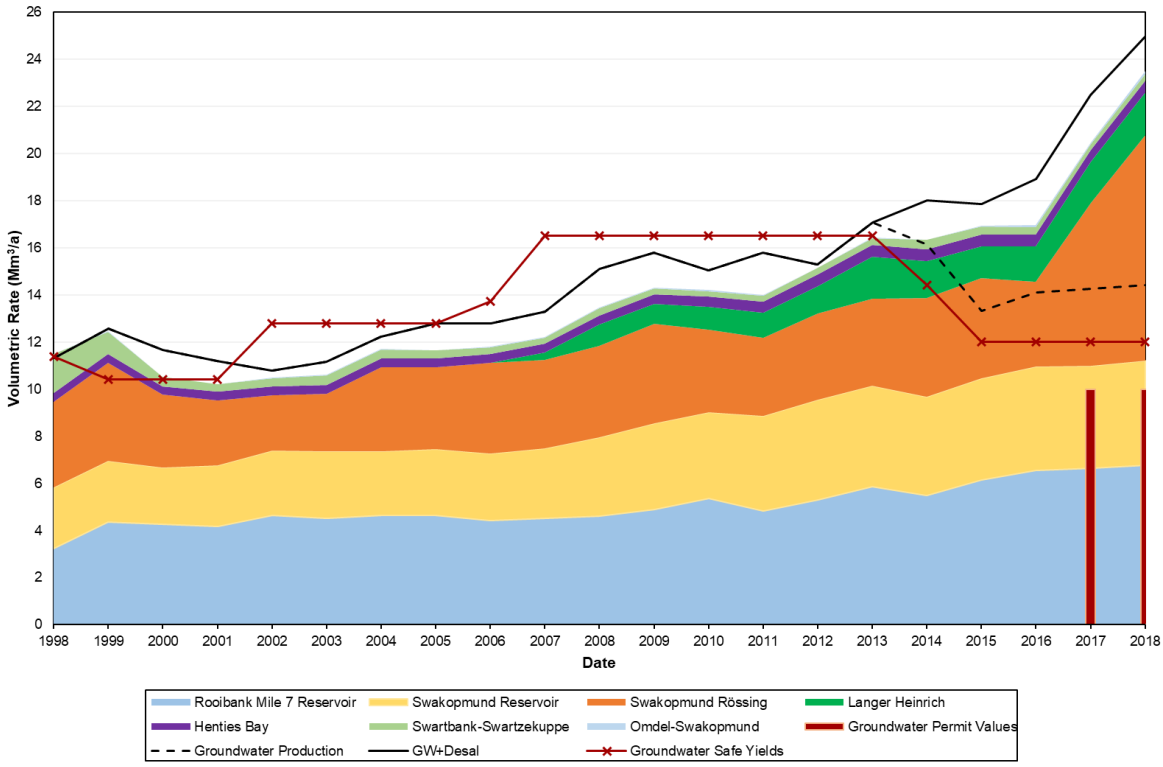

Figure 5.3: Historical Water Sales, Production and Source Capacity in the Central Coastal Area

Notes:
1. Annual data is presented per NamWater's financial year (01 April to 30 March).
2. Permit and abstraction values respectively for the Omdel and Kuiseb Aquifers did not always coincide and were omitted from this figure in those cases.
3. The Rooibank – Mile 7 Reservoir and Swartbank-Swartzekuppe Schemes are currently mainly supplied by the Kuiseb Aquifer, while the remaining areas are supplied by the Omdel aquifer and desalinated water.

Figure 5.4 and **Figure 5.5** provide an overall water balance for the larger Kuiseb, and Omdel schemes respectively, based on NamWater's delineation of these sub-schemes. Production information from the groundwater sources and desalination, permit values and safe yields was generated from data supplied by NamWater.

Groundwater supply has exceeded both permit-abstraction values and sustainable aquifer yields since 2012 for the Kuiseb Aquifer Scheme and since 2015 for the Omdel Aquifer Scheme, indicating that the aquifers have been placed under strain.

The larger difference between supply and demand for the Kuiseb Scheme and the general near equivalence of supply and demand in the Omdel Scheme should be interpreted considering transfers from the Kuiseb Aquifer to Swakopmund base station / reservoir.

Desalination water provision was introduced in August 2013 and remains a critical component of supply for the larger scheme, currently supplying the mines within the supply area, as well as the local authority areas when the demand of these centres exceeds their allocation of groundwater supply (refer to **Section 4.1.3**).

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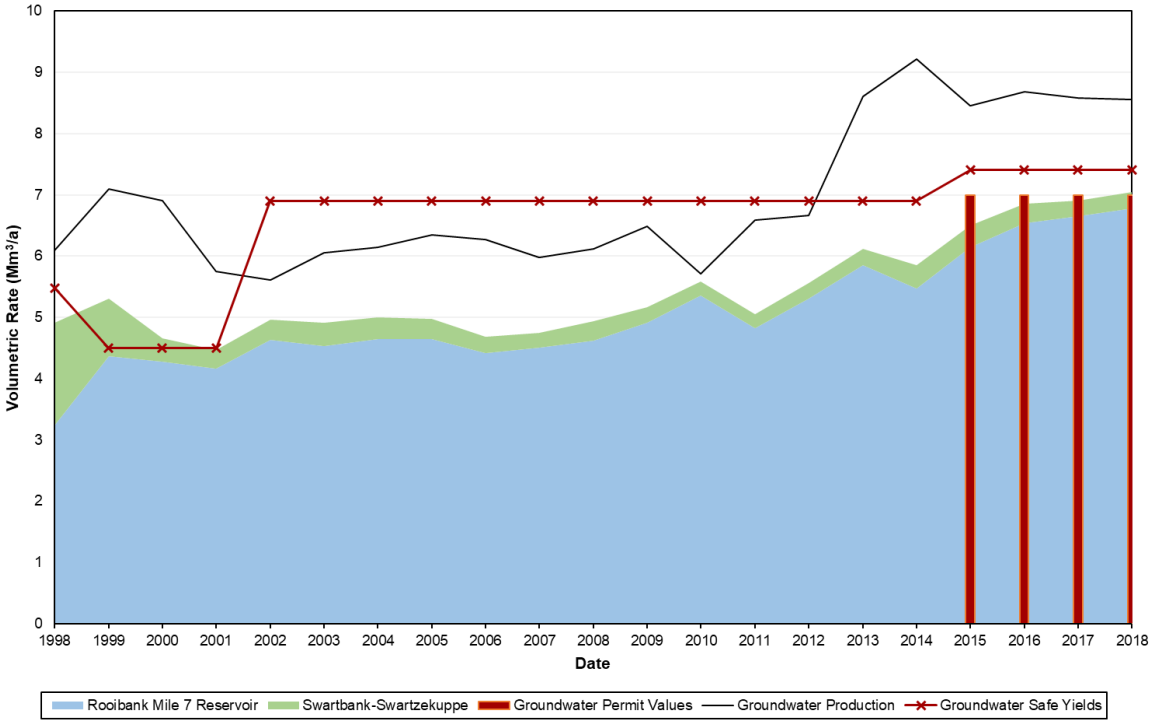

Figure 5.4: Kuiseb Scheme Water Balance

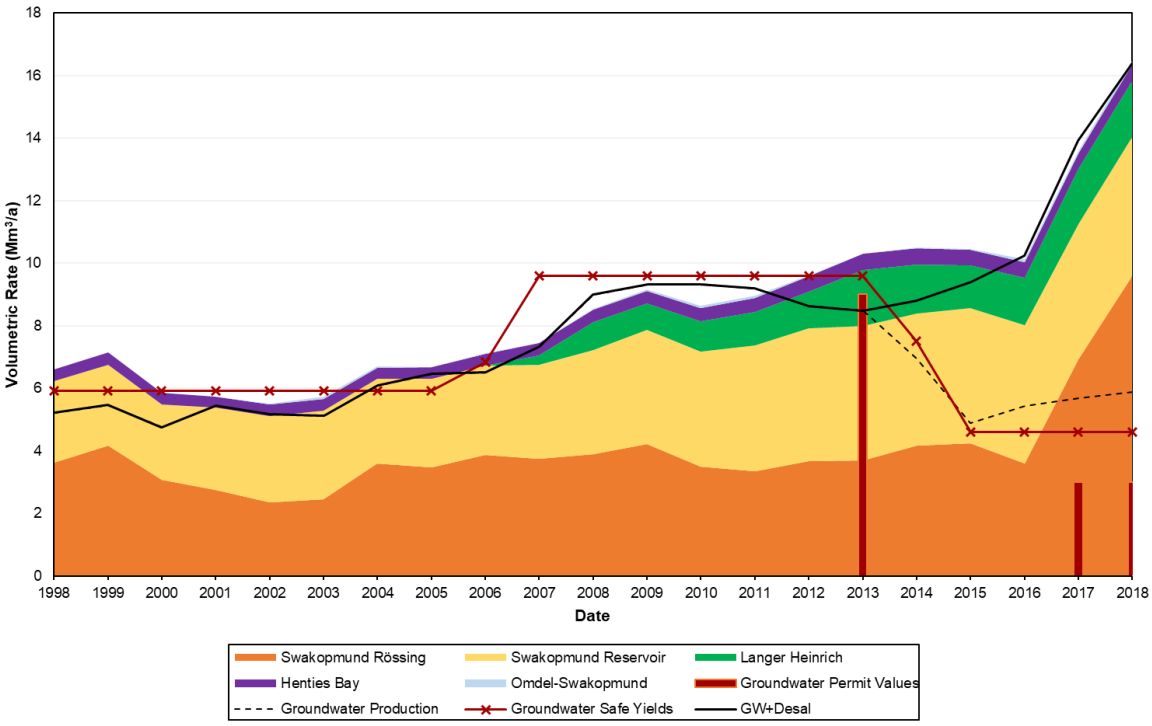

Figure 5.5: Omdel Scheme Water Balance

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5.4 Resource Analysis

5.4.1 Omdel Ground Water Scheme

5.4.1.1 Description

The Omdel – Swakopmund Scheme consists of the Omdel Dam, the Omdel Aquifer, collector pipelines, the Omdel Collector Reservoir and the Omdel – Swakopmund Pipeline. Groundwater is abstracted from the Omdel Aquifer (consisting of the Omdel East, Omdel Central and Omdel West Wellfields) near Henties Bay which contains numerous boreholes in three portions of the aquifer, most of which is pumped into the Omdel Collector Reservoir. Water from two boreholes in the Omdel West Wellfield is supplied directly to Henties Bay (LCE, 2015 and NamWater, 2009).

The Omdel Aquifer is situated along the lower Omaruru riverbed and consists of four eroded paleo-channels filled with alluvial sand, gravel and conglomerate. Only one of these paleo-channels contains good quality potable water. Water enters the Omdel Aquifer by means of continuous sub-surface throughflow and by natural recharge when flood events occur, whilst water is also artificially recharged via infiltration ponds (NamWater, 2009).

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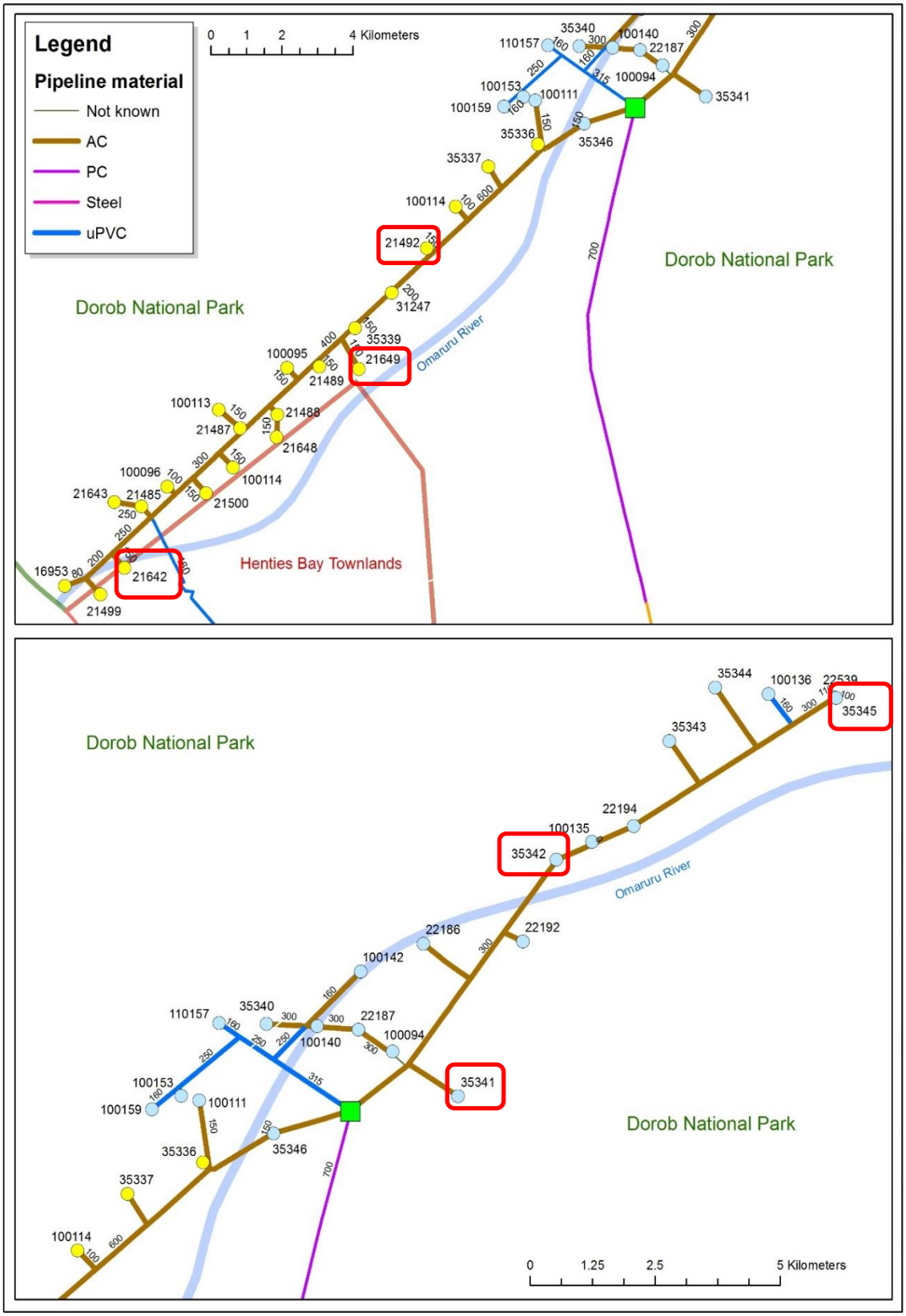

Figure 5.6: Layout of NamWater's Omdel Groundwater Scheme (LCE, 2015)

Water levels for selected boreholes highlighted in red have been plotted.

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5.4.1.2 Water Levels

The water levels in selected boreholes (based on their locations as being representative or important and the continuity of the data available) in the Omdel East and West Schemes have been plotted to ascertain the behaviour of the aquifer over a period of time.

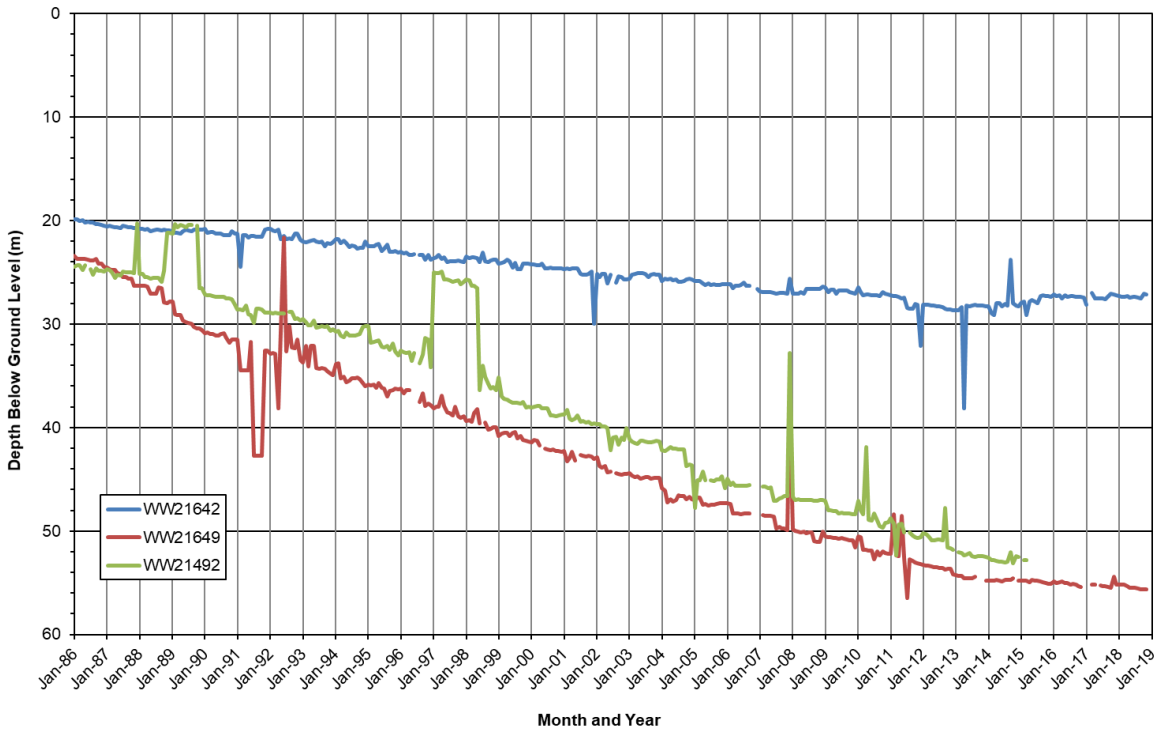

Figure 5.7: Historical Water Levels in Selected Boreholes of the Omdel West Scheme

Water levels in at least two of the boreholes in the Omdel West portion of the aquifer have declined steadily since January 1986, although these levels appear to have stabilised somewhat after 2014, following NamWater's purchase and supply of desalinated water from the EDP, which commenced in August 2013. Abstraction permit values have declined from 9 Mm3/a in 2012 to 3 Mm3/a in 2016 following concerns about the historical over abstraction of the aquifer. The current permitted abstraction from the aquifer is 4.6 Mm3/a. Water levels in borehole WW21642 have not dropped as dramatically as those of the other two boreholes shown in **Figure 5.7**, which is important, given that this borehole is located close to the coast. The historical over abstraction of the Omdel Aquifer, and declining water levels in the western portion of the aquifer are a concern regarding the possibility of salt water intrusion into the aquifer. The water levels plotted in **Figure 5.8** suggest that NamWater has abstracted more water from the inland boreholes than from those closest to the coast to help prevent salt water intrusion into the aquifer.

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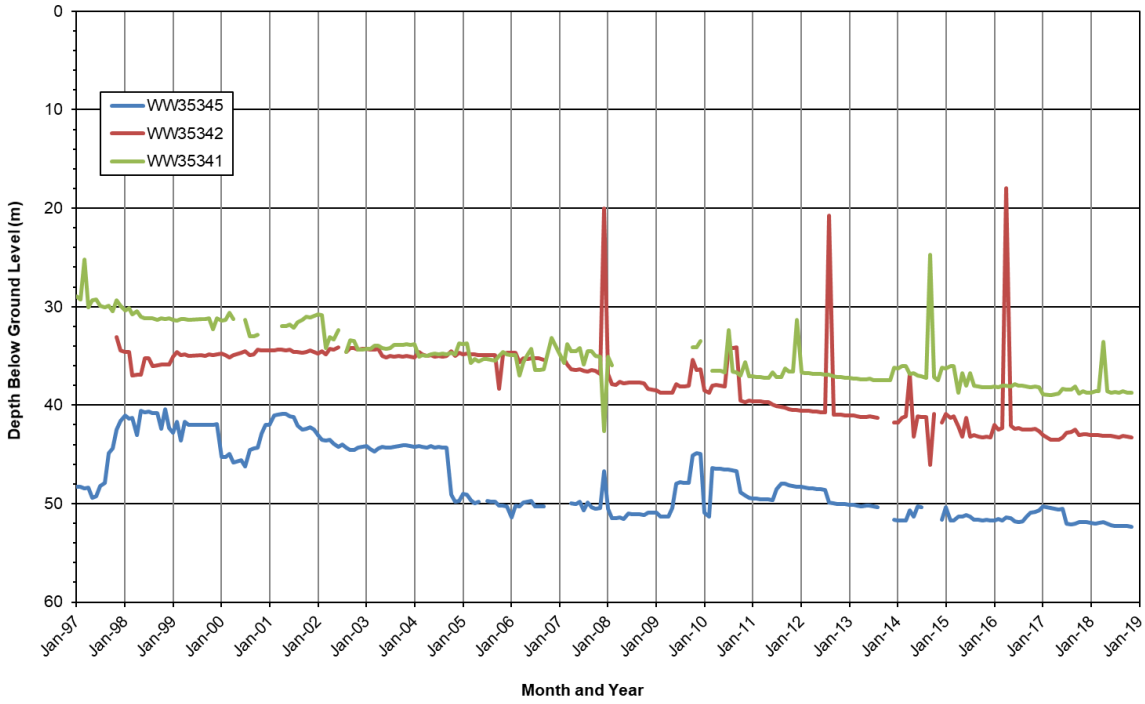

Figure 5.8: Historical Water Levels in Selected Boreholes of the Omdel East Scheme

The water levels of selected boreholes in the Omdel East Scheme do not show as dramatic a decline over time as those in selected boreholes in the Omdel West Scheme. This is likely due to the fact that the Omdel East Scheme is upstream, and thus receives recharge via sub-surface throughflow before the Omdel West Scheme does. If the recharge which does occur is abstracted in the eastern portion of the wellfield, less recharge will reach the western portion of the wellfield, which may also explain the sharply declining water levels in some boreholes in the Omdel West Scheme.

It is also noticeable that no significant increase in water levels in either the Omdel East of West Schemes is observed in 2011, which was an exceptional rainy season countrywide. During 2010/11, the Omaruru River flowed past Omaruru several times and for much longer periods than in other years. However, the lack of an increase in water levels in 2011 suggests that no significant recharge of the Omdel Aquifer took place in 2011. This should be a matter of considerable concern; despite an historic rainy season and several flow events in the Omaruru River upstream, no significant recharge of the Omdel Aquifer occurred (at least in comparison with the Kuiseb Aquifer; refer below). If no significant recharge of the aquifer occurred under such favourable conditions, significant recharge in “normal” or “average” years is unlikely, which may require a reassessment of the safe yield and long-term sustainable use of the Omdel Aquifer.

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5.4.1.3 Water Quality

Total Dissolved Solids (TDS) is principally a measure of the inorganic salts and small amounts of organic matter present in solution in water (WHO, 2017), and is a measure considered to be broadly representative of "water quality". TDS values of water samples for selected boreholes in the Omdel East and West Schemes have been plotted to ascertain if and how the water quality has changed over time.

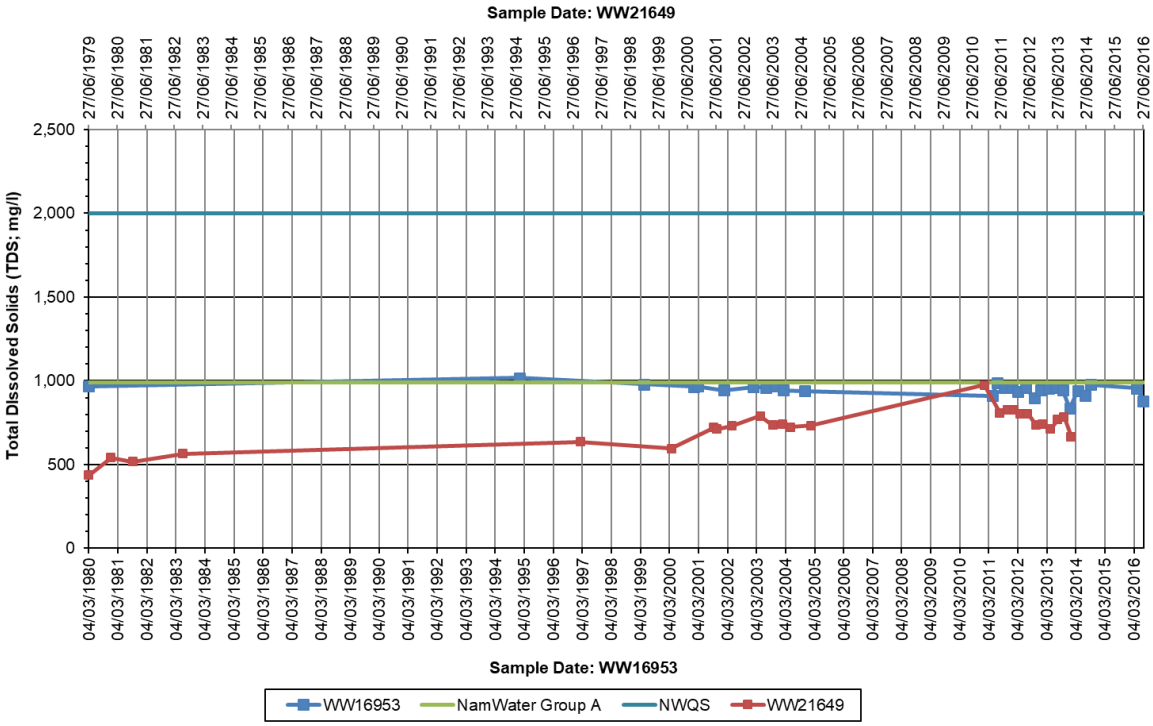

Figure 5.9: Historical TDS Levels in Selected Boreholes of the Omdel West Scheme

Notes:
1. TDS = Total Dissolved Solids.
2. NamWater Group A refers to the TDS limit of 990 mg/ℓ (DWA, 1991) applied to the Limit for Group A water (water of an excellent quality) by NamWater (NamWater, 1998).
3. NWQS refers to the Namibia Water Quality Standard, being the Acceptable Standard for potable water (2 000 mg/ℓ) of the intended regulations which are to accompany the Water Resources Management Act, No. 11 of 2013.

The TDS of water samples from two selected boreholes in the Omdel West Scheme indicate that by this measure, the water quality meets the requirements for Group A water (water of an excellent quality) per the NamWater guidelines (NamWater, 1998) as well as the Namibia Water Quality Standard (NWQS) (acceptable standard).

The TDS of water samples from these two boreholes has not deteriorated over time, as would be expected had salt water intrusion into the aquifer occurred. Nonetheless, the possibility of salt water intrusion into the aquifer remains a danger, given the historical over-abstraction of the aquifer, and is an aspect which should be monitored carefully and continuously by NamWater.

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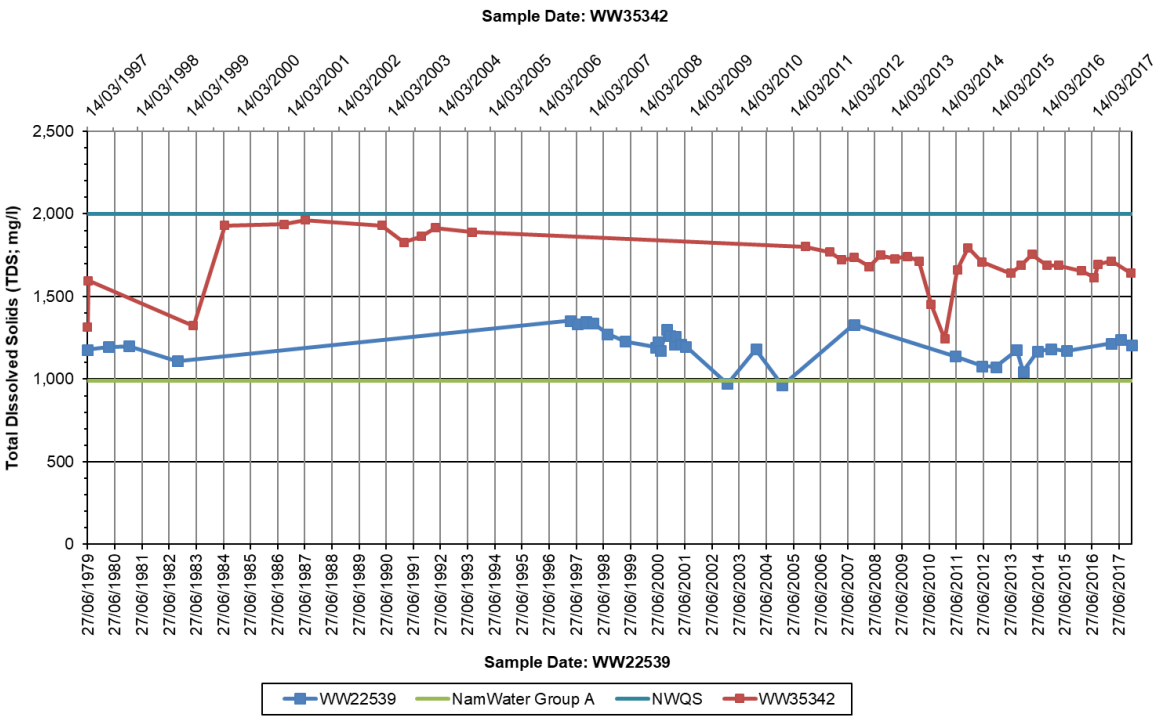

Figure 5.10: Historical TDS Levels in Selected Boreholes of the Omdel East Scheme

Notes:
1. TDS = Total Dissolved Solids, which is principally a measure of the inorganic salts and small amounts of organic matter present in solution in water (WHO, 2017).
2. NamWater Group A refers to the TDS limit of 990 mg/ℓ (DWA, 1991) applied to the Limit for Group A water (water of an excellent quality) by NamWater (NamWater, 1998).
3. NWQS refers to the Namibia Water Quality Standard, being the Acceptable Standard for potable water (2 000 mg/ℓ) of the intended regulations which are to accompany the Water Resources Management Act, No. 11 of 2013.

The TDS of samples from two boreholes in the Omdel East Aquifer are higher than those in samples from two boreholes in the Omdel East Aquifer and generally higher than the NamWater guidelines for Group A water (NamWater, 1998 and DWA, 1991), although below the NWQS limit of 2 000 mg/ℓ and mostly below the limit for Group B water (1 980 mg/ℓ). Therefore, whilst the TDS of the water may be “high”, and unpalatable to some[29], it meets the Namibian guidelines, both of NamWater and the NWQS, for safe drinking water. The difference in TDS values between the Omdel East and West parts of the aquifer is likely due to the hydrogeology of the aquifer and in which paleo-channel the specific boreholes are located.

[29] The WHO indicates that drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1 000 mg/ℓ (WHO, 2017).

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5.4.1.4 Omdel Aquifer Yield

The safe or sustainable yield[30] which mostly guides permitted abstraction from the aquifer, remained unchanged at 5.9 Mm^3/a from 1987 to 2005 and increased from thereon to 9.6 Mm^3/a up to 2013 and decreased to the current 4.6 Mm^3/a. The varying safe yields reflect the water supply challenges in the area: Increasing water demands contrasted with decreasing water levels. By 2013 it was clear that this high reliance on groundwater could not be sustained, leading to greater dependence on desalinated water and decreased abstraction from the aquifer. With still declining water levels and poor recharge events and future climate change concerns such as prolonged and more severe droughts, sustainable yields are expected to remain low for the long term.

Despite strain on the aquifer and lowering of yields and permit abstractions, borehole production has increased since 2013 as illustrated in **Figure 5.11**. Borehole production was measured at 5.87 Mm3/a which is 28% above the current permit abstraction value of 4.6 Mm3/a

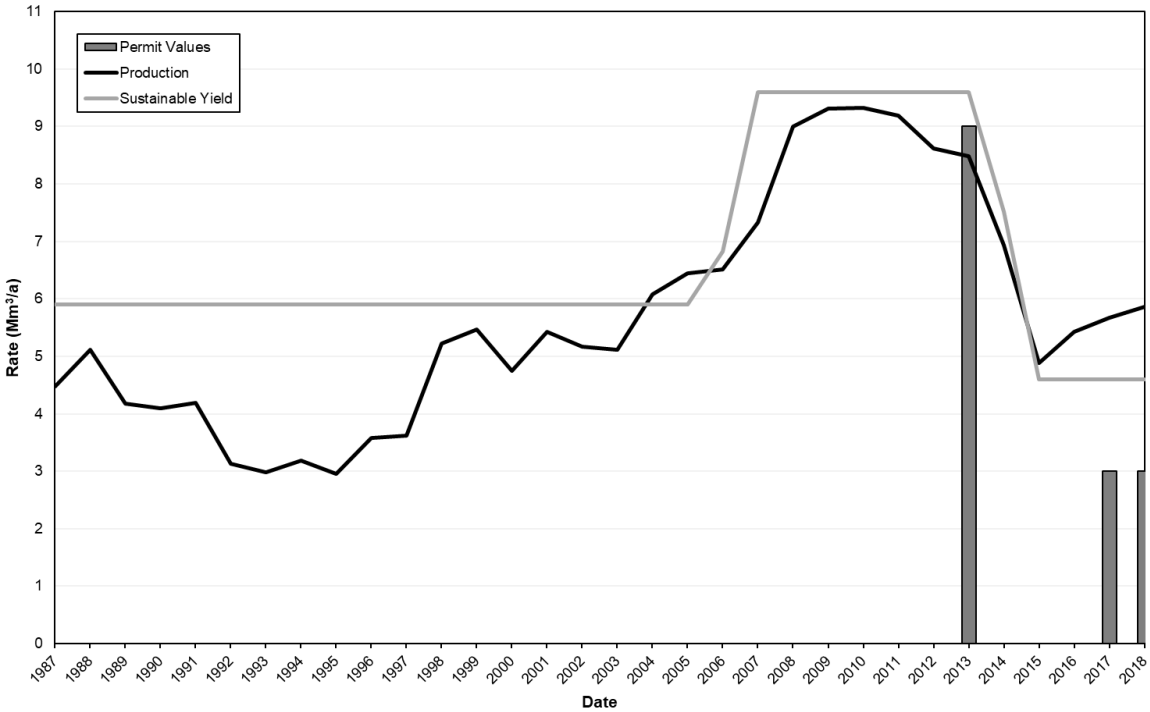

Figure 5.11: Omdel Boreholes: Production, Permit Abstractions and Sustainable Yields

[30] Safe yields were obtained from Omdel Borehole Production files provided by NamWater.

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5.4.1.5 Summary

As **Figure 5.12** indicates, the Omdel Aquifer is currently a resource under strain. General water levels have showed decreasing trends as abstraction has exceeded recharge rates. Despite greatly lowering abstraction from the aquifer, water levels continue to drop. Whilst the water quality remains within drinking water guidelines, possible salt water intrusion in parts of the aquifer needs to be carefully monitored.

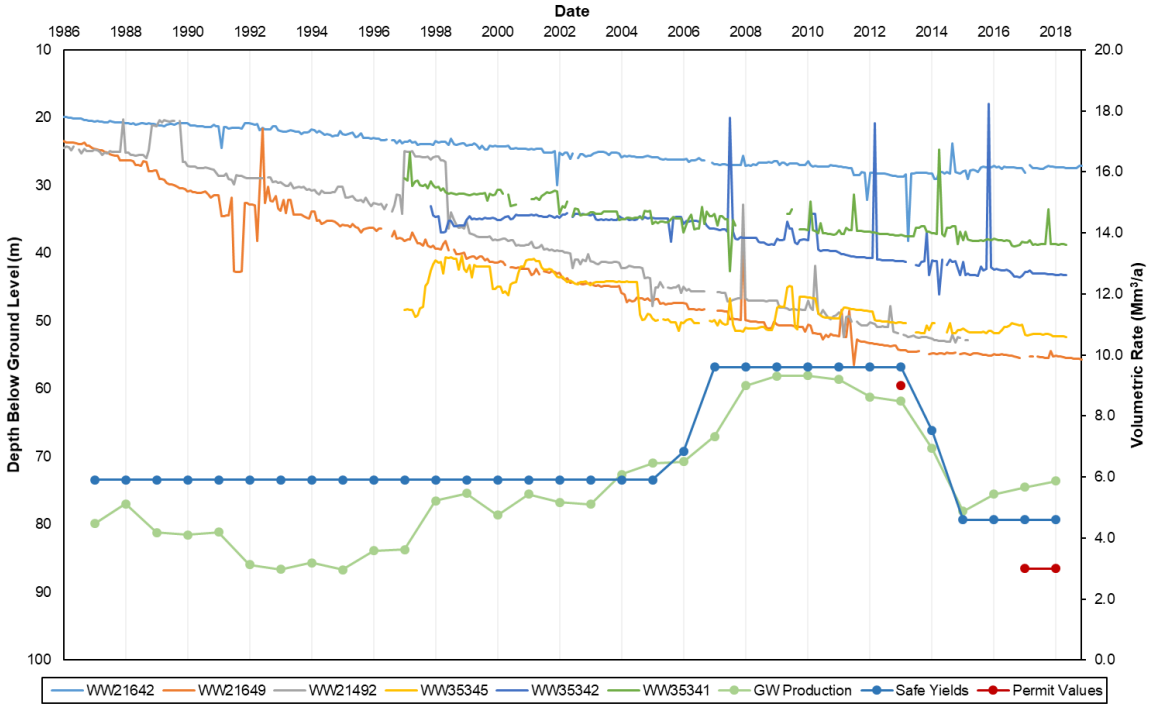

Figure 5.12: Omdel Boreholes: Summary of Groundwater levels, Abstraction, Yields and Permit Abstraction Values

5.4.2 Kuiseb Ground Water Scheme

5.4.2.1 Description

The Kuiseb Water Scheme consists of the Lower Kuiseb Aquifers and all bulk water infrastructure up to and including the Mile 7 reservoirs near Walvis Bay and the terminal reservoir at Swakopmund. In terms of infrastructure, the greater scheme consists of the Swartbank – Swakopmund, the Rooibank – Mile 7 and the High Dune – Mile 7 components (NamWater, 2009).

The Kuiseb Aquifer consists of an alluvial aquifer in the lower Kuiseb riverbed, which consists of the Swartbank, Rooibank A, Rooibank B and Dorop South aquifer compartments (NamWater, 2009).

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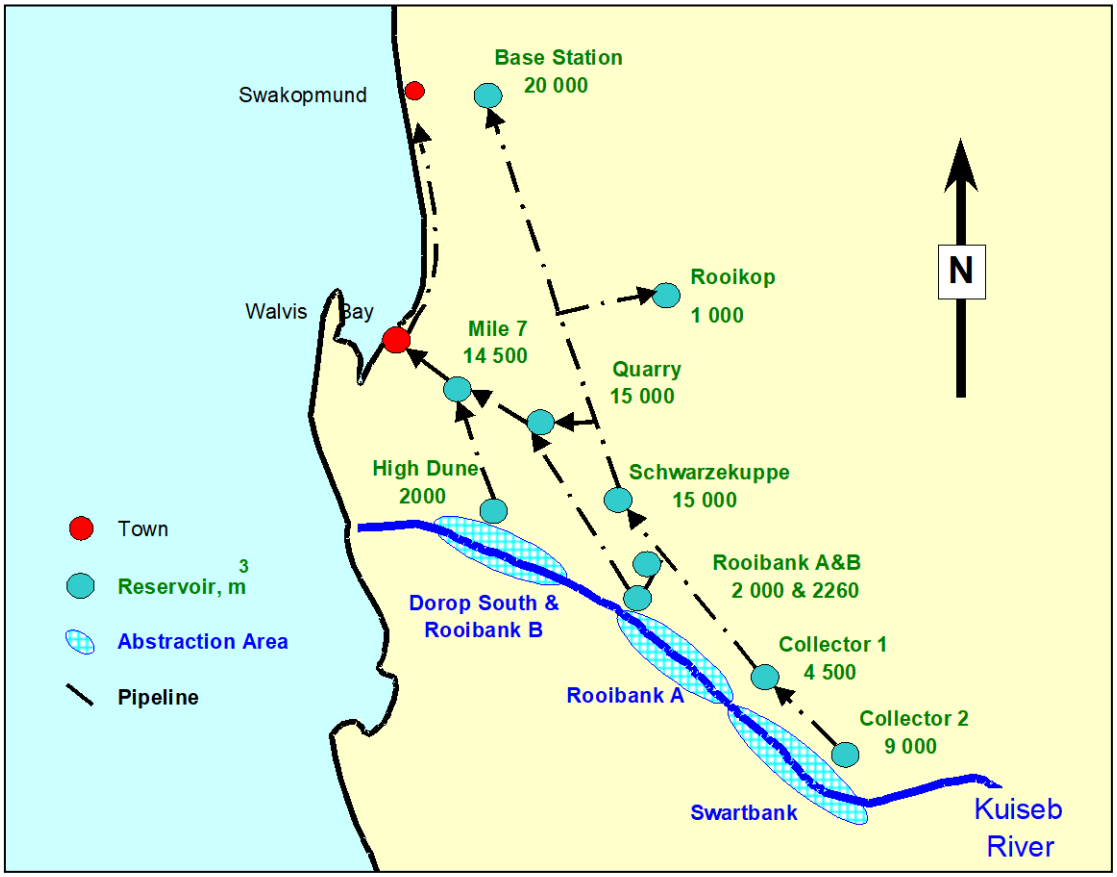

Figure 5.13: Layout of NamWater's Kuiseb Groundwater Scheme (NamWater, 2009)

The Kuiseb River rises in the Khomas Hochland, with the uppermost part of the Kuiseb / Swakop River watershed located about 15 kilometres to the west of Windhoek. The lower portion of the Kuiseb River runs through a desert environment, with more than half of the catchment having a unit runoff potential of 1 mm or less. The upper part of the catchment is generally farmed as cattle ranches and apart from the Friedenau Dam, there are a large number of farm dams on the Kuiseb River. Unit runoff values in the Khomas Hochland range from 4 mm in the west up to 10 mm in the east (SCE, 2011).

5.4.2.2 Water Levels

The water levels in selected boreholes (based on their locations as being representative or important and the continuity of the data available) in the Dorop, Rooibank A, Rooibank B and Swartbank compartments of the Kuiseb Aquifer have been plotted to ascertain the behaviour of the aquifer over a period of time.

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Much less data, overall and in terms of the continuity thereof, is available for the Dorop South compartment of the Kuiseb Aquifer than is the case with the other compartments. The relatively poor data availability for water levels in selected boreholes of the Dorop South compartment, plotted in **Figure 5.14** (other boreholes contain even less data), hampers an assessment of the performance of this compartment of the aquifer. A general decline in water levels can be deduced between December 1994 and December 2009. Water levels towards the end of 2018 appear to be higher than in December 2009, most likely as a result of recharge following the 2010/11 floods, although there is insufficient data to confirm this.

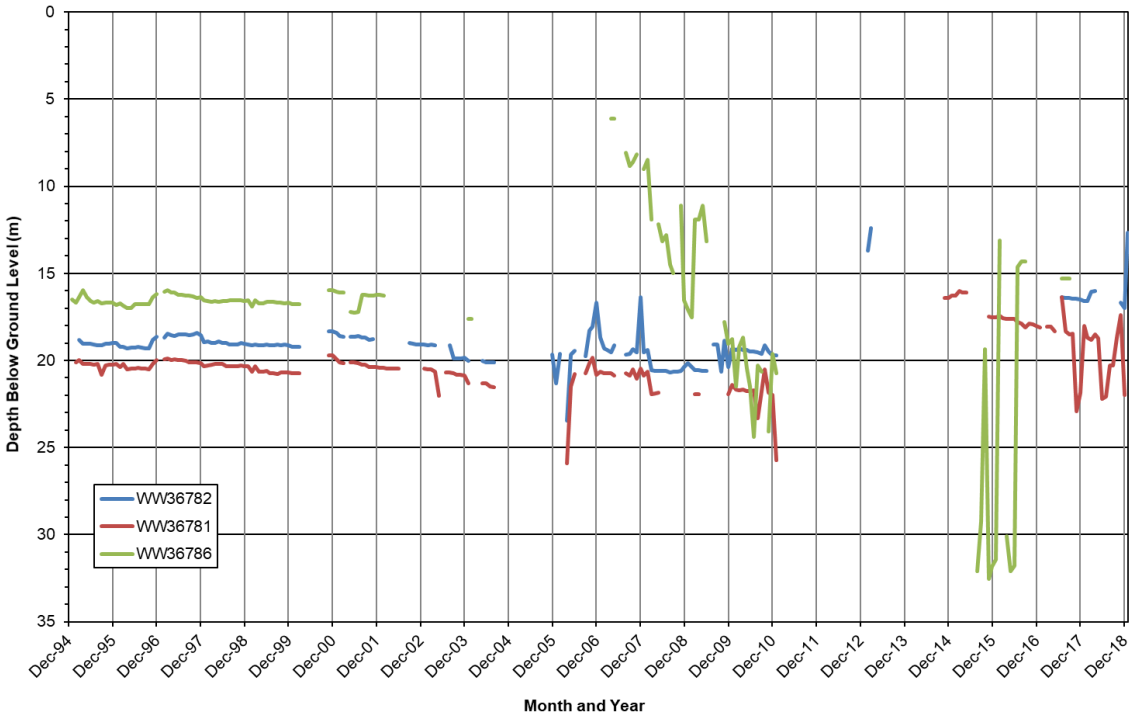

Figure 5.14: Historical Water Levels in Selected Boreholes of the Kuiseb Dorop Scheme

More data is available for the Rooibank A compartment of the aquifer, generally showing the increase in water levels following the 2010/11 floods in the Kuiseb River (**Figure 5.15**). In the period since, water levels have declined, indicating rates of abstraction greater than rates of recharge. The water levels in three of the boreholes selected are higher towards the end of the period than in 1995, largely as a result of the recharge event of 2010/11, although the opposite is true in the case of borehole WW16592.

Although less data is available in the case of the Rooibank B compartment of the aquifer, similar trends to those observed in the Rooibank A compartment can be deduced (Figure 5.16).

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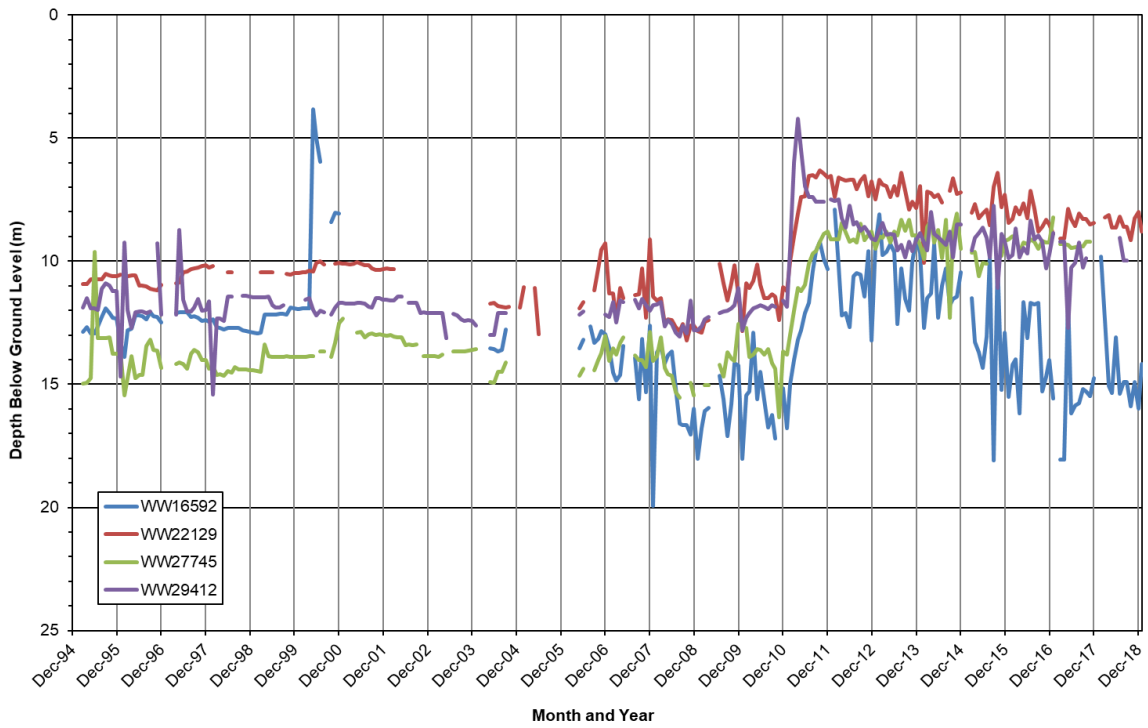

Figure 5.15: Historical Water Levels in Selected Boreholes of the Kuiseb Rooibank A Scheme

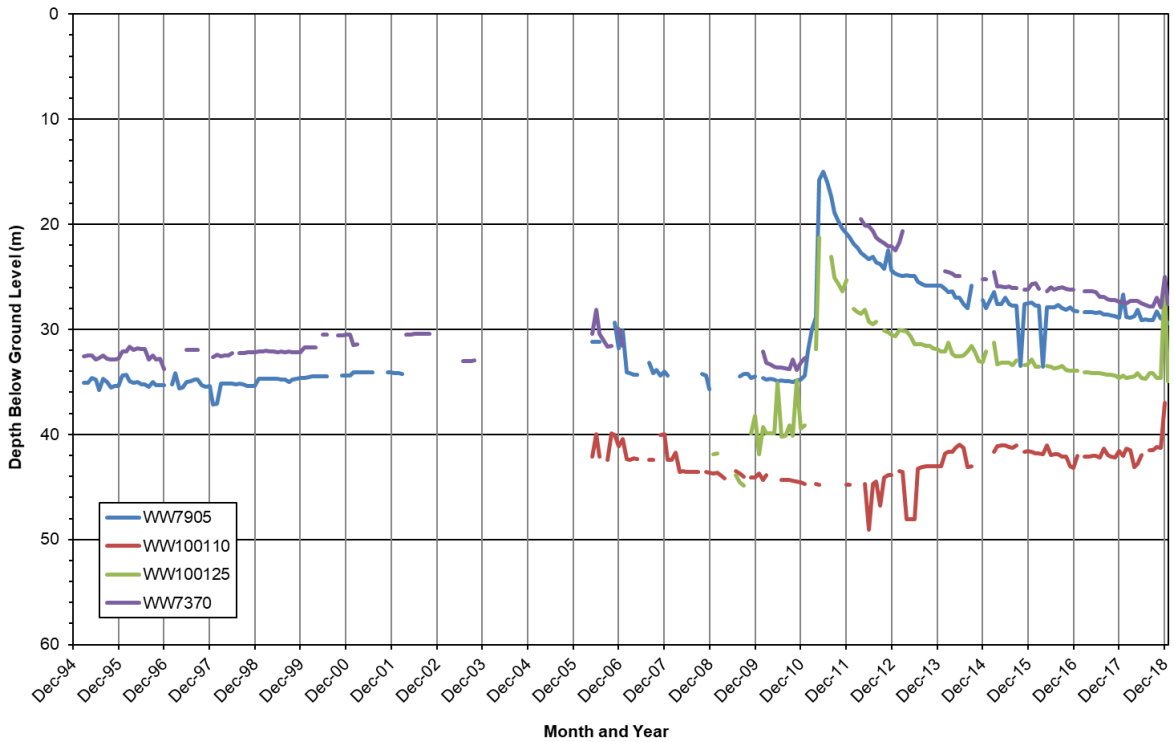

Figure 5.16: Historical Water Levels in Selected Boreholes of the Kuiseb Rooibank B Scheme

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The Swartbank compartment of the Kuiseb Aquifer is likely the oldest (in terms of groundwater abstraction and development), since water level data is available for some boreholes since January 1986. From the variation of water levels in selected boreholes (**Figure 5.17**), recharge events in 1999/2000, 2008/09 and 2010/11 can be identified. Rainfall in Windhoek in these years, of 624 mm, 578 mm and 1 089 mm respectively was well above the (long-term) average of 374 mm/a between 1913/14 and 2016/17, thereby likely resulting in above average flow events in the Kuiseb River. Water levels have generally declined between these notable recharge events, indicating outflows at rates greater than inflows between flood events[31]. In general, water levels are higher (shallower) and these recharge events are much more prominent in the Swartbank compartment than the others, likely due to this being the most upstream compartment of the Kuiseb Aquifer.

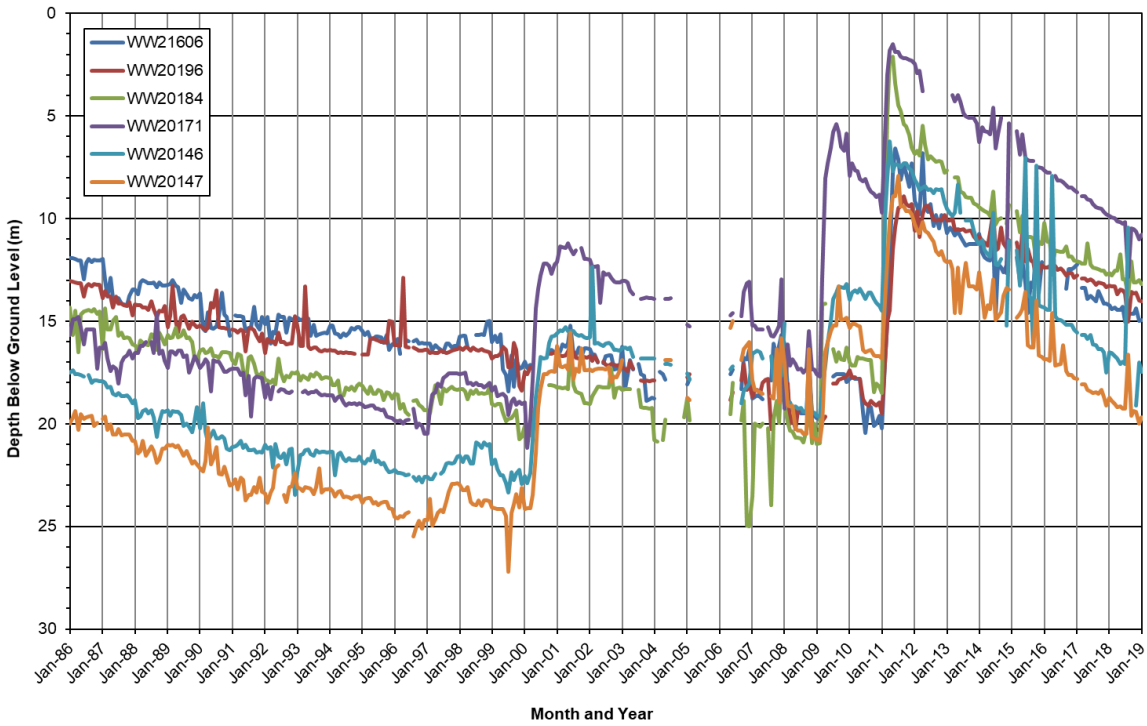

Figure 5.17: Historical Water Levels in Selected Boreholes of the Kuiseb Swartbank Scheme

[31] An aquifer system can be thought of in terms of "inflows" and "outflows", with the water levels as a measure of the status of the "system". "Inflows" typically comprise recharge events and sub-surface flows from hydraulically connected strata (throughflow), whilst "outflows" typically comprise sub-surface flows via hydraulically connected strata (throughflow), evaporation, evapotranspiration and groundwater abstraction. Throughflows, both into and out of aquifer compartments depends on a number of factors, including up- and downstream water levels and hydraulic gradients. Differences between inflows and outflows change the levels of storage in the aquifer, thus the water levels over time.

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Of particular concern is the rate of decline in water levels between mid-2011 and January 2019, which is steeper than the rate of decline observed between January 1986 and January 2000. For example, in borehole WW20147, it took some 11 years for the water level to drop by 5 m (from a depth of 20 m in January 1986 to a depth of 25 m around January 1997). By contrast, it took only slightly more than 3 years for the water level to drop by the same amount between January 2012 (10 m depth) and March 2015 (15 m depth). In 7 years between January 2012 (10 m depth) and January 2019 (20 m), the water level in borehole WW20147 has dropped by 10 m, which is more than double the drop observed over the 11 years between January 1986 and January 1997. Similar trends are observed for a number of other boreholes. Declining water levels indicate reducing storage in the aquifer compartment, as a result of outflows which exceed inflows, including natural recharge, and / or declining rates of natural recharge. Whilst there are more than one type of outflows from the system, groundwater abstraction is likely one of the major components of total outflow and these observations could therefore suggest increasing rates of abstraction from the Swartbank compartment. However, outflows from the aquifer compartment may also increase as a result of higher water levels and a steeper hydraulic gradient relative to downstream compartments and strata. The complexity of groundwater systems, and particularly the geology and hydrogeology of the Lower Kuiseb Aquifers, is why groundwater modelling is conducted to estimate recharge and yield rates, as described by SLR (2014).

The Walvis Bay Municipality have indicated that high levels of sand in the water supplied by NamWater adversely affect the functioning of water meters in the town. The sand / grit content is believed to be due to high rates of abstraction from the Kuiseb boreholes (Mr. Esterhuizen, 2019, pers. comm., 26 March).

5.4.2.3 Water Quality

Total Dissolved Solids (TDS) is principally a measure of the inorganic salts and small amounts of organic matter present in solution in water (WHO, 2017), and is a measure considered to be broadly representative of “water quality”. TDS values of water samples from the Mile 7 Reservoir have been plotted as representing the combined groundwater abstraction from the different compartments of the Kuiseb Aquifer and the water supplied to Walvis Bay (refer to **Figure 5.18**).

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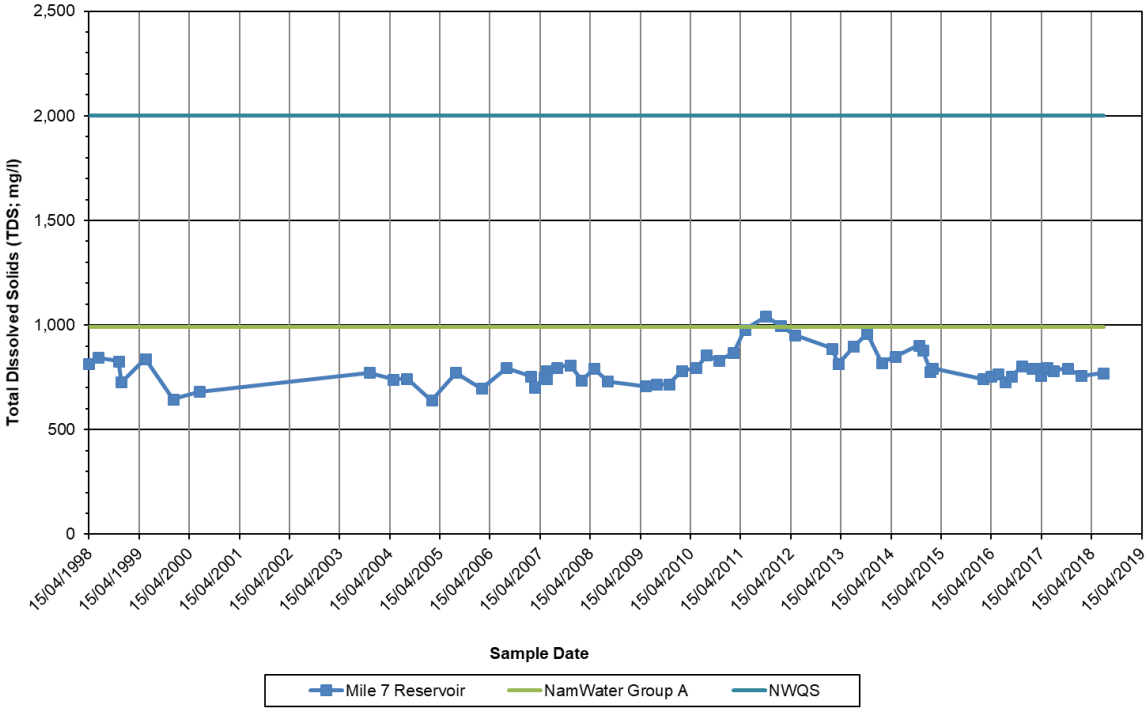

Figure 5.18: Historical TDS Levels in the Mile 7 Reservoir of the Kuiseb Scheme

Notes:
1. TDS = Total Dissolved Solids.
2. NamWater Group A refers to the TDS limit of 990 mg/ℓ (DWA, 1991) applied to the Limit for Group A water (water of an excellent quality) by NamWater (NamWater, 1998).
3. NWQS refers to the Namibia Water Quality Standard, being the Acceptable Standard for potable water (2 000 mg/ℓ) of the intended regulations which are to accompany the Water Resources Management Act, No. 11 of 2013.

The TDS of the Kuiseb Aquifer groundwater has complied with the requirements for Group A water (water of an excellent quality) per the NamWater guidelines (NamWater, 1998) for most of the period since April 1998 and therefore represents good quality groundwater. Although TDS values were relatively higher in 2011-2014, there appears to be no significant increase in TDS values over the period.

5.4.2.4 Reliability of Supply

A water supply emergency occurred in Walvis Bay during February to April 2011 when heavy flooding in the Kuiseb River damaged the collector pipelines between some of the boreholes and the collector reservoirs (refer to **Figure 5.13**). As a result, water supply to the coastal towns, and Walvis Bay in particular, was severely hampered, and rationed for a period of time. In March 2011, water was available in Walvis Bay only between 06h00 and 09h00 and again between 18h00 and 21h00 daily (Namibian, 2011). The Walvis Bay Municipality on 25 May 2011 lifted all water supply restrictions after NamWater successfully carried out N$ 3 million worth of repairs to their supply infrastructure in the Kuiseb River (Steenkamp, 2011).

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These 2011 supply interruptions were not caused by power supply outages to the boreholes, as NamWater had in the previous year spent in excess of N$ 10 million upgrading the power lines to the boreholes, to prevent flood damage (Steenkamp, 2011).

Following the damage to the collector pipelines in the Kuiseb in 2011, NamWater replaced the pipelines with welded HDPE pipes which are reportedly more flood resistant[32].

The measures instituted by NamWater notwithstanding, the reliability of supply from the Kuiseb system, and the robustness thereof with regard to possible future flood events remains a concern to the Walvis Bay Municipality (Mr. Esterhuizen, 2019, pers. comm., 26 March).

5.4.2.5 Kuiseb Aquifer Yield

Sustainable yields have generally decreased along with borehole production from approximately 7.2 Mm^3/a in 1987 to 4.5 Mm^3/a in the late 1990s. These have since increased again to 6.9 Mm^3/a from the 2000s and again in 2014 to 7.4 Mm^3/a. Recent investigations into the aquifer have recommended higher yields, up to 9 Mm^3/a including further development of the aquifer.

Permit abstraction values were only provided by NamWater from 2014 onwards, all at 7 Mm^3/a. The latest permitted abstraction value was increased to 9 Mm^3/a in 2019 and allows for an emergency abstraction rate of up to 11.4 Mm^3/a.

Production, safe yields and permit values are illustrated in **Figure 5.19**. Production exceeded safe yields from 1987 to 2002, though it generally followed a decreasing trend along with the lowering yields. From 2002 to 2012, production remained below the safe yield, but has since exceeded it. As of 2018, the production of 8.46 Mm3/a exceeded the safe yields by 16%, but would be below the 2019 permitted abstraction value of 9 Mm3/a.

[32] Personal communication with Mr. S. Shaanika, Head: Civil Engineering of NamWater; 03 July 2019).

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Figure 5.19: Kuiseb Boreholes: Production, Permit Abstractions and Sustainable Yields

5.4.2.6 Summary

As **Figure 5.20** shows, the Kuiseb Aquifer is heavily reliant large flood events which recharge the aquifer. In the last 30 years, only three such events occurred, although their impact, especially the 2011 floods, significantly improved water levels. Of concern however, is the decrease in water levels since 2011, likely resulting from increased abstraction. The rate of decline in water levels is the highest in 30 years and should this trend continue, 30 year lows could be achieved at some boreholes within the next 5 years. Water quality of the aquifer is generally is good, of drinking standard and no major negative trends in quality were observed.

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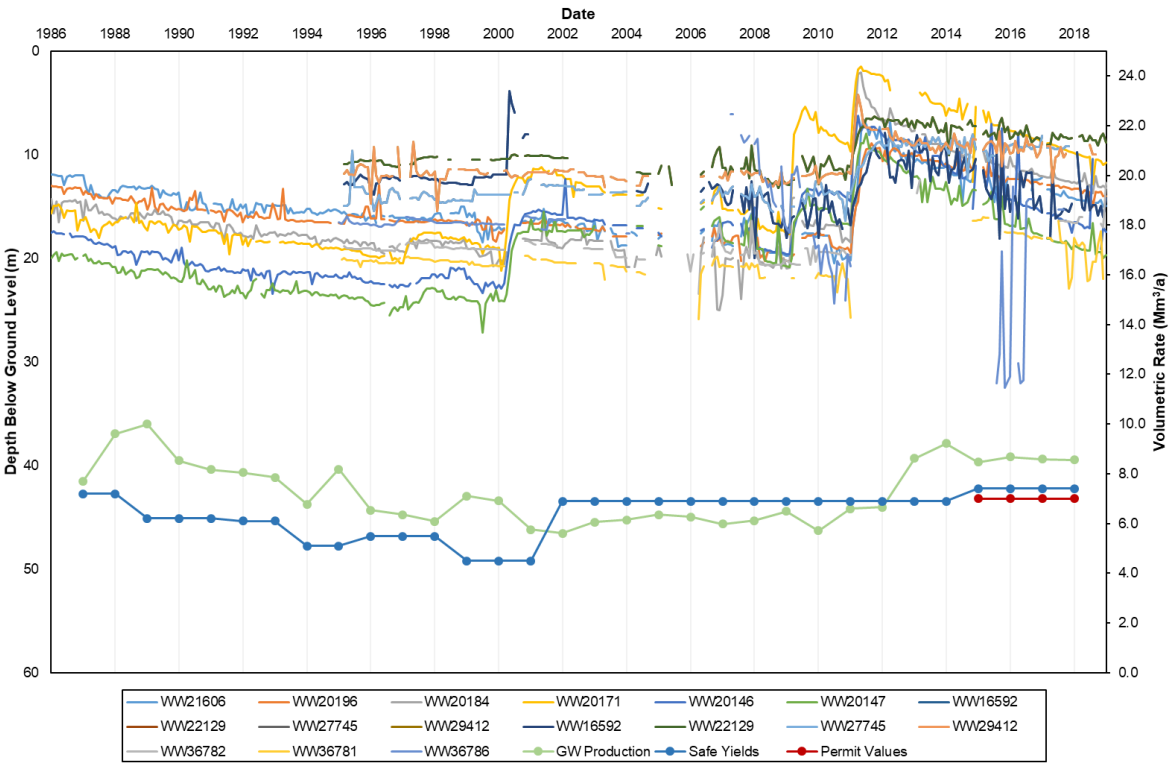

Figure 5.20: Kuiseb Boreholes: Summary of Groundwater levels, Abstraction, Yields and Permit Abstraction Values

5.4.3 Erongo Desalination Plant

The Erongo Desalination Plant (EDP) has been in operation since June 2010, where it at first exclusively supplied water to the Trekkopje Mine up until August 2013, when supply to NamWater was introduced. The plant produced 9.78 Mm^3/a in FY 2018, although its historical peak was the previous year, at 10.66 Mm^3/a. The plant has a current design supply capacity of 20 Mm^3/a, implying that the plant is currently running at 50% capacity.

The use or off-take of the desalinated water has almost swopped completely from FY 2013 to 2014, with NamWater receiving 99-100% of the recent supply, since the Trekkopje Mine is currently under care and maintenance.

As indicated in **Figure 5.21**, consumption at Trekkopje's Areva Mine peaked in only the first year at 1.24 Mm3/a and has since declined. By FY 2019, the mine received no water supply per the information provided. Essentially, desalinated supply went from exclusive supply to the mine prior to 2013, to NamWater-dominated supply from 2014 onwards.

For a in depth analysis of the Erongo Desalination Plant, please refer to the Chapter on Desalination Plant Options.

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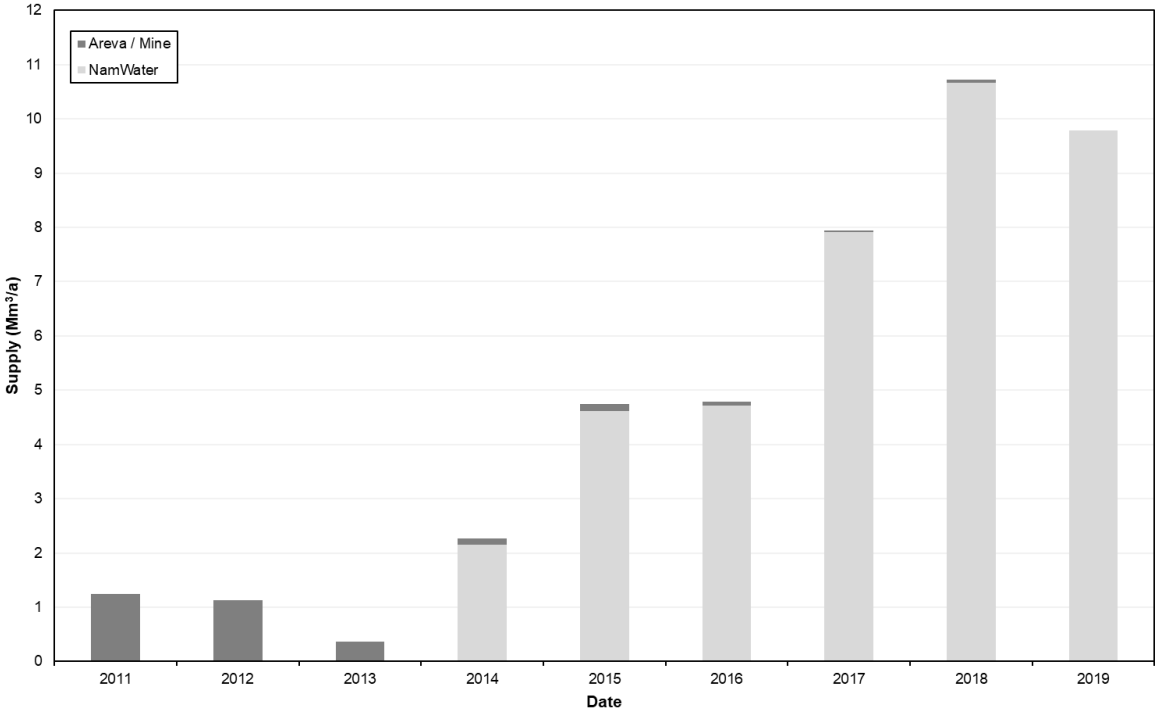

Figure 5.21: Erongo Desalination Plant Production

5.4.4 Water Reclamation

Semi-purified water is currently utilised for restricted irrigation in Swakopmund and Walvis Bay, including at the Rössmund Golf Course in the former case.

During the stakeholder consultations carried out under the Inception Phase of this Study, the Walvis Bay Municipality made available information (on an “eyes only” basis) that they are in the process of examining the feasibility of implementing DPR. Since this applies only to the Walvis Bay Municipality, allowance for these proposals has been included in the demand projections for that town, rather than as a “supply option”. Likewise, the semi-purified irrigation water utilised in Swakopmund.

5.4.5 Summary of the Resource Analyses and Supply Scenarios

Different options have been put forward for the utilisation of the groundwater resources available to the CCA.

With Fichnter’s 2011 assessment, the need to safeguard the natural resources of the Erongo Region, with respect to the Omdel and Kuiseb Aquifers was recognised (Fichtner, 2011). The *Rapid Assessment of Desalination Options* report based their approach to long-term supply on the use of the Omdel and Kuiseb Aquifers “*at safe yields in order to preserve these important natural resources at the coast in the long-term perspective*” (BCT and DME, 2016).

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The long-term abstraction rates from the Omdel and Kuiseb Aquifers proposed by the *Rapid Assessment of Desalination Options* report, at 7.7 Mm^3/a, has been considered as an option, albeit the most conservative one.

The Consultant's proposal for the utilisation of these groundwater resources (for the sizing of desalination supply / volumes in 2050) is based on a similar philosophy, and numerically on half of the currently recognised safe yield / abstraction values (8.0 Mm^3/a). This philosophy is based on allowing the recovery of water levels for emergency availability of groundwater in the event of an interruption in the supply of desalinated water for whatever reason (climatic conditions, breakdown, power supply interruptions, etc.).

An alternative option, based on the utilisation of the groundwater sources according to the safe yield values determined by NamWater and others, and according to the permit-approved values per the MAWLR has also been considered. Based on recommendations from NamWater, this option proposed groundwater supply of 12.0 Mm^3/a which corresponds with the sustainable supply of 11.5 Mm^3/a and a maximum of 12.0 Mm^3/a noted by Fichtner (2011).

Overall, there are thus two supply scenarios for the CCA:

1. Supply Scenario 1: 8.0 Mm^3/a (recommended by the Consultant);
2. Supply Scenario 2: 12.0 Mm^3/a (recommended by NamWater).

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Table 5.2: Alternatives for the Utilisation of Existing Sources in the Central Coastal Area of Namibia for 2050

Resource	Available Capacity			Source Option 1: Lower utilisation of groundwater sources to allow for uncertainty and the recovery of water levels			Source Option 2: Allow utilisation of groundwater sources in accordance with safe yield and permit values	
				Capacity (Mm^3/a)		Comment		
	Capacity (Mm^3/a)	Description	Reference	Option 1a: Rapid Assessment[2]	Option 1b: Consultant Proposal[3]		Capacity (Mm^3/a)	Comment
Omdel Aquifer	4.6	Permit-approved abstraction for 2018 Also, safe yields given for 2015 onwards.	MAWLR permit, dated January 2018	2.7	2.3	Reduced yields (conservative) for higher security of supply (reduced variability) and to allow the recovery of water levels for emergency availability in future, if required.	4.6	Allow utilisation of groundwater sources according to the safe yield values determined by NamWater and others, and according to the permit-approved values per MAWLR.
Kuiseb Aquifer	7.0	Permit-approved abstraction from 2015 onwards	MAWLR permits	5.0	5.7		7.4 or 9.0	Kuiseb: NamWater has been granted a permit (May 2019) allowing abstraction of 9 Mm^3/a with an emergency abstraction of 11.4 Mm^3/a. However, NamWater have recommended that the value of 7.4 Mm^3/a be applied for the long term use of the Kuiseb Aquifer.
	7.4	Safe yield given for 2015 onwards.						
				7.7	**8.0**	**Totals**	**12.0**	**Recommended by NamWater**
							13.6	Alternative option

Notes:
1. Permit and safe yield values per the information provided by NamWater.
2. Option 1a: Abstraction / utilisation rates proposed for the Omdel and Kuiseb Aquifers in the *Rapid Assessment Report* of 2016 (BCT and DME, 2016).
3. Option 2: Abstraction / utilisation rates proposed by the Consultant are half of the current permit-approved abstraction and safe yield of the Omaruru Aquifer (4.6 Mm^3/a) and half of the increased abstraction from the Kuiseb Aquifer for which NamWater had applied in late 2018 (11.4 Mm^3/a).
4. Shaded values indicated the selected values for Source Option 1 (8.0 Mm^3/a) and Source Option 2 (12.0 Mm^3/a).

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5.5 Water Consumption Analysis

For NamWater's 2018 financial year, there were a total of 115 active supply points in the area representing 92 clients. The largest users represent the major urban centres in the CCA, namely Swakopmund and Walvis Bay, and the major active mines, namely Langer Heinrich, Husab and Rössing. The schemes supplying these major demand nodes represent nearly 96% of the total CCA demand. In fact, the top 5 CCA clients of NamWater represent 94% of water sales, while the top 10 clients represent 99% of water sales. In other words, the lower 82 active clients in this area represent only 1% of total water sales.

Figure 5.22 illustrates the type of consumers in the CCA. Unsurprisingly, the two major supply groups represent municipal supply and mining supply. Mining supply has grown from only 3.0 Mm^3/a in FY 1998 to 10.6 Mm^3/a in FY 2018, representing a near 250% increase in 20 years (6.5% annual growth rate). With the development of Husab Mine, NamWater's supply to mines has increased considerably since 2016 and is likely to increase even more. As of 2018, municipal demand represented 51% of NamWater's total supply, while mining 45%. Domestic water use, including supply to town and regional councils, municipalities and private consumers represented 53% of total consumption, while industrial and mining supply represented 47% of NamWater's supply.

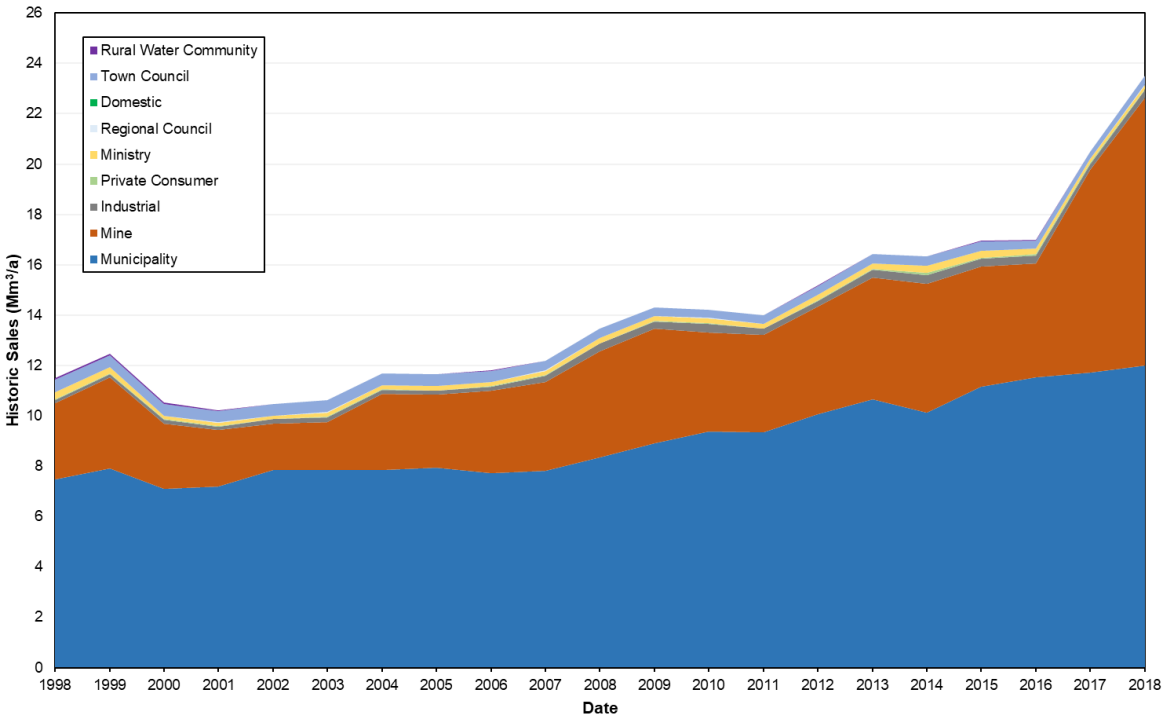

Figure 5.22: CCA Water Consumption per Category

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5.5.1 Major Domestic Users

The major domestic users are represented by the towns of Walvis Bay, Swakopmund, Arandis and Henties Bay. The smaller users, mostly along the Omdel – Swakopmund pipeline and around the Kuiseb Aquifer area, will also be briefly discussed. The analysis of each of these were heavily dependent on the quantity and quality of the information submitted by either NamWater or the various users in this area.

5.5.1.1 Walvis Bay Municipality

Walvis Bay Municipality currently represents the largest single consumer within the CCA. NamWater's sales from the Mile 7 Reservoir grew from 3.1 Mm^3/a in FY 1998 to 6.7 Mm^3/a in FY 2018. The Walvis Bay Municipality provided information on the quantities purchased from NamWater and those sold and the losses or non-revenue water (NRW) for the period 2015-2017, as listed in **Table 5.3**. For the last three years, the Municipality recorded an average NRW of nearly 917 000 m^3 or 14.5%. This level of NRW is "good" in the context of Namibia, below the target of 15% NRW recommended by the *Rapid Assessment of Desalination Options* (BCT and DME, 2016) and less than half the world average of 36.6% in 2012 (per McKenzie et al. 2012).

Table 5.3: Walvis Bay Municipality: Water Purchased, Sold and Losses

Year	Purchased from NamWater	Sold	Loss / NRW	% Loss / NRW
	Mm^3/a	Mm^3/a	Mm^3/a	
2015	5.964	5.279	0.685	11.5%
2016	6.364	5.294	1.070	16.8%
2017	6.510	5.515	0.995	15.3%
Average	**6.279**	**5.363**	**0.917**	**14.5%**

Reservoir outflows from 1984 to 2018 for the major supply areas within Walvis Bay were provided by the Municipality, as indicated in **Figure 5.23** (limited to the period 1988 to 2018). Major supply points within the town are to Kuisebmond, the fish processing plants and to the main portion of the town, representing 86% of total supply in FY 2018. Whilst supply to the major portion of town slowly decreased from 2.09 Mm^3/a in FY 1988 to 1.85 Mm^3/a in FY 2006 (also the lowest on record), it has since grown considerably to its peak of 3.40 Mm^3/a in FY 2018. Nearly all other supply areas have experienced growth in excess of rates of 3% to nearly 5% per annum in the last decade, with the exception being NamPort (Mile 7), Dolphin Park and Kuisebmond. Supply at the Dolphin Park reservoir increased since 1998 but in the last 5 years has decreased. The NamPort supply has varied over time, with the supply during FY 2018 being the second lowest since 1988.

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Supply to Kuisebmond also consistently increased up until its peak of nearly 1.76 Mm^3/a in FY 2017 and has shown a drastic drop in FY 2018 to 1.21 Mm^3/a (the last time supply was that low was in FY 2003.

This is unexpected given the large development of Kuisebmond in recent years, especially with the mass housing projects launched there and constant expansion in the area. It is posited that the Municipality may have changed their supply configuration in the area or may have improved on supply efficiency in the area. However, it is expected that growth in Kuisebmond will persist.

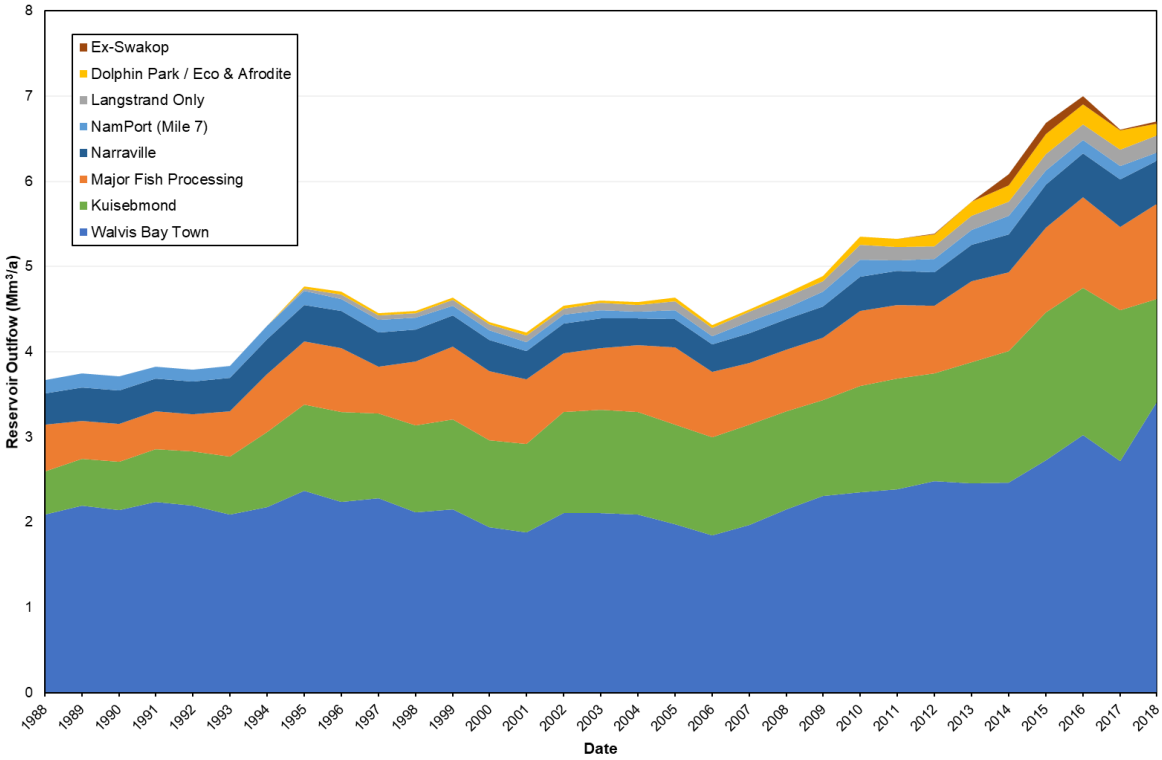

Figure 5.23: Walvis Bay Reservoir Outflows

The Municipality also supplies select users with semi-purified water for irrigation purposes. Currently, consumers make use of approximately 24% of the purified effluent produced by the Municipality (refer to **Table 5.4**), indicating that there is considerable scope for expanding reuse to both direct potable and non-potable uses. The Municipality has indicated their plans to expand reuse in Walvis Bay to direct usage up to 20% of the total potable demand.

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Table 5.4: Walvis Bay Municipality Semi-Purified Effluent

Year	Produced Effluent	Effluent used	% Effluent Used	% Available
	Mm³/a	Mm³/a		
2015	2.6110	0.908	34.8%	65.2%
2016	2.8650	0.657	22.9%	77.1%
2017	3.2900	0.438	13.3%	86.7%
Average	**2.922**	**0.668**	**23.7%**	**76.3%**

Figure 5.24 illustrates previous projections from the Central Namib Area Master Plan (NamWater, 2009) and also the water demand projections of the Integrated Spatial Urban Development Plan (ISUDP) of 2013 (UD, 2013). As indicated, all 2009 Master Plan projections were generally exceeded, especially from 2014 onwards. By contrast, demand expectations under the ISUDP for 2017, at 7.5M m³/a, were much higher than the corresponding sales value of 6.51 Mm³a. The projected 2030 values are also expected to be overestimated.

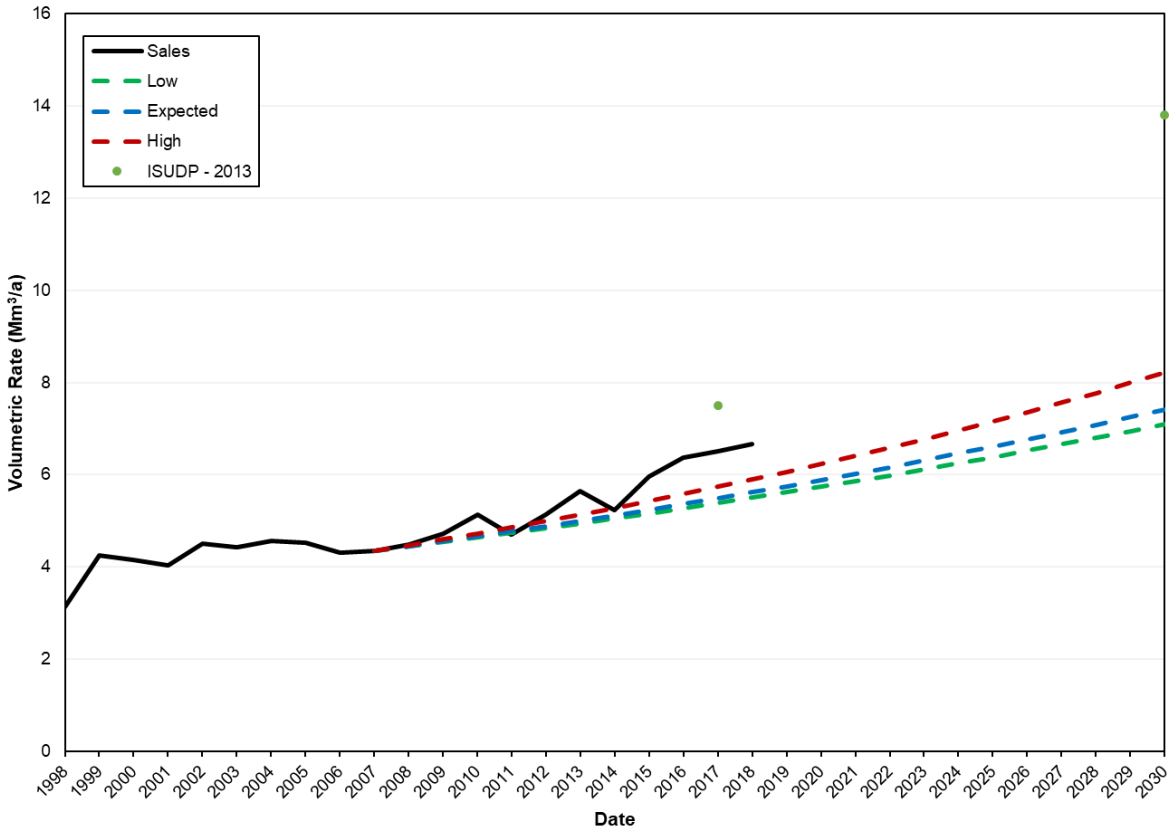

Figure 5.24: Walvis Bay: NamWater Sales and Previous Demand Projections

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5.5.1.2 Swakopmund Municipality

The Swakopmund Municipality is currently the third largest consumer in the CCA, after the Walvis May Municipality and Husab Mine, consuming a total of 4.78 Mm3/a in FY 2018, of which 4.44 Mm3/a (93%) is supplied from the Swakopmund Terminal Reservoir for the bulk of the town and the remaining 7% from the Swakopmund-Rössing and Omdel-Swakopmund supply schemes. Overall sales from NamWater to the Municipality grew from 2.79 Mm3/a in FY 1998 to 4.78 Mm3/a in FY 2018 at an overall growth rate of 2.7% per annum (refer to **Figure 5.25**). Growth was much higher in the latter part of this 20 year period at 3.3% per annum from FY 2008 to 2018. Population growth in Swakopmund far exceeded growth in water consumption, with annual growth rates of 6.6% and 3.6% recorded between the 1991-2001 and 2001-2011 censuses respectively. With the interim census of 2016, the Erongo Region saw a further 5% per annum growth in its urban population. It is expected that much of this growth occurred at Walvis Bay and Swakopmund. Given this high population growth, it seems that water efficiency improved in Swakopmund over the last 20 years and / or that a large part of the population settling in the town use relatively low volumes of water on a per capita basis.

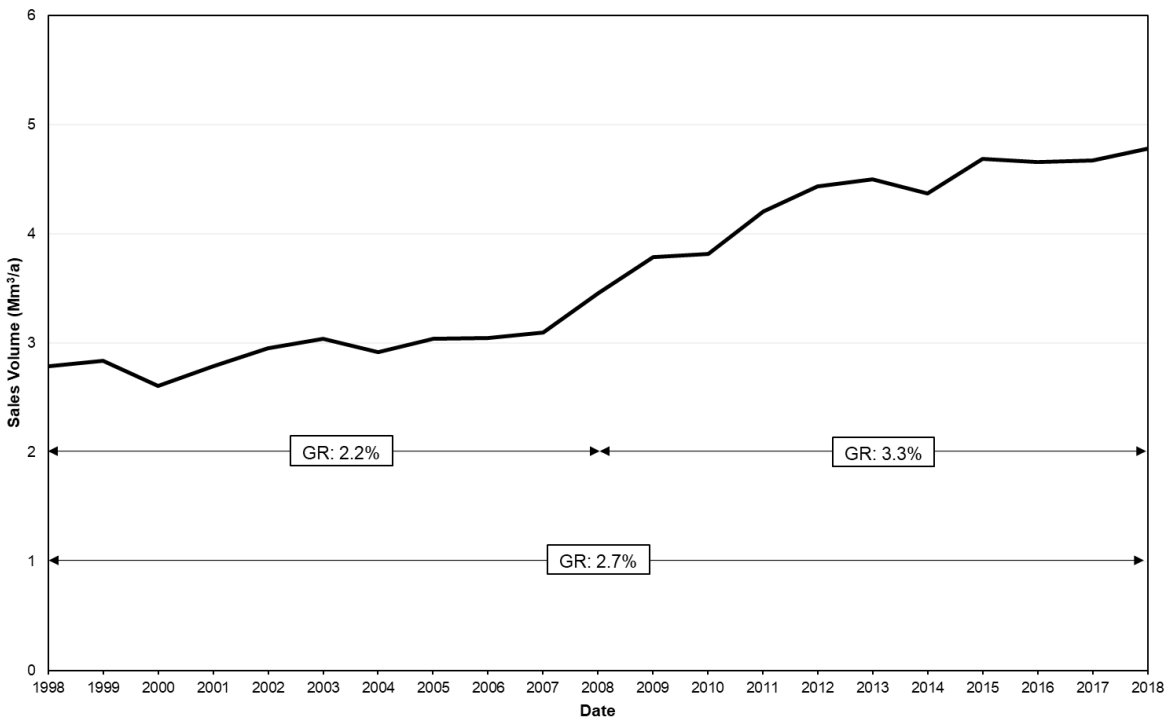

Figure 5.25: NamWater Sales to Swakopmund and Growth Rates

The Swakopmund Municipality provided information on daily water meter readings of the NamWater supply reservoir and a pump station from 2001 to the present and monthly consumption per supply area within the Municipality from 2014 onwards.

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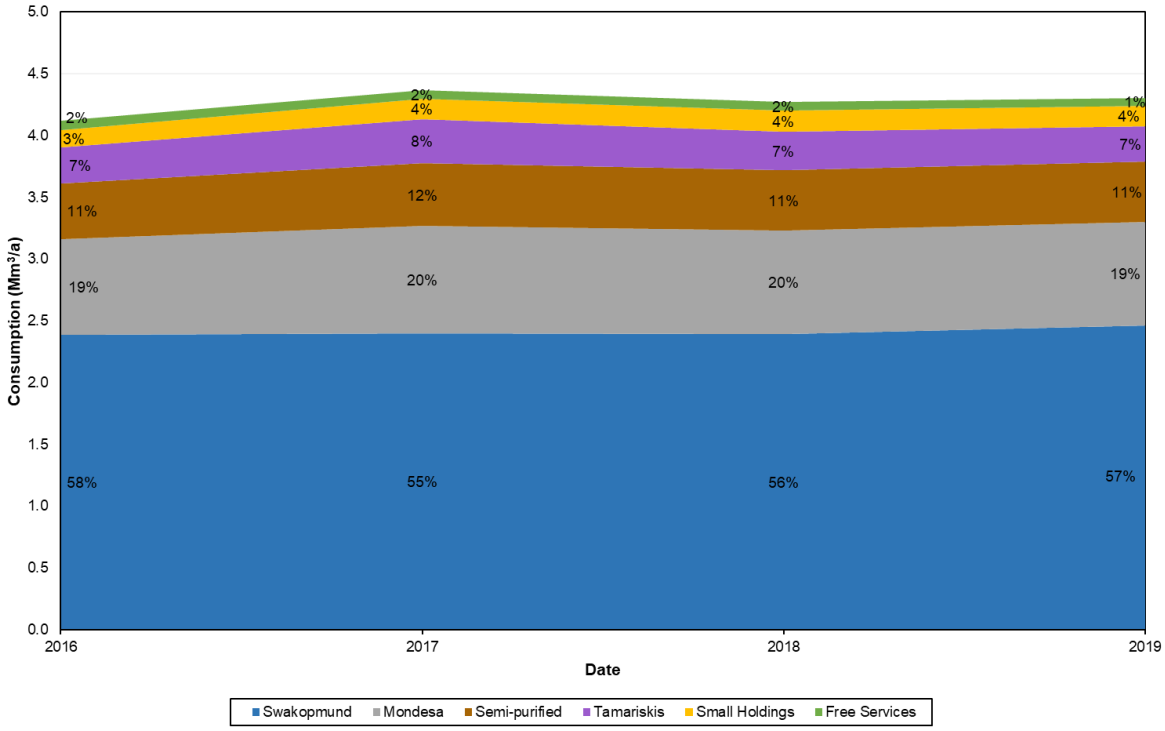

Figure 5.26: Swakopmund Municipal Sales Disaggregation

Figure 5.26 indicates the municipal consumption profile for FY 2016-2019. The bulk of supply (55-58%) is for the "Swakopmund" area, while 20% is to Mondesa, 8% to Tamariskis and 4% to small holdings. Included in the information was the semi-purified supply at 11% and "free services", the representation of which is unknown to the Consultant and could not be confirmed at the time of writing, at 2%. Potable supply represents 89% of total consumption and semi purified (reuse) 11%.

Losses for potable water supply were estimated to vary between 9-16% for the period 2016-2018 when compared to the NamWater sales for the same period[33]. The inclusion of the "Free Services" category into the losses results in an estimate of 12-18% for NRW for the period 2016-2018. This is of a similar magnitude to NRW in Walvis Bay and the 15% NRW recommended by the *Rapid Assessment of Desalination Options* (BCT and DME, 2016), whilst being well below the world average of 36.6% in 2012 (per McKenzie et al. 2012).

Figure 5.27 illustrates the previous projections from the Central Namib Area Master Plan (NamWater, 2009). As indicated, all 2009 Master Plan projections were generally exceeded, almost immediately after the projections were made. Only by 2017 and 2018, did the actual sales seem to correspond with the high scenario projections.

[33] Estimation of the losses and non-revenue water proved challenging, as the Swakopmund Municipality provided a variety of data regarding consumption, often with little correlation between the sets. Requests for clarification from the Swakopmund Municipality could not be obtained during the time of writing.

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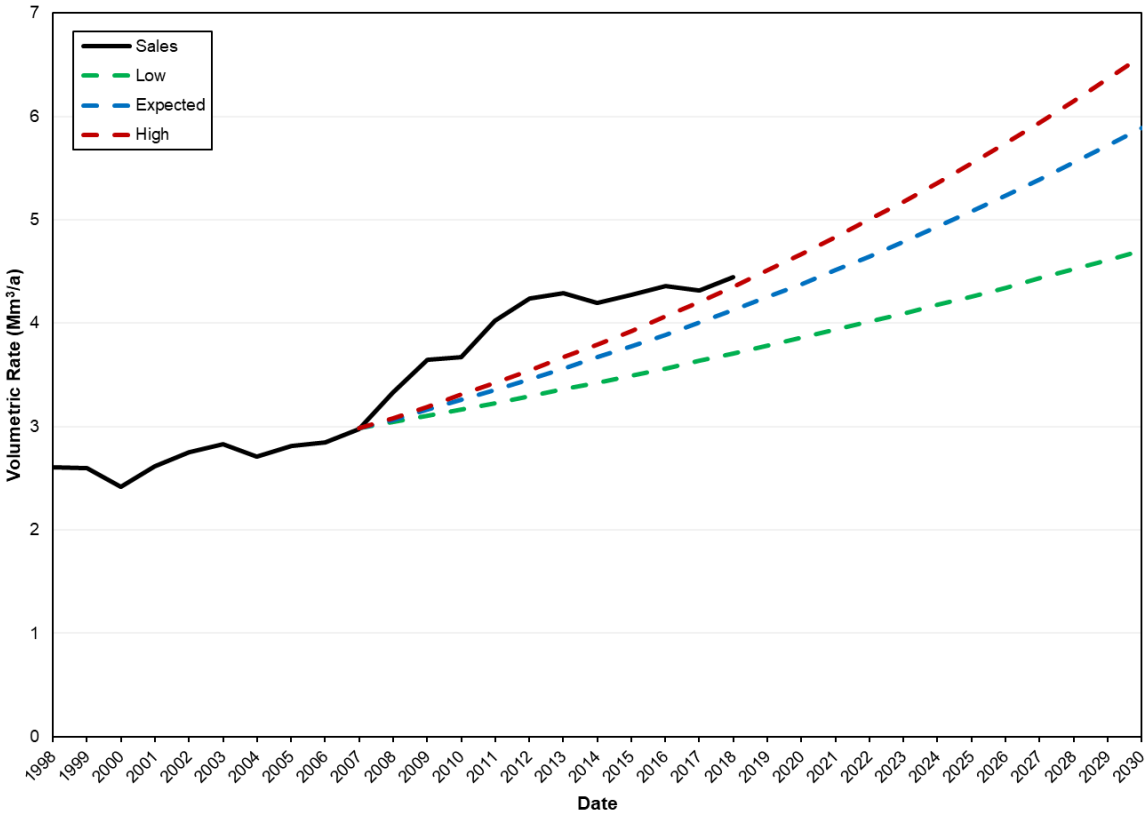

Figure 5.27: Swakopmund: NamWater Sales and Previous Demand Projections

5.5.1.3 Arandis Town Council

Consumption at Arandis Town could only be determined from NamWater's sales information, which represents approximately 1.5% of the total CCA consumption for FY 2018. Efforts to obtain sales information of the town itself were unsuccessful. **Figure 5.28** indicates NamWater sales to the Arandis Town Council. The information shown includes projections from the 2009 Central Namib Area Master Plan (NamWater, 2009).

Arandis Town Council represents the only major town in the CCA that has reflected negative growth in water use / demand. Consumption decreased from 0.51 Mm^3/a in FY 1998 to only 0.34 Mm^3/a in FY 2018 (overall 33% decrease), despite the town population increasing by 31% between 2001 and 2011. The decrease in water use can be attributed to water efficiency interventions, including a project to identify and reduce NRW, as well as the installation of night-time pressure reduction, and possible economic fluctuations as a result of being a mining town and thus largely dependent on the sector's performance. The 2009 water demand projections had, with some reasonable and conservative expectation, assumed growing demands.

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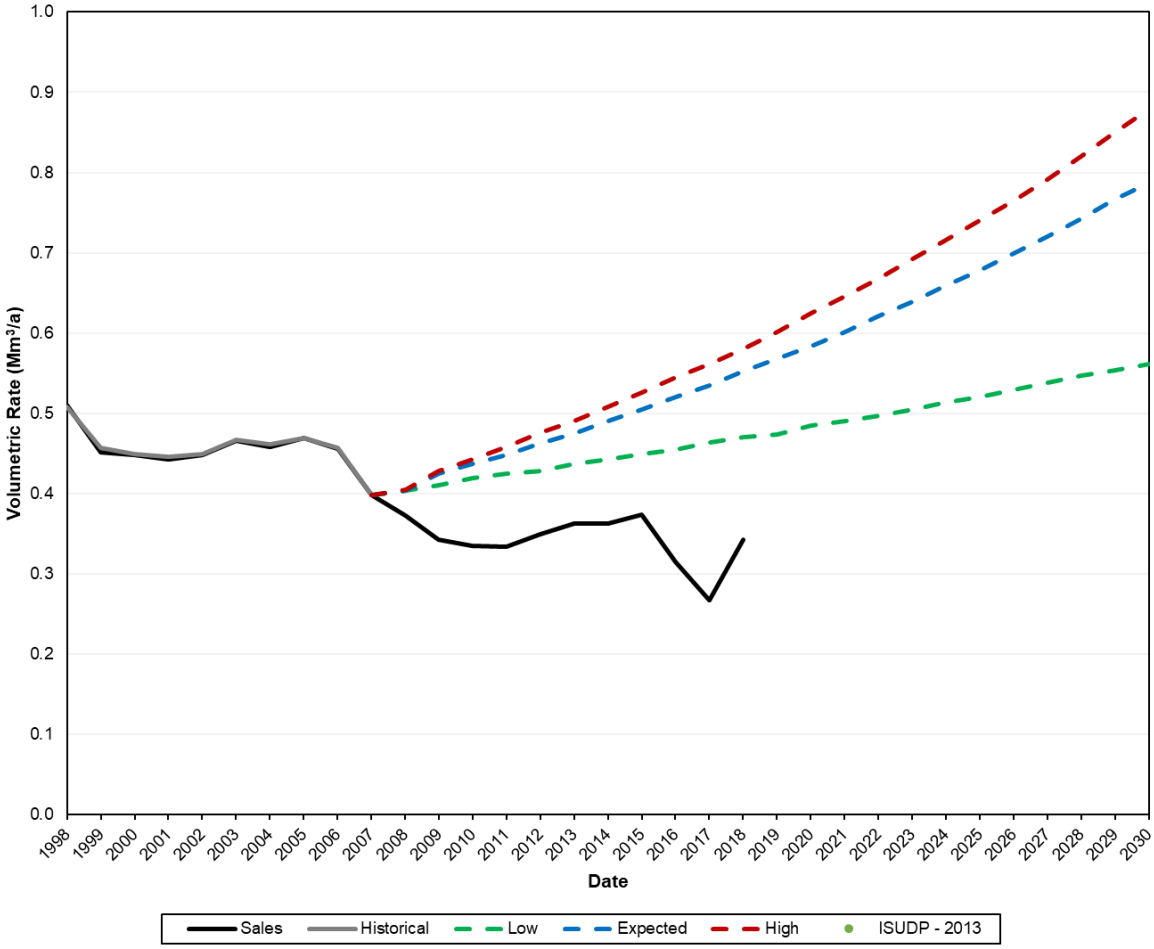

Figure 5.28: Arandis: NamWater Sales and Previous Demand Projections

Planned developments in the area were discussed with Town Council, including plans to expand semi-purified irrigation and develop additional residential and industrial areas. These were only discussed on a conceptual basis and explicit documentation of such could not be obtained for this Study.

5.5.1.4 Henties Bay Municipality

Water consumption in Henties Bay represents 2.8% of the CCA's consumption s per FY 2018. The Henties Bay Municipality provided information on the quantities purchased from NamWater and those sold and the losses or non-revenue water (NRW) for the period July 2013 to June 2017. An annual summary based on municipal financial years is provided in **Table 5.5**. Losses are generally high, in order of 31% on average.

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Month to month comparisons of the municipal sales against purchases from NamWater revealed some inconsistencies where municipal sales sometimes exceeded NamWater purchases[34]. The differences between purchases and sales also varied from month to month, between 10% and 50%. Finally, the NamWater purchases per the Henties Bay municipal consumption sometimes also differed from values derived from NamWater's own sales database. The quality and accuracy of the information is therefore questionable.

Table 5.5: Henties Bay Municipality: Water Purchased, Sold and Losses

Date	Purchased	Sold	Loss / NRW	
	Mm^3/a	**Mm^3/a**	**Mm^3/a**	**%**
2013	515,455	367,626	147,829	29%
2014	497,429	352,504	144,925	29%
2015	546,758	363,231	183,527	34%
2016	536,865	387,652	149,213	28%
2017	577,320	373,612	203,708	35%
			Average	**31%**

Figure 5.29 indicates bulk water sales to the Henties Bay Municipality. The information includes projections from the 1998 Report into the Extension of Henties Bay, the 2009 Central Namib Area Master Plan (NamWater, 2009) and also the Integrated Spatial Urban Development Plan (**ISUDP**) of 2015 (UD, 2015).

Water demands in Henties Bay have essentially undergone three major phases: rapid growth from 1986 to approximately 1996, near "flatlining" from 1997 to 2008 and a second rapid growth phase from 2009 onwards. The population in the town has grown by 44% between 2001 and 2011. All previous attempts at water demand projections have proven to be completely inaccurate, with recent water demands being upper-bound by the low scenario of the 1998 report and lower-bound by the scenarios of the 2009 NamWater Master Plan. The 2015 ISUDP estimation of a water demand of 1.4 Mm^3/a by 2033 does however seem excessive.

[34]Typical inconsistencies occurred for the holiday seasons, where the NamWater sales recorded high consumption for January sales, whilst the municipal sales would only reflect this in February. However, inconsistencies during other months were also noted.

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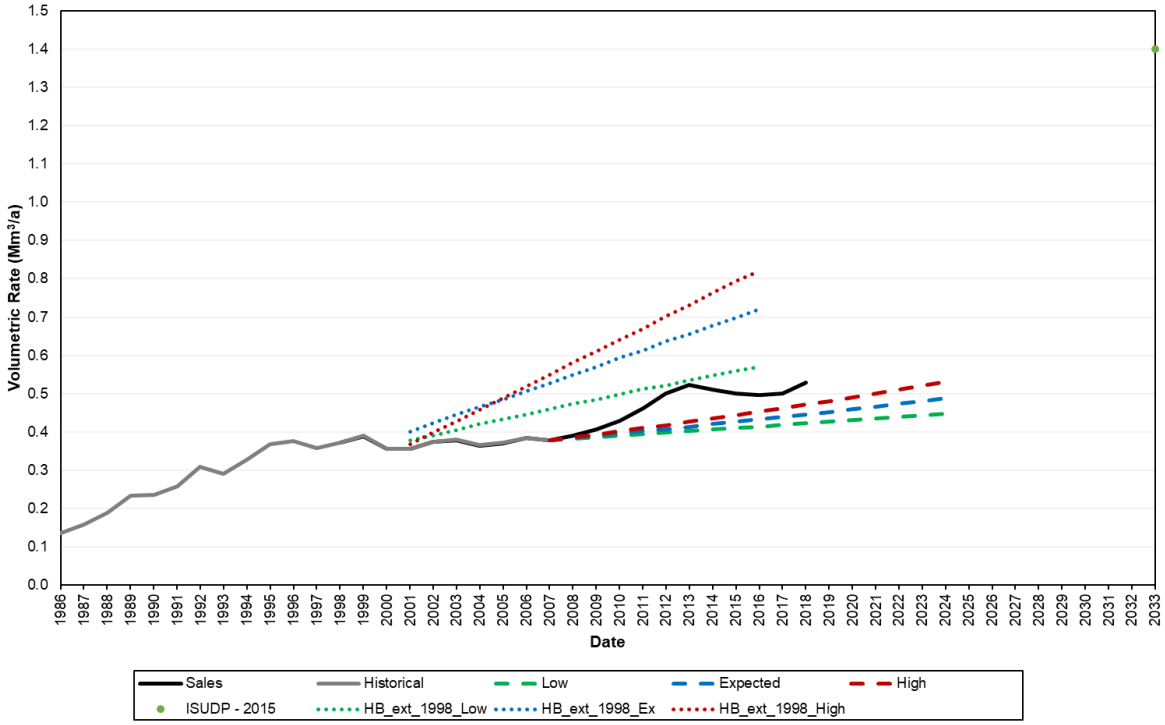

Figure 5.29: Henties Bay: NamWater Sales and Previous Demand Projections

5.5.1.5 Smaller Domestic and Other Users

Smaller consumers, that is, those excluding the four major urban centres in the CCA and the large uranium mining operations, represent only 0.891 Mm^3/a or 3.8% of water consumption in the CCA for FY 2018. Per NamWater's cost centre codes, these include smaller customers supplied from the Rooibank / Mile 7 Reservoir, the Swakopmund Terminal Reservoir, and those along the Swakopmund – Rössing, Swartbank – Schwarzekuppe and Omdel – Swakopmund pipelines.

provides a summary of the number of consumers, consumption and key consumers within these supply schemes.

Table 5.6 provides a summary of the number of consumers, consumption and key consumers within these supply schemes.

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Table 5.6: Summary of Small Domestic Consumers in the CCA

Area[1]	Number of Consumers	Consumption FY 2018 (Mm^3/a)	Key Consumers
Rooibank / Mile 7	21	0.110	Namport (supply to Walvis Bay), various industrial and private consumers
Swartbank - Schwarzekuppe	38	0.277	Rooikop Base, Walvis Bay Airport, Marble Mines, Topnaars
Swakopmund Terminal Reservoir	12	0.011	Construction and industrial users
Swakopmund - Rössing	19	0.375	Domestic developments and small users, construction and industrial users
Omdel - Swakopmund	14	0.118	Construction and industrial users
Total	**104**	**0.891**	

Note:
1. Referenced areas exclude major urban consumers and mines.

Consumption for all schemes or cost centre codes, except the Swakopmund – Rössing supply scheme have remained relatively stable for about 18 years, varying between 0.4 to 0.6 Mm^3/a. The consumption of the smaller users along the Swakopmund – Rössing supply scheme has grown considerably since 1998, from 0.076 Mm^3/a to 0.375 Mm^3/a in 2018 at an annual growth rate of 8.3% per annum. This has mainly occurred from housing developments and plots along the Swakop River that fall under the Swakopmund Municipality, including the Rössmund golf estate and Nonidas development, among others.

Figure 5.30 indicates the historical consumption for the various smaller users along each of the schemes. The extreme peaks under the Swartbank – Schwarzekuppe scheme for the years 1998 and 1999 arose from a single account billed to the Municipality of Walvis Bay with the supply point called “Quarry Schwarzekuppe”, which has since June 1998 recorded no consumption.

Demand projections prepared under NamWater’s 2009 CNA Master Plan assumed much lower growth for all demand scenarios than the historical record, as indicated in **Figure 5.31**. It can be assumed that the aggressive housing developments along the Swakopmund – Rössing pipeline were underestimated or not anticipated at the time.

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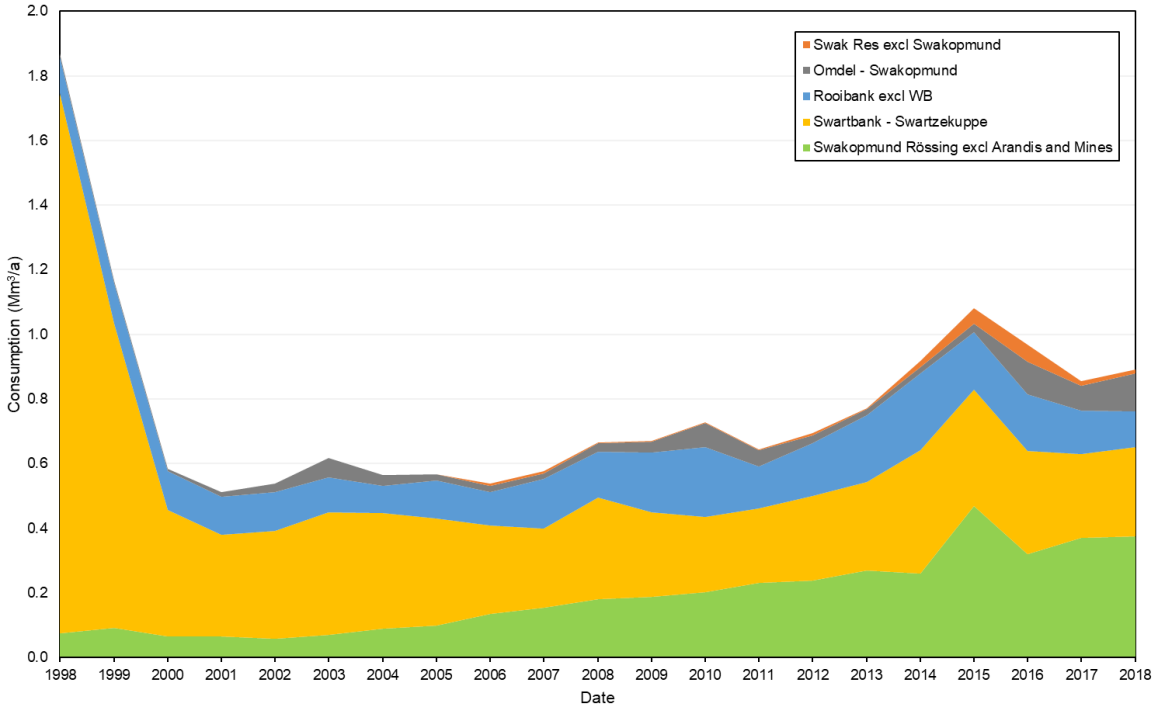

Figure 5.30: Small Domestic Consumers in the CCA: Historical Consumption

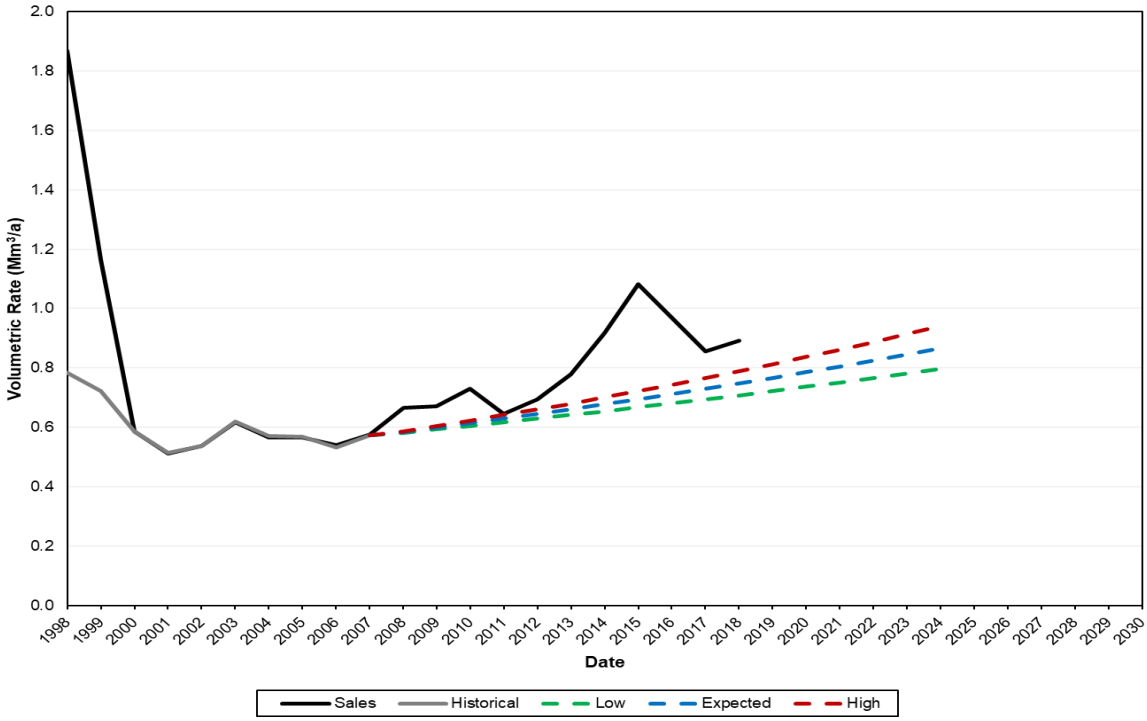

Figure 5.31: Small Domestic Consumers: NamWater Sales and Previous Demand Projections

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5.5.2 Mining Users

For FY 2018, there were three large active uranium mines within the CCA, namely the Rössing Uranium, Langer Heinrich Uranium and Husab Mines, which dominated mining supply in the area. The Trekkopje Mine supplied from the Areva / Orano desalination plant consumed significant quantities of water during its start in 2011 and 2012, with water use peaking in its first year at 1.242 Mm^3/a. However, due to the unfavourable uranium price, the mine has been placed in care and maintenance. Figure 5.32 indicates the historical consumption of these 4 mines.

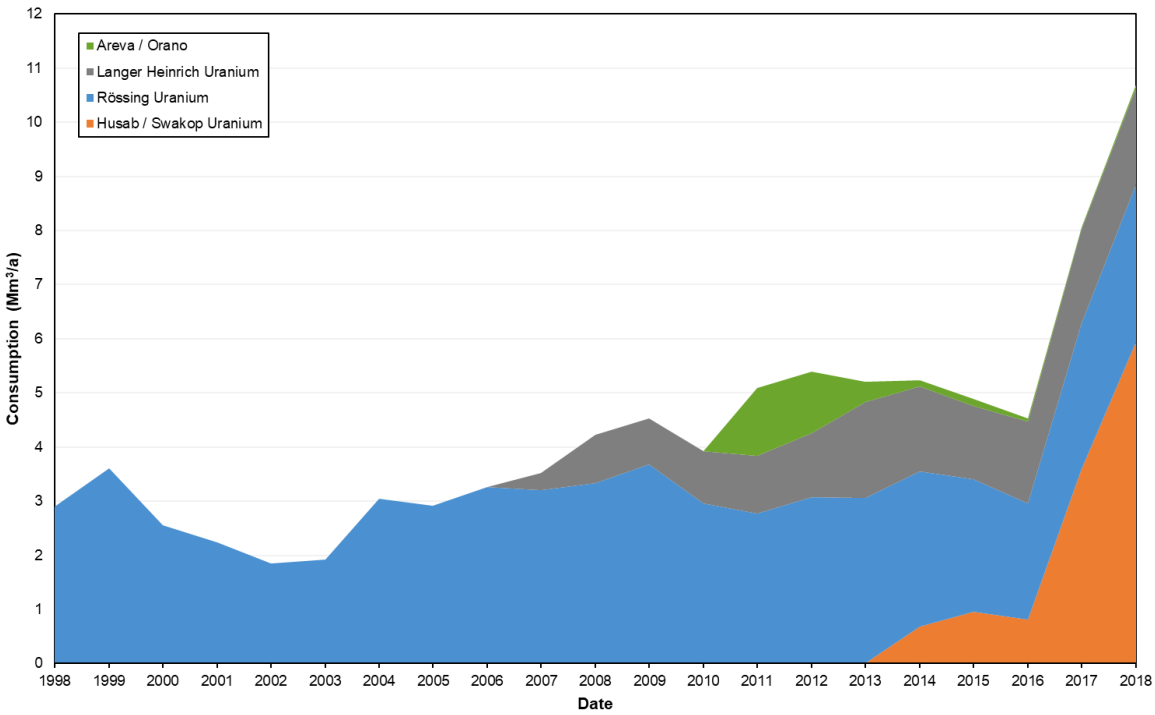

Figure 5.32: Mining Consumption: Historical Consumption

The Husab Mine (Swakop Uranium) has within its 5 years of operations grown considerably to record its current peak demand of 5.9 Mm^3/a in 2018. Consultations with representatives of the mine indicate that growth will continue, up to peak output where demand is estimated at 10.2 Mm^3/a.

The Rössing Mine's consumption has varied greatly during the 20 year period analysed, peaking in 1999 and 2009 at over 3.5 Mm^3/a, but also dropping to values around the 2 Mm^3/a range (and even below it). Mining output, corresponding with water consumption, has been heavily dependent on the Uranium price, which has declined since 2009. Current mining activities are largely dependent on the change of ownership of the mine from Rio Tinto to China National Uranium Corporation Limited and development plans could not be established due to this change in ownership, which was underway during the period of this Study.

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Finally, the Langer Heinrich Mine went into operation in December 2006 and water use at the mine rose steadily, peaking at 1.79 Mm^3/a in 2018. However, since August 2018, consumption dropped, with the mine going into a care and maintenance phase. Future operations are currently under investigation in a feasibility study being undertaken by Paladin Energy, the majority shareholder in the Mine (Duddy, 2019).

With the introduction of operations from the Husab mine, mining demand has reached an historic high since 1998, at 10.6 Mm^3/a in FY 2018, with water demand expected to increase further in the future, at least as a result of growth at Husab Mine.

NamWater's 2009 CNA BWMP was drafted during an extremely optimistic uranium market and it was expected that by 2012, the water demands of uranium mines would reach 28 Mm^3/a, which is a far cry from the actual 4.3 Mm^3/a consumed by the existing mines. Furthermore, this projection excluded Trekkopje's demands which were based on the Areva / Orano desalination plant's design capacity of 20 Mm^3/a, resulting in a total projected peak mining demand of close to 50 Mm^3/a.

The overall uranium price (US$/lb U_3O_8) compared to overall mining water demand is illustrated in **Figure 5.33**. Rössing Uranium's water consumption, included here because of its longer period of activity in the region, corresponds relatively well with the uranium price in terms of general decreasing and increasing trends. However, the total mining consumption, dominated by Husab Mine in recent years, seems to grow irrespective of the uranium price.

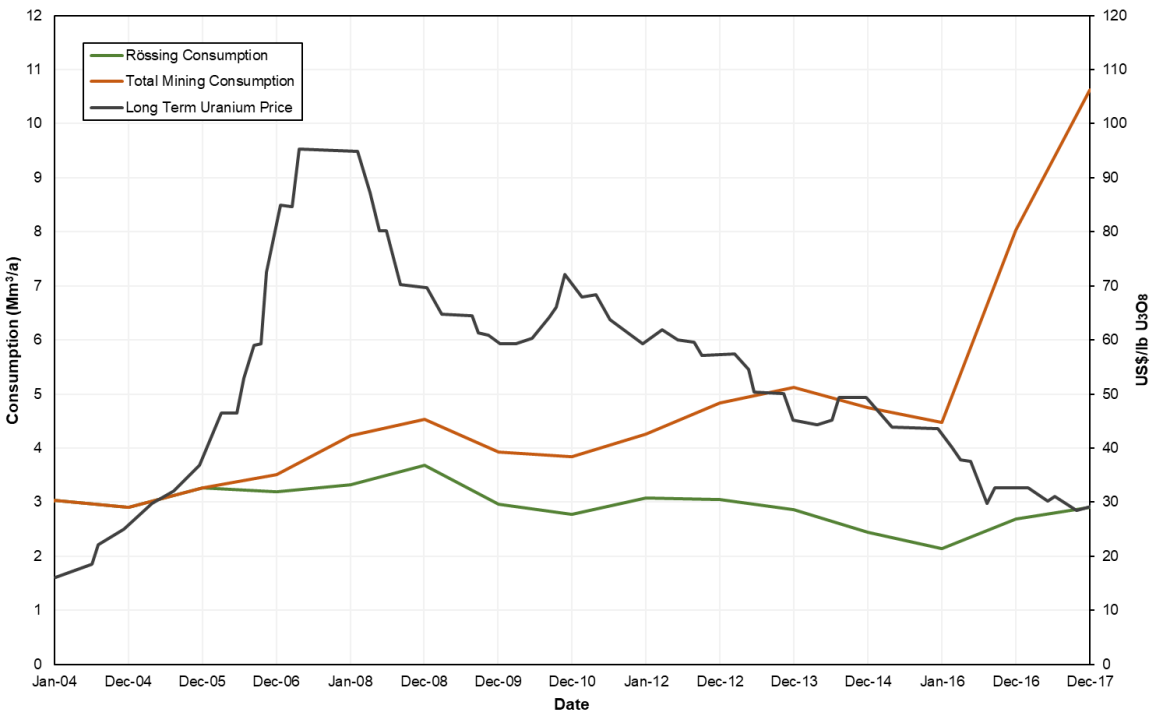

Figure 5.33: Mining Consumption and the Uranium Price

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This would seem to indicate that "vertically integrated" operations by Husab Mine and those of China National Uranium Corporation Limited (the new owners of Rössing Uranium), where uranium is mined for use in nuclear power plants in China, is not subject to the same dynamics as operations were uranium was mined for sale on the world market, as was done by Rio Tinto (Rössing Uranium), Areva (Trekkopje Mine) and Paladin (Langer Heinrich Mine).

Overall, previous water demand projections for the uranium mines, mostly drafted during a period of optimism in the sector, and before the Fukushima disaster in 2011, have proven to be overly optimistic, specifically those of the CNA BWMP of 2009 (NamWater, 2009) and the Fichtner assessment of 2011. The water demand projection which most closely approximates the actual water demand of existing mines is that for "existing mines" from NamWater's CNA BWMP. However, that projection was made only for the Langer Heinrich (since closed) and Rössing Uranium Mines and did not anticipate the Husab Mine.

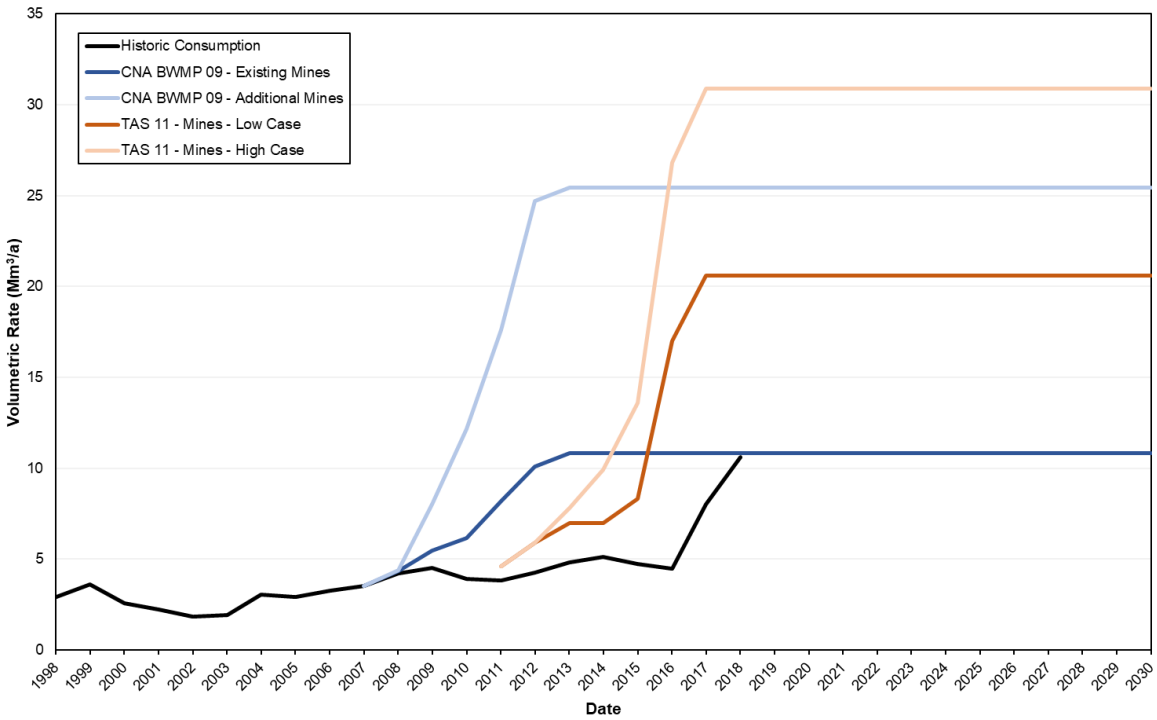

Figure 5.34: Previous Mining Demand Projections

Notes:

1. CNA BWMP = Water Supply Infrastructure Development and Capital Replacement Master Water Plan for the Central Namib Area (NamWater, 2009).
2. TAS = Transaction Advisory Services with Regard to the Technical, Legal, and Financial Advisory for the Procurement of a Desalination Plant and Related Infrastructure in the Erongo Region, Namibia, Southern Africa: Final Concept Report (Fichtner, 2011).

These observations illustrate how difficult it has proven to be to prepare water demand projections for the uranium mining sector; which is expected to be the case in the future as well.

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The Trekkopje Mine is not supplied by NamWater, but directly from the Erongo Desalination Plant. Whilst the desalination plant was primarily constructed to supply the Trekkopje Mine, with potentially up to 20 Mm^3/a, the decline in the uranium price has kept the mine in care and maintenance for the last six years.

5.6 Benchmarking of Water Use Efficiency

Water use efficiency in the major urban centres of the CCA was evaluated based on non-revenue water figures, night flows and per capita consumption per centre, depending on the information available.

5.6.1 Benchmarking of Non-Revenue Water

Key to any successful determination of NRW is the availability of data concerning water provision to and sales from a local authority. Only the Walvis Bay and Henties Bay Municipalities could provide information on non-revenue water, which averaged of 14. 5% for the period 2015 – 2017 for Walvis Bay (refer to **Table 5.3**) and 31% for the period 2013-2017 for Henties Bay (refer to **Table 5.5**). Attempts to establish NRW figures in the Swakopmund Municipality were less successful due to uncertainty regarding the interpretation of municipal sales compared with sales from NamWater. NRW was broadly estimated to be 12-18% for the period 2016-2018.

These values for NRW in Walvis Bay and Swakopmund (estimated only) are of a similar magnitude to the 15% NRW recommended by the *Rapid Assessment of Desalination Options* (BCT and DME, 2016), whilst being well below the world average of 36.6% and the average of 36.8% for South African municipalities, both in 2012 (per McKenzie et al., 2012).

NRW in Henties Bay is generally high at about 30%, but as mentioned in **Section 5.5.1.4**, the quality and accuracy of this information is questioned. Sales information to enable estimates for NRW could not be obtained for Arandis Town Council. A general NRW of 15% was assumed for the major urban areas in the CCA in line with the recommendation of the *Rapid Assessment of Desalination Options* (BCT and DME, 2016).

5.6.2 Night Flows

NamWater provided average hourly outflows from their various supply reservoirs for the four major urban centres. This information is less useful for successful night flow analyses in Walvis Bay and Swakopmund, as the operation of municipal supply reservoirs downstream of the NamWater supply reservoirs in each town distorts the actual night flows (transfers to municipal reservoirs occurs in both towns, whereas there are no municipal reservoirs in Henties Bay and Arandis, with the NamWater reservoirs in each town being the only water storage available).

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Water use in Walvis Bay is also more “industrial” in nature, whereas use is more “domestic” in nature in the other towns, due to the operations of the fish factors, NamPort and other industries, which also hinders the analysis of night flows.

Table 5.7 summarises the night flow analysis for Arandis and Henties Bay, based on the methodology described in **Section 4.4.5.7**.

Table 5.7: Night Flows and Unaccounted for Water in Arandis and Henties Bay

Item	Unit	Arandis	Henties Bay
Average daily flow rate	m^3/h	39.22	69.52
Minimum night flow (MNF)	m^3/h	25.00	31.00
Time of MNF	hours	03:00	03:00
Estimated normal night use	m^3/h	4.23	4.44
Unaccounted for leakage	m^3/h	20.77	26.56
Unaccounted for leakage	**% of daily flow**	**53%**	**38%**
Daily unaccounted leakage	m^3/day	478	611
Annual unaccounted leakage	m^3/a	174 466	223 143
Equivalent i.t.o. average monthly sales	Months	6.2	4.7

Figure 5.35 illustrates the diurnal daily flow rates (normalised around the average hourly rate) of Arandis and Henties Bay as well as their respective estimated normal night use values. The difference between the minimum daily and normal night use flows is the unaccounted-for leakage value.

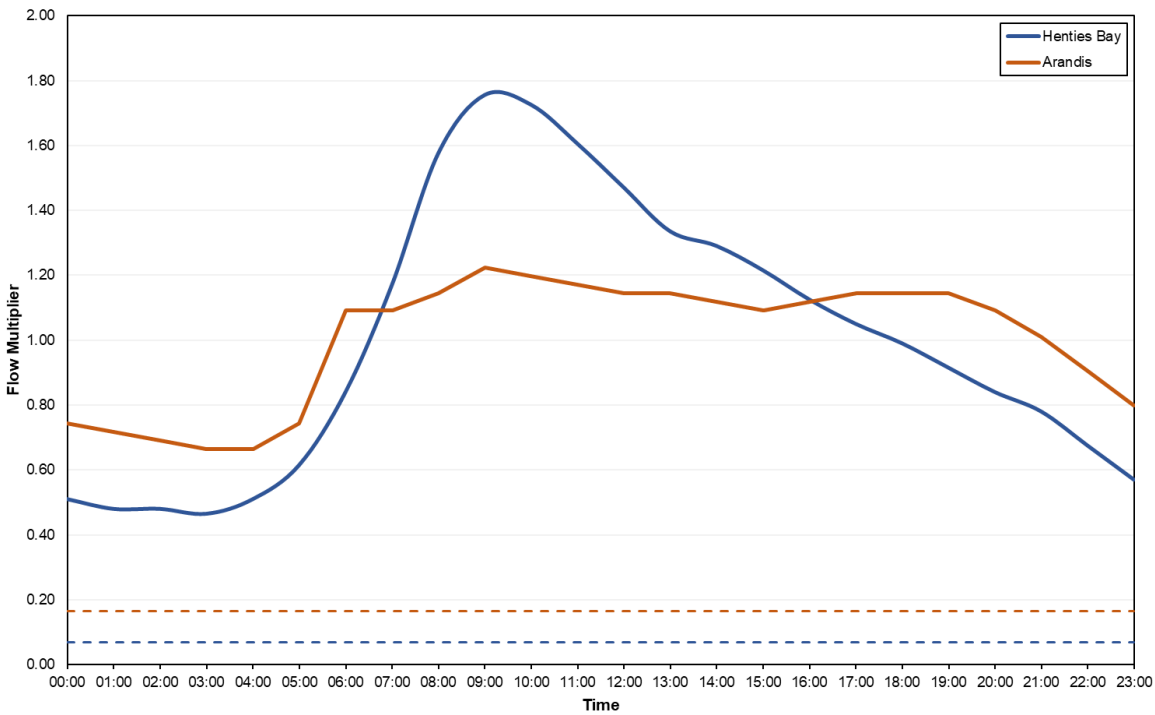

Figure 5.35: Average Daily Flows in Arandis and Henties Bay

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Unaccounted for leakage in Arandis is more than half of the average daily flow, whilst in Henties Bay, it is nearly 40% of the daily flow. This essentially means that in Arandis, more than six months of consumption per year may be as a result of unaccounted for leaks. Similarly, in Henties Bay, nearly 5 months of consumption may be lost due to leaks.

The night flow analysis indicates the urgent need for improvement in water use efficiency at both the towns analysed. The extent to which these towns could successfully reduce these leaks will greatly depend on either the willingness of these local authorities to address the matter or drastic changes in tariffs which will force the authorities to improve on their efficiencies.

5.6.3 Benchmarking of Per Capita Water Consumption

Per capita consumption was based on the data from the Namibian censuses and NamWater's sales data and is illustrated in **Figure 5.36**.

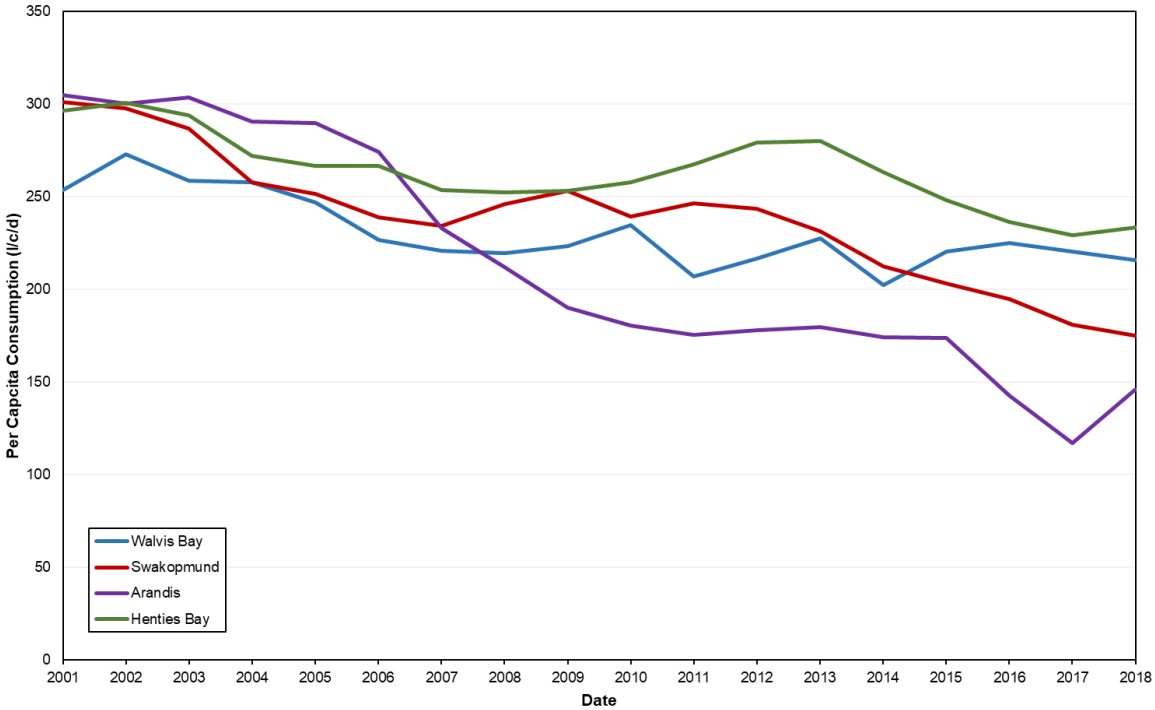

Figure 5.36: Per Capita Consumption in the Major Urban Centres of the CCA

Of primary consideration is that per capita consumption in all major urban centres in the CCA has consistently decreased, though to varying degrees. Although the lowest consumer on a per capita basis in 2001, Walvis Bay at 254 ℓ/c/d, has shown the smallest decrease in per capita consumption rates, to 216 ℓ/c/d 2018. The remaining three urban centres had per capita consumption rates of 300 ℓ/c/d in 2001, but by 2018, Henties Bay had the highest rate of all the centres at 234 ℓ/c/d, Swakopmund a rate of 175 ℓ/c/d and Arandis with the lowest per capita consumption rate of 146 ℓ/c/d.

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The general drop in per capita consumption, especially in Henties Bay, Walvis Bay and Swakopmund, can likely be attributed to growing informal settlements which represent a high per capita increase in population, but very low individual rates of water consumption, thereby resulting in overall decreases in per capita consumption rates. Low metering rates and collection efficiencies in informal settlements may also contribute to the trends observed. Increased water use efficiency is also likely to result in lower per capita consumption. However, the relative influence of these various factors could not be ascertained with the information available for this Study.

Arandis has been exposed to campaigns to improve water use efficiency, which is evident in the decline of NamWater sales volumes to the town, which is the only major demand node in the CCA that has shown a decrease in water demand / use between 1998 and 2018. The decrease in sales volumes and increasing population and relatively low industrial and business development resulted in lower per capita consumption rates for this town compared with the others in the CCA.

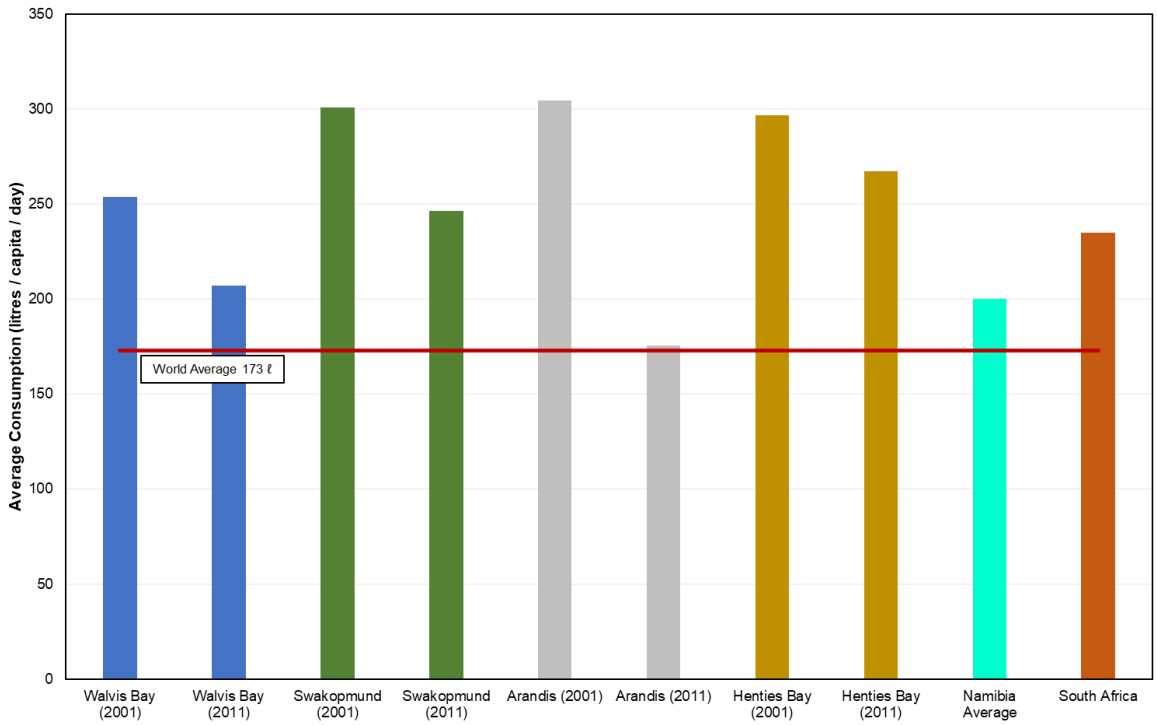

Figure 5.37: Benchmarking of Per Capita Water Consumption in the CCA Towns

Notes:
1. Namibia average of 200 ℓ/c/d per NamWater (2017a).
2. Average of 235 ℓ/c/d for South Africa per McKenzie et al. (2012).
3. World average of 173 ℓ/c/d for South Africa per McKenzie et al. (2012).

Of concern is that per capita consumption rates in all the urban centres of the CCA are above the world average of 173 ℓ/c/d (per McKenzie et al., 2012). For an area with such water scarcity, per capita consumption rates should be considerably lower than the word average and there is therefore much room for improvement in water use efficiency.

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5.6.4 Summary of Water Use Efficiency in the Major Urban Centres of the CCA

Only Walvis Bay provided estimates of NRW, which is estimated at 14.5%. Night flow analyses could only be determined for Arandis and Henties Bay and these show very high unaccounted leakage rates; 53% and 38% of the daily flows respectively. Per capita consumption has dropped for all urban centres, especially for Arandis. The apparent paradox between greater efficiency on a per capita consumption basis compared with the high night flows observed for Henties Bay and Arandis makes both current and future expectations of water use efficiency very challenging for the urban centres in the CCA. Further investigations and full non-revenue water and leakage benchmarking exercises are thus recommended for the four local authorities in the CCA.

Given the lack of data and thus the lack of a proper assessment of NRW for the CCA towns, it was assumed that NRW in all towns would be at least equivalent to that of Walvis Bay at 14%.

5.6.5 Mining Water Use

5.6.5.1 General Comments

All the mines contacted under this Study have indicated that they are improving on water use efficiency, especially in the light of increasing costs of water. Pending market and supply-demand requirements, water use efficiency will tend towards increased output per unit volume of water used, rather than a reduction in water consumption.

5.6.5.2 Water Use by Rössing Uranium Mine

Rössing Uranium provided data on their fresh water use and water use efficiency, as measured on a per tonne of ore milled basis. Water use in 2017 and 2018 slightly exceeded their target of 0.30 cubic metres of water per tonne of ore milled (Rio Tinto, 2018).

Rössing Uranium states that since 1980, they have been recycling 60 to 70% of their water (Rio Tinto, 2017). A generally declining trend in the ratio of fresh water to total water use over the period 2014 (0.35) to 2018 (0.33), with a low in 2016 (0.29), indicates continued efforts towards water use efficiency.

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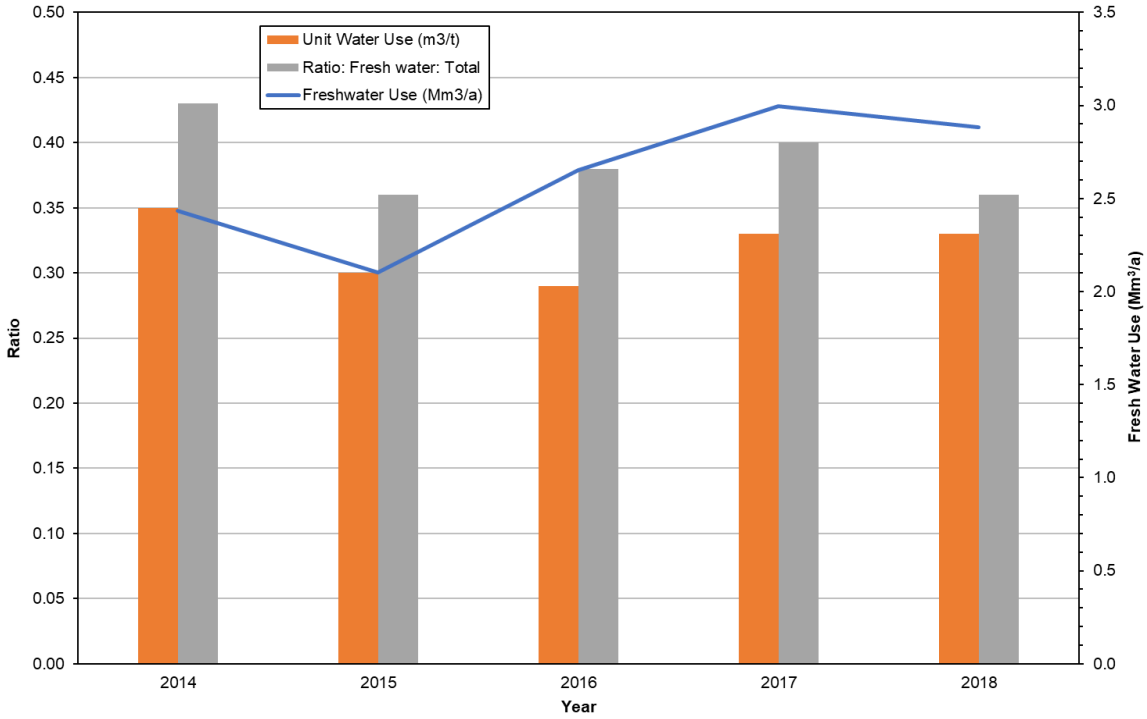
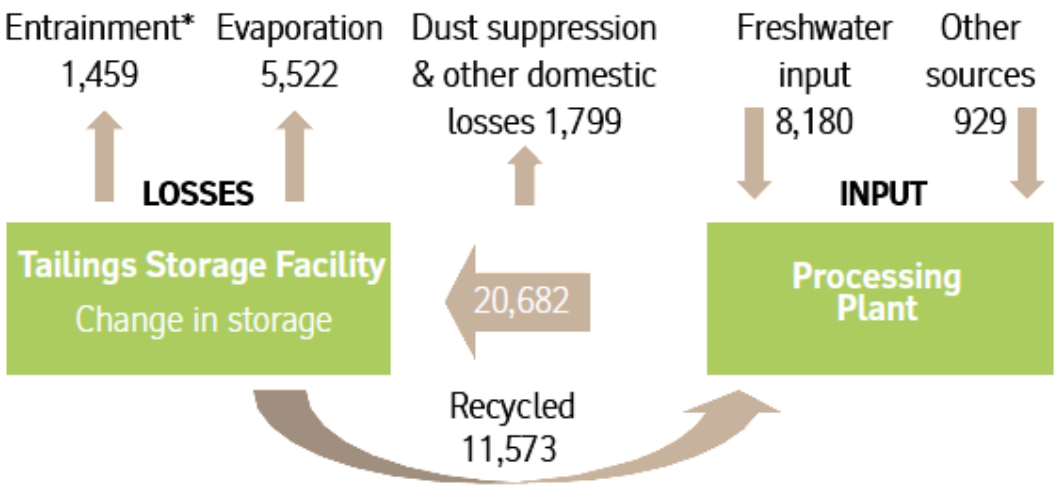


Figure 5.38: Water Use by Rössing Uranium Mine

Notes:
1. Data provided by Rössing Uranium Mine.
2. Unit Water Use is the fresh water use per tonne of ore milled (m^3/t). Rössing Uranium targets a value of 0.3 m^3/t (Rio Tinto, 2018).



* Water entrainment is the permanent loss of water to the pore spaces of the tailings material and is not recoverable anymore.

Figure 5.39: Water Balance for Rössing Uranium (m^3/d) (Rio Tinto, 2018)

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5.7 Water Demand Projections

5.7.1 Development Proposals

5.7.1.1 Major Urban Centres

5.7.1.1.1 Walvis Bay

The Walvis Bay Municipality made available their Integrated Urban Spatial Development Framework for Walvis Bay (**IUSDF**) which sets out their proposals for development between 2014 and 2030 and in broad terms for the period after 2030. Key proposals include the following (UD, 2013):

- Between 2014 and 2030: Residential developments: A total of 90 townships and 44 200 households are to be developed. The IUSDF states that commercial, open space, recreational, community and services developments and infrastructure will follow from these residential targets;
- Beyond 2030: Eight portions of land ranging in size from 100 ha to 5 400 ha and totalling 7 500 ha, are to be designated as “strategic land reserves” for future developments. Approximately 5 000 ha of this area is to be “built up”. The IUSDF states that these strategic land reserves are capable of accommodating additional growth of at least 150%, which should be sufficient up to 2060, it growth continues at the current rate of 4.7% per annum.

5.7.1.1.2 Swakopmund

The Swakopmund Municipality was not able to make available any formal development plan, as they have just recently embarked on the process of compiling an updated “structural plan” which is to cover the period 2020 to 2040. However, they did indicate their intention to develop 1 500 housing units similar to the Mass Housing initiative, in blocks of 120 to 200 erven each. Development is envisaged to take place on the northern side of the town in the next 2 – 3 years (mixed residential) and to the east (residential), with commercial developments to be located toward the south. Light industrial development is to take place near the airport, whilst there are proposals for an industrial hub, possibly including noxious industries, to develop opposite Rössmund, possibly including a cement factory and the Gecko industrial development. The latter development anticipates very extensive developments around Swakopmund, including a port, sulphuric acid plan, a phosphate processing facility, gas fired power station and desalination plant in the first phase and in the second, a phosphoric acid plant and granular fertilizer plant (Gecko Namibia, 2019).

5.7.1.1.3 Henties Bay

The Henties Bay Municipality made available their Integrated Urban Spatial Development Framework for the town which sets out their proposals for development up to 2033. Strategic guidelines are provided in the IUSDF for beyond 2033.

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West of Main Road MR44, extensions to the east and north east will be mostly residential, whilst those to the east of MR44 will be industrial and small holdings (UD, 2015). Key proposals include the following (UD, 2015):

- Residential developments: planning, surveying and servicing of 9 townships, 1 473 erven, to create 2 010 housing opportunities to accommodate approximately 6 300 people;
- Commercial and industrial development:
  - Servicing 22 ha of the 70 ha reserved for an industrial area for the east of town;
  - Allowing the rezoning of erven to allow the extension of low impact business opportunities from the current CBD area;
  - Extending the CBD on a vacant portion of land between the Henties Bay and Omdel townships;
  - Supporting the Henties Bay Waterfront Development Proposal;
  - Allowing the rezoning of residential erven within identified policy areas for the development of accommodation (tourism) establishments;
- Open space and recreational developments;
- Public and civic facilities: Proposals include the development of a fire station and emergency services, a secondary school, primary school and crèche, community centre, small clinic and satellite police station, the upgrading of the existing clinic to a Health Centre, among others;
- Proposals for the development of 30 smallholdings plots for urban agriculture (some 3 ha are currently in use).

These plans notwithstanding, the Henties Bay Municipality have noted that in the current (2019) weak economic climate, many people are selling their second or holiday homes, which will impact on the life and livelihood of the town. Nearly half (46%) of residents in Henties Bay were classified as housewives, students/pupils or pensioners (UD, 2015), which impacts on the economy of the town.

5.7.1.1.4 Arandis

The Arandis Town Council could not provide any master plan for future development, but reported industrial expansion in the southeast of the town, and additional residential development. Semi-purified water may in future be used for small scale irrigation, but no firm commitment could be provided.

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5.7.1.2 Mining Water Demand

Development prospects in the uranium mining industry have been greatly impacted by the events of the Fukushima disaster in Japan in 2011, resulting in a large dip in the uranium price. Prior to this event, the CCA received an enormous amount of applications for new mines with an expected total water demand of 30 Mm^3/a. Since the Fukushima disaster, the general development prospects have greatly diminished, with only two mines active at the time of writing, namely the Rössing Uranium and Husab Mines. Both of these mines are at currently Chinese owned, and the Husab Mine has generally bucked the trend regarding the uranium outlook, being the largest mining water consumer and may soon become the largest single water consumer in the CCA.

All of the uranium mines contacted expressed frustration at production days lost due to water supply interruptions as a result of sulphur outbreaks at the Erongo Desalination Plant. Both the Husab and Rössing Uranium Mines expressed interest in developing their own water supply via desalination due to these losses in production. All mines contacted also indicated that water use efficiency would increase but would be unlikely to lead to lower water use, but rather an increase in product output.

5.7.1.2.1 Rössing Uranium (Previously Rio Tinto, now China National Uranium Corporation Limited)

The Rössing Uranium Mine is at the time of writing undergoing a change of ownership from Rio Tinto to China National Uranium Corporation Limited (CNUC). This in the least indicates continued production prospects at the mine for the foreseeable future. Correspondence with Rössing Uranium was conducted during uncertainties regarding this change of ownership of the mine and thus expectations regarding future operations and water demands could not be provided by the Mine.

In the 2009 CNA BWMP, mining water consumption was expected to peak at 8 Mm^3/a by 2013, lasting up until 2030. Whilst this was not achieved, this remains the theoretical upper limit of water demand by the mine. From discussions with NamWater, it was indicated that the 8 Mm^3/a is not expected to be achieved and 5 Mm^3/a was suggested as a more realistic water demand for the mine.

5.7.1.2.2 Husab Mine (Swakop Uranium)

Correspondence with representatives of the Husab Mine indicated that water demand / consumption would increase from the current 6.0 Mm^3/a to 10.2 Mm^3/a by 2021 as operations are geared upwards towards full capacity.

5.7.1.2.3 Other Mines

The Langer Heinrich Mine is currently in a care and maintenance status and at the time of writing, feasibility studies have been launched by Paladin Energy, the majority shareholder in the Mine, regarding the reinstatement and future operation of the mine (Duddy, 2019).

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In the 2009 CNA BWMP, mining water demand was expected to peak at 2.8 Mm^3/a by 2011, lasting up until 2030. Whilst this was not achieved, this remains the theoretical upper limit of water demand for the mine.

The Trekkopje Mine is currently also under care and maintenance due to the poor uranium price and will only become active once economic conditions become more favourable. Theoretically, the Erongo Desalination Plant was designed to supply the mine with 20 Mm^3/a. The demand of the Trekkopje Mine was previously estimated to be between 10 and 14 Mm^3/a (Fichtner, 2011), but as the mine never became fully operational, the possible demand of the mine is unconfirmed. With water supply to NamWater in the order of 10 Mm^3/a from the EDP, water use in excess of 10 Mm^3/a by Trekkopje Mine, which would thus exceed the currently estimated capacity of the EDP (20 Mm^3/a) would result in difficulties to NamWater, should water supply to the mine be prioritised by Orano. It is thus uncertain how supply to the Trekkopje Mine might proceed if the EDP is purchased from Orano.

5.7.2 Water Supply and Demand Options

5.7.2.1 Alternative Water Supply Options

Natural water resources in the CCA are extremely limited and existing groundwater sources have already been over abstracted (historical perspective). Since 2013/14 (August 2013), the CCA has been partially supplied with desalinated water from the EDP and this will only continue as water demands grow into the future. As desalinated supply is already a reality in the CCA, the only other or additional alternatives worth consideration would be:

- To improve supply efficiencies at both a bulk water and localised level by reducing losses and managing water demands;
- Considering water reuse in both potable and non-potable forms. In both Swakopmund and Walvis Bay, semi-purified water supply is ongoing whilst the Walvis Bay Municipality is currently investigating Direct Potable Reuse (DPR). Water reuse could be applied at municipal, mine and industrial level but will greatly depend on the impacts of increased water tariffs on the various users.

Increasing supply efficiencies and applying water reuse will help to reduce the demand for potable water, but increased demands in future will still require supply augmentation beyond the capacity of the existing groundwater sources, which will most likely come in the form of desalinated supply, as is the case presently.

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Given the existing vulnerability of the groundwater sources in the CCA, proportionally, their overall supply contribution is expected to decrease into the future. With continued growth in demand of both the mines and other users, NamWater will not be able to maintain exclusive groundwater supply to non-mining usage. Consequently, non-mining usage will increasingly make use of desalinated water to satisfy these growing demands. With desalinated water supply already supplying the CCA since 2013/14, it is therefore no longer a question of "if" (feasibility) but rather "how much" (quantity) desalinated water will be required in future.

5.7.2.2 Domestic or Non-Mining Water Demands

Water demand projections were prepared for three scenarios (low likely, likely and high likely) for the major towns in the CCA as well as the small non-mining (domestic) users, incorporating expected growth rates, reductions in NRW and portions of water reuse (varying for different users) as described in **Section 4.4.5.4**.

Draft water demand projections were first prepared by the Consultant and then "workshopped" with NamWater. The revisions requested by NamWater were affected, following which the demand projections for the four towns in the CCA were provided to representatives of each local authority in July 2019 and discussed at a meeting with these representatives on 24 July 2019, to obtain their approval, which was granted at that meeting. The approved, likely scenario water demands and supply requirements are provided in the tables below. Full details, together with the values for the low likely and high likely scenarios are provided in **Appendix 1**.

5.7.2.2.1 Water Demands for the Major Domestic Users

The water demand projections for the four major urban domestic users (likely scenario) are provided in **Table 5.9** and are illustrated in **Figure 5.40a.** The total projected demands for 2050 for the major domestic users are approximately 27.14 Mm^3/a, consisting of Walvis Bay, Swakopmund, Henties Bay and Arandis.

5.7.2.2.2 Water Demands for the Smaller Domestic Users

The water demand projections for the smaller domestic (likely scenario) are provided in **Table 5.8** and are illustrated in **Figure 5.40b.** The total projected demands for 2050 for the smaller domestic users are approximately 3.06 Mm^3/a, consisting of remaining users along the Rooibank / Mile 7 node, users along the Swartbank – Schwarzekuppe area, remaining users from the Swakopmund Terminal Reservoir, remaining users between Swakopmund and Rössing and users in the Omdel – Swakopmund area.

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Table 5.8: Client's Recommendation for the Water Demands for Large Domestic Users in the CCA (Likely Scenario)

Item			Water Demands (Mm^3/a) and Other Values Per Node				
			Walvis Bay	**Swakop-mund**	**Henties Bay**	**Arandis**	**Total**
Growth Rate (%) p.a.	Short Term	2018-2023	4.0%	4.0%	3.0%	2.5%	N/A
	Medium Term	2023-2035	3.5%	3.5%	2.5%	2.0%	
	Long Term	2035-2050	3.0%	3.0%	2.0%	1.0%	
Non-revenue water (%)		2018	15%	15%	15%	15%	
		2050	12%	12%	12%	12%	
Reuse (%)		2018	0%	0%	0%	0%	
		2050	20%	10%	5%	10%	
Water Demands (Mm^3/a)		2018	6.66	4.44	0.53	0.34	11.98
		2020	7.10	4.76	0.56	0.36	12.78
		2025	8.21	5.59	0.63	0.39	14.82
		2030	9.39	6.50	0.70	0.42	17.01
		2035	10.67	7.52	0.78	0.45	19.42
		2040	11.89	8.52	0.85	0.46	21.73
		2045	13.22	9.66	0.93	0.48	24.29
		2050	14.69	10.95	1.01	0.49	27.14

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Table 5.9: Client's Recommendation for the Water Demands for Small Domestic Users in the CCA (Likely Scenario)

Item			Water Demands (Mm^3/a) and Other Values Per Node					
			Rooibank / Mile 7	**Swartbank - Schwarzekuppe**	**Swakopmund Terminal Reservoir**	**Swakopmund - Rössing**	**Omdel - Swakopmund**	**Total**
Growth Rate (%) p.a.	Short Term	2018-2023	5.5%	6.5%	5.0%	5.0%	3.0%	N/A
	Medium Term	2023-2035	5.0%	6.0%	4.5%	4.0%	3.0%	
	Long Term	2035-2050	4.5%	3.0%	4.5%	2.5%	2.5%	
Non-revenue water (%)		2018	16%	16%	10%	16%	20%	
		2050	15%	15%	10%	15%	15%	
Water Demands (Mm^3/a)		2018	0.11	0.28	0.01	0.37	0.12	0.89
		2020	0.12	0.29	0.01	0.41	0.13	0.97
		2025	0.16	0.34	0.02	0.52	0.16	1.19
		2030	0.20	0.39	0.02	0.65	0.19	1.45
		2035	0.26	0.44	0.03	0.81	0.23	1.77
		2040	0.32	0.49	0.03	1.01	0.26	2.12
		2045	0.39	0.55	0.04	1.25	0.30	2.54
		2050	0.49	0.62	0.05	1.56	0.34	3.06

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5.7.2.3 Mining Water Demands

5.7.2.3.1 Current Mining Water Demand and General Considerations

A critical consideration will be how the demands of the major mines[35] in the CCA will be accommodated. Existing mining demands represent some of the largest single consumers in the CCA. Total mining consumption/demand for 2018 was 10.6 Mm^3/a, which comprised 45% of the total CCA consumption per NamWater's sales data, which demands are expected to increase further in future. Whilst two uranium mines (Trekkopje and Langer Heinrich) are currently in a care and maintenance phase due to the low world uranium prices, these mines may recommence operations in future (specifically or more likely Langer Heinrich), should the uranium price rise to an economically feasible level again.

Despite the low uranium prices of the last few years, mining water consumption is currently the highest on record per NamWater's sales data, mostly because of the activities if the Husab Mine (Swakop Uranium).

However, the erratic nature of mining operations, combined with their large demand requirements, poses a supply challenge to NamWater, as the operations of at least some mines are linked to the commodity prices (Uranium), which are difficult to anticipate, especially over the long term.

Furthermore, correspondence with the currently active mines in the region (Husab and Rössing), indicates a general dissatisfaction with the water supply tariffs and security of supply provided by NamWater (refer below). Rössing Uranium has already attempted to develop their own desalination plant (though unsuccessfully) and Husab Mine is currently investigating the possibility of constructing their own desalination plant.

How these existing mines will be supplied with desalinated water and how future mines or mining activities will be supplied, is a key question which needs to be determined for this Project.

Past experience has shown that the mines are reluctant to provide a binding commitment on water demands and / or enter into longer-term water supply agreements with NamWater which would be needed in order to plan, size and finance a desalination plant. This was the case in the period prior to the development of the EDP, which at least in part contributed to Areva (at the time, now Orano) developing their own desalination plant at Wlotzkasbaken. These considerations again came to the fore during NamWater's planning for the proposed Mile 6 desalination plant (Fichtner, 2011). Given the magnitude of the mining water demand in the CCA (as above), the in/exclusion thereof would make a major difference to the water supply situation in the CCA, the planning,

[35] In this section, "mining" demand should be interpreted to include "large commercial water demand" as well.

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sizing and financing of any desalination plant (including whether the existing plant is to be purchased and / or extended and / or a new plant is to be constructed).

5.7.2.3.2 Provisions of the Water Supply and Sanitation Policy and Related Considerations

A first consideration regarding whether or not to include provision for the mining (and large commercial) water demand in the CCA is an examination of the legislative and policy provisions in this regard.

The Water Supply and Sanitation Policy (**WSASP**) states that "*mining companies should develop their own water supply schemes or should provide the capital for the construction and development of WSS infrastructure……Mines may negotiate and agree with any service provider to operate and maintain the water supply infrastructure based on full cost recovery principles on a commercial basis avoiding subsidies to the mines or pre-financing by government or service providers*" (MAWF, 2008a).

A number of factors can be considered with regard to the supply of water to the mines:

1. The WSASP policy clearly states that "*mining companies should develop their own water supply schemes…"*. Presumably under this principle, Orano (then Areva) was able to develop their own desalination plant and supply pipeline scheme. However, Rössing Uranium (Rio Tinto) was relatively recently prevented from doing so, indicating an inconsistent application of this principle;

2. NamWater should not fund the construction of water supply schemes to mines, including costs associated with supply (for example a new desalination plant). As noted above, the variability of commodity prices which influences the water demands by and determines the viability of mines would badly expose NamWater in the event that NamWater incurred capital costs in providing supply infrastructure to a mine, which costs are to be recovered from the water tariffs, and this mine then closes or enters care and maintenance and the supply infrastructure has not been fully amortised or depreciated. The recent instance of Langer Heinrich Mine entering care and maintenance after NamWater had committed to purchasing water from Orano to supply to them, thus exposing NamWater to unrecoverable costs, serves as an example. One of two approaches should rather be followed:

   a. "The Orano Model": The mine develops and operates their own infrastructure, bearing the associated risks and costs should they close down;

   b. "The Husab Model": The mine develops their own infrastructure, which is operated by NamWater under agreement and cost recovery principles;

3. A situation whereby new (commercial) customers or developments develop to the extent that they appropriate capacity which was developed by and for an older / existing customer base, should be avoided;

4. The Namibia Water Corporation Act, No. 12 of 1997, under Section 7(1)(a) gives NamWater the power to impose tariffs on a "*full cost-recovery basis for water sup-*

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plied". There are a number of aspects to this concept or principle, as outlined elsewhere (LCE, 2008). Under this section, it can be said that in general, NamWater's tariffs can be regarded as being based on cost-recovery principles. The implication being that NamWater should not aim to "make money" or generate a profit from water supply to mines (refer also to the WSASP), and thus in principle, not supplying water to the mines should not jeopardise NamWater's financial position;

5. However, as a possible counter to the abovementioned Item 4, there may be economies of scale to be achieved, at least in terms of a desalination plant, possibly in terms of pipeline distribution and power supply, by combining mining and non-mining supply. Practical, environmental and possibly other considerations may dictate that it is undesirable to have a number of different desalination plants along the coastline and therefore that at least the location of seawater intake and brine discharge be consolidated, even if mining and non-mining supply are to be desalinated separately. In particular, the environmental and related considerations, but also the financial considerations, form part of assessments which will be conducted only under later phases of the Project;

6. When companies decide to establish a new mine, they typically need to do so as quickly as possible, in order to begin operation and generating income to repay loans as soon as possible. From the information received from Husab Mine, it appears that the mine intends to increase operations and hence water use markedly in the next few years. It is surmised that NamWater would not be able to react in supplying additional supply capacity to a new mine in the same timeline as the development of that mine, or for example develop a new desalination plant to supply the proposed increase in demand of Husab Mine (based on historic precedent at any rate). This serves as further justification for allowing the mines to develop their own infrastructure, at their own pace and to their own standards, without needing to involve NamWater. Any requirements placed on NamWater for the operation of such infrastructure (as with Husab Mine) are not likely to be as onerous (as would be those relating to the development of new infrastructure, including timelines, cashflow requirements, and other resource capabilities);

7. The supply of potable water for domestic use and the supply of water for largely mineral processing at mines may imply different standards in terms of water quality parameters and reliability of supply. The construction and operation of the EDP illustrates this. The aim of this plant was the supply of water to the Trekkopje Mine and not primarily domestic supply. The design of the plant reflects this, as the lack of a Dissolved Air Flotation (DAF) treatment step implies that the EDP experiences problems during sulphur upwellings[36]. The operator's solution to this shortcoming is to turn off the plant for the duration of events where the sulphur concentration is greater than 20 µg/ℓ (Drummond, 2019). A DAF treatment step has been recom-

[36] Further details are provided in the chapter on desalination and not in this Report.

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mended for a desalination plant to minimise "*the risk of a plant shutdown*" (Fichtner, 2011) and it is thus highly likely that should a desalination plant be designed for domestic supply, appropriate pre-treatment, including a DAF step, would be included to increase the reliability of supply. Thus, a desalination plant designed for domestic supply vs mining water supply would need to provide greater availability / reliability and would thus be more expensive.

5.7.2.3.3 Options for the Supply of Mining Water Demand

Basic or Principle Options

On the basis of the aforementioned considerations, three principle options are possible regarding desalinated supply to the mines:

1. **Desalinated water / potable supply will only cater for non-mining demands, while the mines fund and supply their own water via desalinated sea water**. This option is arguably simpler in terms of NamWater projecting water demands and planning and providing suitable supply, as the fluctuating mining activities are very difficult to anticipate and thus to design for. In essence, NamWater will supply water for non-mining use. The mines are to provide their own water supply (as done by Orano (then Areva) and own supply infrastructure. This infrastructure could then be operated by the mine(s) themselves (as done by Orano (then Areva)) or by NamWater (as with Husab). This option may however be challenging to implement from a funding point of view, as the mines have been the single largest developer of water resources in the CCA in the recent past and recovering costs exclusively from the remaining users may be a high burden to bear, and there may be economies of scale to be achieved by combining mining and non-mining supply. However, in principle, this option would align with the principles of the Water Supply and Sanitation Policy (WSASP);

2. **Desalinated water / potable supply will only cater for the existing and active CCA users**. NamWater currently supplies desalinated water to existing mining users, mainly the Rössing Uranium and Husab Mines (previously also to the Langer Heinrich Mine) and it would not be possible, nor reasonable, to stop doing so, at least not without a notice period of some years. Thus in the short- to medium-term at least, NamWater will continue supplying water to the existing mining customers. However, it could be argued that any major future mining developments will have to provide their own desalinated seawater supply. This option may be financially more attractive than Option 1, but is exposed to current mining demands which may vary, especially if the mines close or enter a care and maintenance phase, as was most recently the case with the Langer Heinrich Mine;

3. **Desalinated water / potable supply for all mining activities, both current and future**. Under this scenario, NamWater might seek to supply all potential future mining water demand, seeking to maximise any economies of scale. As already indicated, this option is however heavily dependent on commodity prices, which vary

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greatly and are hard to predict. Should this option be considered, a heavy burden is placed on the supplier (NamWater) to anticipate these demands, satisfy them when needed and maintain sustainable operations when these mines close or scale down activities. In the case of mine closures, it is possible that NamWater may be left with surplus infrastructure and supply capacity which are not fully amortised or depreciated, thus jeopardising their financial position. On the other hand, there may be economies of scale to be achieved on some infrastructure components should this option be considered.

Mining Options Proposed

In order to differentiate further between these three principle options, five water options for considering the water demands of the mines in the CCA were put forward, as follows:

1. Scenario M1: No mining water demand is included, as outlined above, in order to comply with the WSASP, 2008.

2. Scenario M2: Peak use of the "existing" Rössing Uranium, Husab and Langer Heinrich Mines: 18.0 Mm^3/a

   - Husab Mine: Peak use of 10.2 Mm^3/a per information received from Swakop Uranium;
   - Rössing Uranium Mine: Expected peak use of 5 Mm^3/a per NamWater;
   - Langer Heinrich Mine: Expected peak use of 2.8 Mm^3/a per the CNA Bulk Water Master Plan (NamWater, 2009) should this mine become operational again, which is the subject of a feasibility study by Paladin Energy, the majority shareholder in the Mine (Duddy, 2019);

3. Scenario M3: Peak use of the "existing" Rössing Uranium, Husab and Langer Heinrich Mines: 21.0 Mm^3/a. This demand corresponds with the "low case" demand estimate (also 21.0 Mm^3/a) previously estimated by Fichtner (2011):

   - Husab Mine: Peak use of 10.2 Mm^3/a per information received from Swakop Uranium;
   - Rössing Uranium Mine: Possible peak expected use of 8.0 Mm^3/a per the CAN Bulk Water Master Plan (NamWater, 2009);
   - Langer Heinrich Mine: Peak expected use of 2.8 Mm^3/a per the CNA Bulk Water Master Plan (NamWater, 2009) should this mine become operational again, which is the subject of a feasibility study by Paladin Energy, the majority shareholder in the Mine (Duddy, 2019);

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4. Scenario M4: Total 29.62 Mm^3/a: In addition to Scenario M3, the demand of prospective new mines (those not included in Scenario M3) is included, based on the assessments of the CNA Bulk Water Master Plan (NamWater, 2009);

5. Scenario M5: Total 49.62 Mm^3/a: In addition to Scenario M4, 20 Mm^3/a is included for the possible demand of the Trekkopje Mine, based on the design capacity of the EDP (20 Mm^3/a) which was built primarily to supply water to this mine by Areva (at the time, now Orano). The demand of the Trekkopje Mine was previously estimated to be between 10 and 14 Mm^3/a (Fichtner, 2011), but as the mine never became fully operational, the possible demand of the mine is unconfirmed. Scenario M5 is therefore believed to represent a conservative, upper bound estimate of the possible mining water demand in the CCA. This estimate is greater than the "high case" demands of 31.0 Mm^3/a previously estimated by Fichtner (2011), but it should be noted that this estimate predates the development of the Husab Mine which is set to become the single largest water user in the CCA.

5.7.2.3.4 Water Demands for Mines as Selected by NamWater

The mining demand options were discussed with NamWater's offices in Windhoek and Swakopmund, following which NamWater selected Option M2 (18.0 Mm^3/a) as the preferred option.

Table 5.10: Client's Recommendation for the Water Demands of the CCA Mines

Item		**Water Demands (Mm^3/a) Per Mine and Total**			
		Rössing	**Husab**	**Langer Heinrich**	**Total**
Water Demands (Mm^3/a)	2018	2.90	5.94	1.79	10.63
	2020	2.90	8.40	0.01	11.31
	2025	3.64	10.20	1.83	15.67
	2030	5.00	10.20	2.80	18.00
	2035	5.00	10.20	2.80	18.00
	2040	5.00	10.20	2.80	18.00
	2045	5.00	10.20	2.80	18.00
	2050	5.00	10.20	2.80	18.00

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5.7.2.4 Total Water Demands in the Central Coastal Area

A combination of three demand scenarios for the "domestic" water demands (local authorities and small, non-mining users) with five different scenarios investigated for the supply of the mining water demands, has resulted in fifteen overall demand options, giving a broad range of water demands for 2050; between 19.12 Mm^3/a and 106.34 Mm^3/a as detailed in **Appendix 1**. The approved (Client's recommendations) domestic water demands in combination with NamWater's option for the mining water demands (M2), results in an expected water demand of 48.20 Mm^3/ for the CCA in 2050, which falls slightly above mid-way within the range of water demands for the CCA (as defined) between 24.32 Mm^3/a (minimum or lowest of the scenarios) and 109.01 Mm^3/a (maximum or highest of the scenarios) which results from the overall combination of scenarios and options.

Table 5.11: Client's Recommendation for the Total Water Demands in the CCA

Item		Water Demands (Mm^3/a) per Category and Total			
		Major Domestic	**Small Domestic**	**Mines**	**Total**
Water Demands (Mm^3/a)	2018	11.98	0.89	10.63	23.50
	2020	12.78	0.97	11.31	25.07
	2025	14.82	1.19	15.67	31.68
	2030	17.01	1.45	18.00	36.47
	2035	19.42	1.77	18.00	39.19
	2040	21.73	2.12	18.00	41.85
	2045	24.29	2.54	18.00	44.83
	2050	27.14	3.06	18.00	48.20

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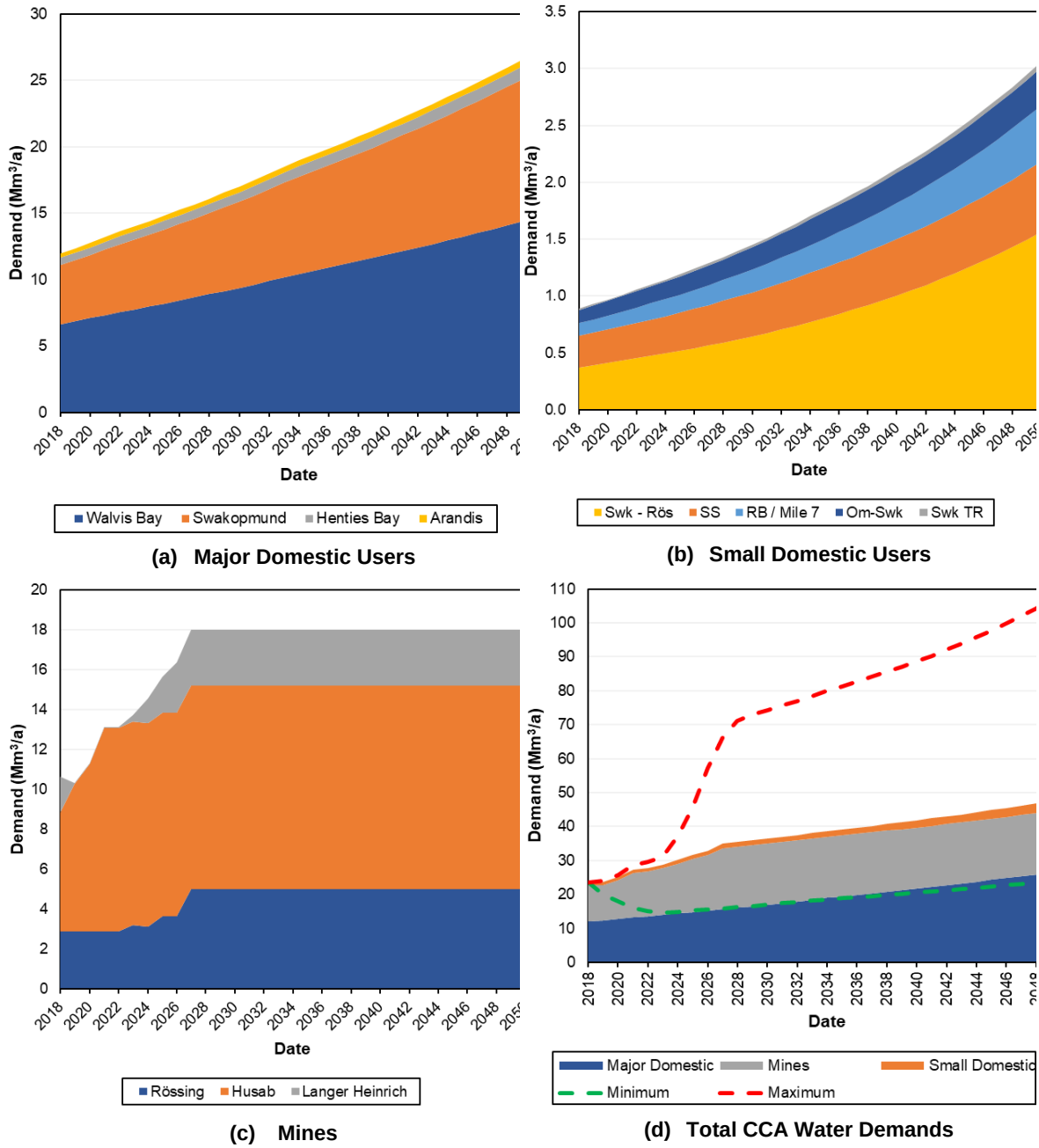

Figure 5.40: Client's Recommended Water Demands for the Various CCA Nodes

5.8 Total Water Deficits in the Central Coastal Area

5.8.1 Approach to the Derivation of Water Deficit Options and Projections

From a hydrological perspective, the water supply system in the Central Coastal Area is generally much simpler than in the CAN, without any surface water supplies and the variability associated with this type of water source. Whilst groundwater recharge for the sources in the CCA is dependent on rainfall and runoff events which are already and will in future become even more variable, abstraction from these sources is constrained by their sustainable yields (or at least it should be).

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In following a "deficit approach" (refer to **Section 4.4.5**), the augmentation of deficit volumes represent the difference between the projected water demands (including losses) and the capacity of the existing and local sources, and thus the volumes of desalinated seawater required, either from the existing EDP and / or another seawater desalination plant.

The approach to the estimation of the water demands, the utilisation of existing and local sources and the derivation of deficits requested by NamWater has been that of providing options for each component. From fifteen overall water demand options (three options for "domestic" water demands combined with five options for the mining water demands; refer above), 30 overall deficit options are derived.

5.8.2 Water Deficit Projections for the Central Coastal Area

The two water resource options (**Section 5.4.5**) combined with the fifteen water demand options (**Section 5.7.2.4**) are detailed in **Appendix 1**. The 30 water deficit options provide a broad range of water deficits for 2050; between 11 Mm^3/a and 98 Mm^3/a. NamWater's recommendation for the utilisation of the existing sources (12 Mm^3/a) combined with the approved / selected demand option of 48.20 Mm^3/a, results in an expected water deficit of 46.20 Mm^3/a in 2050.

Table 5.12: Summary of the Expected Water Deficits for the Central Coastal Area

Year	Water Deficits (Mm^3/a)		
	Minimum Option Combination[1]	**Maximum Option Combination[2]**	**Client's Recommendation[3]**
2018	0.87	15.50	11.50
2020	1.39	17.80	13.07
2025	2.56	37.62	19.68
2030	3.66	65.93	24.47
2035	4.76	72.55	27.19
2040	5.53	79.45	29.85
2045	6.32	87.92	32.83
2050	7.12	98.34	36.20

Notes:
1. Minimum deficits derive from the lowest combination of water demand projections and the combination with the highest utilisation of existing sources.
2. Maximum deficits derive from the highest combination of water demand projections and the combination with the lowest utilisation of existing sources
3. The Client's Recommendation derives from the water demand projections recommended by the Client (NamWater and the CCA stakeholders) and NamWater's recommendations for the utilisation of existing sources.

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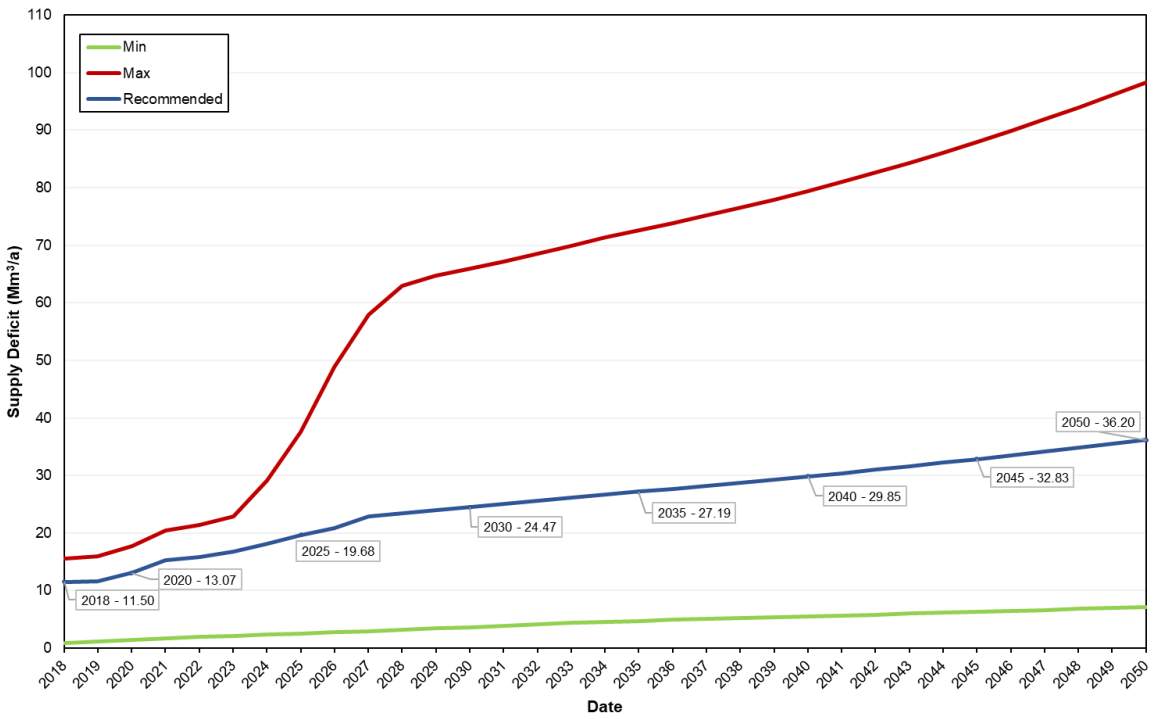

Figure 5.41: Total Water Deficit Projections for the CCA

5.8.3 Additional Considerations: Groundwater Back-up Supply

With first version of the Inception Report submitted under this Study (16 April 2019), the Consultant proposed that 14 days' worth of exclusive groundwater supply be subtracted from the long term sustainable groundwater supply rates and that the remaining sustainable availability of groundwater will be allocated to the demands. The reservation of 14 days' worth of groundwater supply to the CCA was proposed in order to make provision for scheduled maintenance on the desalination plant (7 days) or an emergency shut down of the plant (possibly for sulphur outbreaks, red tide events or any other unforeseen event; 7 days), during which period supply from the existing groundwater sources will have to be relied on exclusively. This proposal was not supported by NamWater.

During June 2019, the Consultant received a copy of the report associated with the transaction advisory services for the proposed Mile 6 desalination plant conducted by Fichtner (2011). It is interesting to note that this report recommended that in order to "*avoid unreasonably high water costs from the Plant it is expected that no large redundancies would be built into the Plant (e.g. in the form of spare RO trains, etc.)*". Instead, storage reservoirs "*as well as the possibility of NamWater to overcharge the Omdel and Kuiseb Aquifers for a short time period will cover the losses during outages of the desalination plants*" (Fichtner, 2011). This is in essence the same proposal put forward by the Consultant.

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It is acknowledged that by 2050, the wellfield infrastructure may no longer be able to provide the full demand with groundwater. However, sufficient groundwater supply should be available to serve as “lifeline supply”, possibly excluding water supply to the mines if needs be. This would avoid a repeat of the situation which occurred in Walvis Bay in 2011, whereby a failure or interruption in supply resulted in widespread disruption and water rationing (refer to **Section 5.4.2.4**).

In other words, the combination and integration of groundwater and desalinated water supply provides the opportunity to provide a robust and resilient water supply to the CCA. This opportunity should be embraced by implementing measures to ensure that at least a “lifeline supply” is available to key demand nodes from both sources in the event of an interruption in supply from the other.

5.8.4 Scenarios for Water Augmentation in the Central Coastal Area

The water deficits represent the volumes of desalinated water which are to augment the existing and locally available water resources in the CCA and which are thus to be supplied by either the existing EDP and / or another seawater desalination plant. However, these options can only be fully developed once it has been established whether or not the existing EDP will be used for supply to the Project, and if so, whether this will be via purchase by or the Namibian Government or via long-term water supply agreement with Orano, and whether this will be with/out refurbishment.

Further options include the expansion of the existing EDP and / or the construction of a new desalination plant. These and other options are detailed under the separate chapter covering the desalination options.

5.9 Other Considerations: Stakeholder Feedback

5.9.1 Local Authority Stakeholders

The EWF was established as a body representing the interests of the major non-mining customers of NamWater, as an initiative of the Office of the Governor of the ERC. The establishment of such a body as a counterweight to NamWater is of itself an indication of a lack of trust between NamWater and its major consumers in the CCA in particular. This was borne out during consultations with the EWF, the ERC and the individual local authorities in the CCA. Key grievances of the these NamWater customers include:

- A lack of consultation, a top-down approach and a lack of transparency on the part of NamWater. In particular, this has manifested in the manner in which NamWater approached the introduction of the blended tariff (consisting of groundwater and desalinated water supplied to local authorities in the CCA);
    - Henties Bay and Walvis Bay are required to pay the blended tariff for water use above their groundwater quota, but regardless, do not in fact receive any desalinated water, only groundwater from the Omdel and Kuiseb Aquifers respectively;

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- No track record of success on the part of NamWater, in terms of adequately addressing the security of water supply in the CCA;
- Steep tariff increases in recent years as a result of a historical under-recovery and lack of maintenance on the part of NamWater;
- NamWater's monopoly of supply and their perception that they have the sole right to (bulk) water supply;
- A lack of trust between NamWater and its major consumers.

The EWF has proposed acquiring the EDP or constructing their own desalination plant under a business model which includes ownership by the local authorities as major stakeholders (Louw, 2018), in order to become more independent of NamWater, which is a reflection of the lack of trust between these stakeholders and NamWater. These proposals were rejected by the Technical Committee of Experts (TCE) (Louw, 2018).

The EWF have indicated that any proposals for the purchasing of the EDP or the construction of a new desalination plant which may arise from this Study, should be cognisant of their views, namely:

- That NamWater's monopoly should be broken up and NamWater should relinquish their perceived sole right of (bulk) water supply (the concept cited in this regard is that of the introduction of Independent Power Producers which have broken up NamPower's monopoly on power supply);
- NamWater should preferably not be involved;
- Stakeholders should be involved and should have much greater input than is currently the case.

5.9.2 Mining Stakeholders

The two currently active mining customers (Rössing Uranium and Husab Mine) also expressed frustration with the supply situation on the part of NamWater, which can be summarised as:

- NamWater is unable to supply groundwater to the mines in the event that supply from the EDP is interrupted due to climatic conditions or maintenance, resulting in lost production time at the mines, which has financial consequences;
- The mines have no recourse to NamWater or the EDP for the recovery of lost production due to supply interruptions;
- The high cost, but inconsistent supply, with customers having no real negotiating power, is a cause of concern;
- The water from the EDP is costly, and fluctuates monthly, as a result of the exchange rate to the US$, the volumes purchased from the EDP, used and paid for

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by other consumers, and other factors, which are beyond the influence of any single mine or consumer. These varying costs are undesirable from the point of view of the mines;

- A higher reliability of supply from the EDP to cater for climatic variability (red tides and sulphur plumes) will require further investment, which will result in higher costs to consumers if these are to be recovered via the tariff(s);
- The matter of desalinated water has been on the cards in the CCA for more than a decade, and there is still no satisfactory supply-side solution.

Rio Tinto (the owners of Rössing Uranium) investigated constructing their own desalination plant to secure their own water supply, finalising a social and environmental impact assessment report in January 2015 (Aurecon and SLR). This assessment report and environmental management plan were then submitted to the Ministry of Environment and Tourism (**MET**) for review and an environmental clearance certificate, which was not issued (Rio Tinto, 2016). In June 2016, Rio Tinto received an environmental clearance certificate from MET but not a water permit from the MAWLR (Rio Tinto, 2017). Swakop Uranium (the owners of Husab Mine) have indicated they are also considering investigating constructing their own desalination plant. As with the EWF, the fact that NamWater's major customers are investigating implementing their own water supply, is an indication of their dissatisfaction with the status quo.

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6 CENTRAL AREA OF NAMIBIA

6.1 Configuration of Supply in the Central Area of Namibia

The Central Area of Namibia or CAN, which is sometimes also referred to as Nam-Water's Central Water Supply Area, is defined as that part of the country served with water by the Grootfontein – Omatako Eastern National Water Carrier (**ENWC**) canal and the 3-dam system consisting of the Omatako, Von Bach and Swakoppoort Dams.

This area, shown in **Figure** 6.1, includes the capital city of Windhoek, as well as Okahandja, Karibib and Okakarara. Groundwater sources are also used to supply this area, namely the Windhoek Aquifer which is used to supply the capital and the Karst Area aquifers, whose water is pumped into the ENWC. Unconventional water sources, being reclaimed domestic effluent and managed aquifer recharge, form part of the supply mix to Windhoek only.

Groundwater from the Karst areas near Grootfontein, abstracted from boreholes and the Berg Aukas mine, is pumped into the ENWC canal, which conveys this water to the Omatako Dam under gravity. Surface runoff which enters the Omatako Dam and the groundwater transferred via the ENWC is pumped to the Von Bach Dam via a pipeline with a base and one booster pump station. Surface water in Von Bach Dam is purified at the Von Bach Water Treatment Plant (**VBWTP**), located approximately 2.3 km downstream of the dam wall, which supplies treated water to the main centres of Okahandja, Gross Barmen, Windhoek, Otjihase Mine and the Hosea Kutako International Airport, plus a large number of small consumers along the pipeline routes. Okahandja is also supplied with water from two boreholes in the bed of the Okahandja River which are owned and operated by the Municipality of Okahandja. Water is pumped from the VBWTP to Windhoek via three pump stations, to the Windhoek Terminal Reservoir where the City of Windhoek / NamWater handover takes place at the bulk sales meter at the outlet end of the reservoir. Surface water in Swakoppoort Dam is abstracted and pumped either into the Okongava Reservoir to the west of the dam or upstream and to the east to the Von Bach Dam. Raw water from the Okongava Reservoir is transferred to the Karibib Treatment Plant and to the Navachab Mine (LCE-SCE JV, 2017).

Water is supplied to Windhoek from multiple sources. The main source of supply is surface water from the 3-dam system, which has been treated at the VBWTP, which can be augmented by groundwater from the Karst area in emergency periods. Groundwater is also supplied to the City from the Windhoek Aquifer which is located beneath the southern part of the Capital, via boreholes owned and operated by the City of Windhoek (**CoW**). Up to 35% of the City's water can be supplied from treated sewage (direct reclamation) via the Gammams Waste Water Treatment Plant (**GWWTP**) and the New Goreangab Water Reclamation Plant (**NGWRP**). Up to approximately 7% of the water used is semi-purified water supplied via a dual pipe system for the restricted irrigation of sports fields, parks and cemeteries in the City (LCE-SCE JV, 2017).

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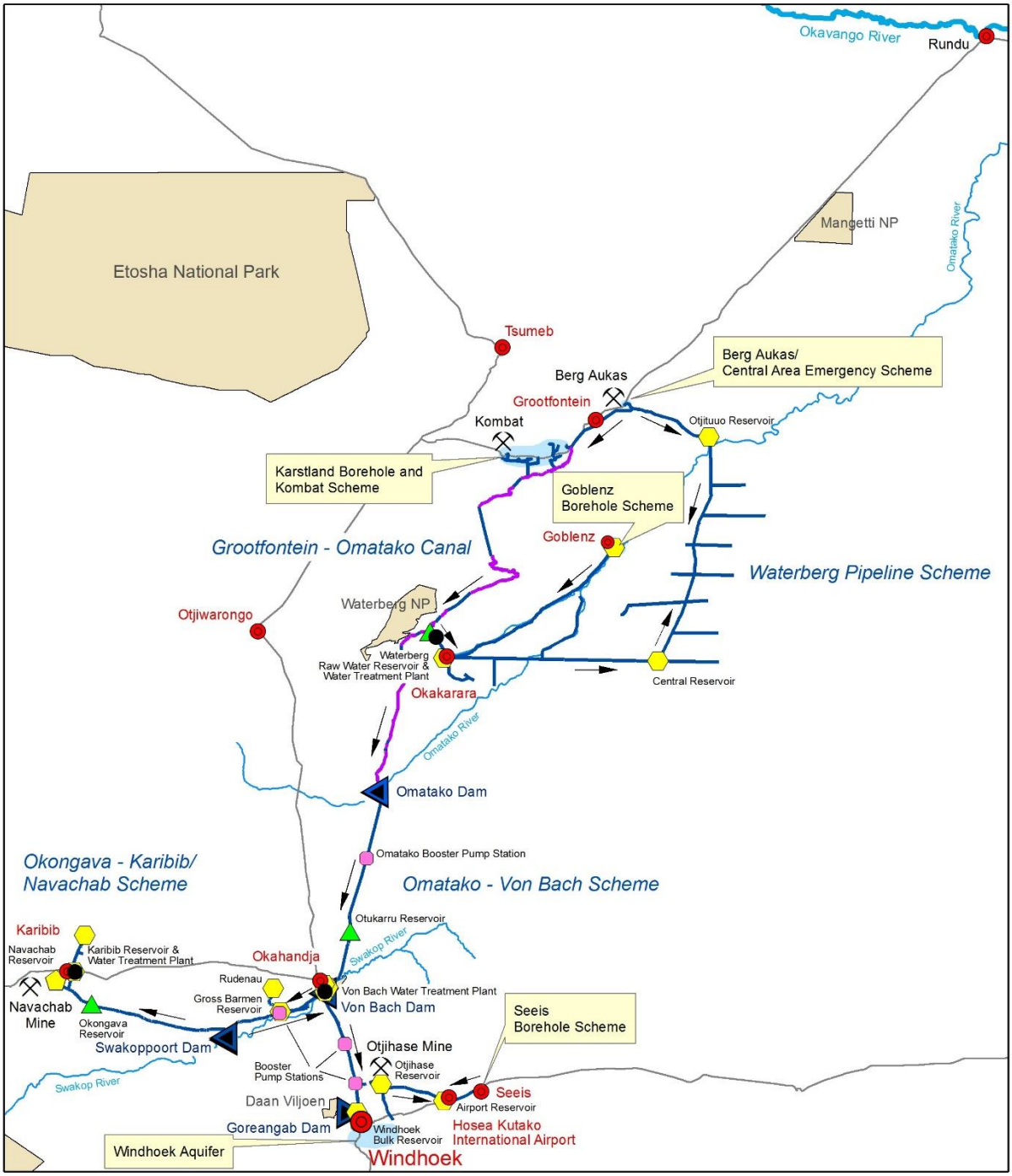

Figure 6.1: Configuration of Water Supply Infrastructure in the Central Area of Namibia (LCE-SCE JV, 2017)

Overall, the water supply configuration in the CAN is complex, since it entails the use and conjunctive use of a number of sources (surface water, groundwater and reclaimed water), extensive infrastructure schemes which transfer water over long distances, and with different priorities for transfer, as well as involving different entities with the ownership and operation of the various sources and schemes (NamWater, the City of Windhoek and a private company) (LCE-SCE JV, 2017).

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A schematic layout of the supply infrastructure in the CAN is provided in **Figure 6.2**, which includes the source and scheme capacities and the water demand values from a recent assessment for NamWater.

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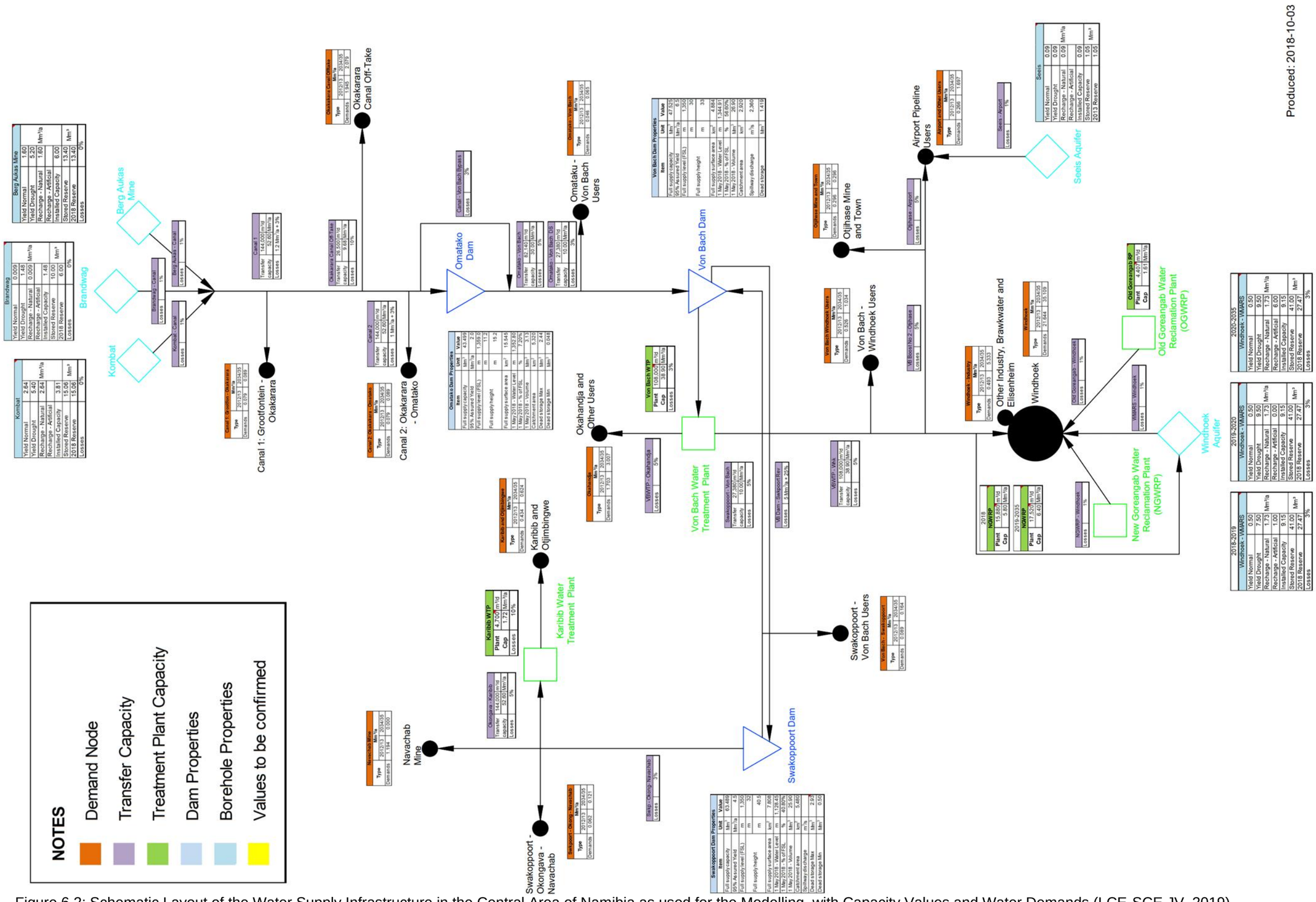

Figure 6.2: Schematic Layout of the Water Supply Infrastructure in the Central Area of Namibia as used for the Modelling, with Capacity Values and Water Demands (LCE-SCE JV, 2019)

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6.2 Overall Supply and Demand Summary

6.2.1 Historical Perspective on Supply and Demand

An assessment of the historical water supply to and the demands of Windhoek and the CAN, which was recently undertaken by Bruce and Burger (2019) using data provided by NamWater, is instructive in terms of providing perspective on the past and current water supply situations. This assessment showed that in 2007 and between 2009 and 2006, source abstraction (being sales plus abstraction, treatment and transfer losses) exceeded the long-term sustainable capacity of the sources supplying the CAN. This indicates that water supply to the CAN has been precarious for some time already.

An important note **Figure 6.3** is that the indicated availability of surface water sources is based on the 95% safe yield of the combined 3-Dam system (20 Mm^3/a). NamWater aims to secure water supply to the CAN with a 99% reliability (approximately 1% or 1:100 years occurrence of a supply shortfall). However, the 99% safe yield of the combined 3-Dam system is not available as a stand-alone figure, although it is certain that it will be much lower than 20 Mm^3/a (yield values decrease with increasing assurance of supply). Furthermore, the 95% safe yield figure of 20 Mm^3/a is believed to have been established under the 2004 Augmentation Study (CAJVC, 2004c) and would thus be 16 years old (2020) and should be updated. It is highly likely that with a longer period of analysis, the historic firm yield will be lower for the same confidence level.

In the period since the completion of the 3-dam system, significant droughts or supply shortfalls in the CAN have occurred on three occasions; 1980-82, 1994-96 and more recently over 2015-17, in all instances because of low rainfall / runoff into the dams. Whilst low rainfall / runoff can easily and obviously be identified as the main mode of failure in the CAN water supply system, the experience of 2012/13, in which no runoff was received in Von Bach Dam, though in the other two dams, with no immediate supply emergency, indicates that this is not necessarily the case. Preceding conditions and dam levels therefore clearly play and important role; the carry-over effects of the historically exceptional 2010/11 rainy season preventing the lack of inflow in Von Bach Dam in 2012/13 from resulting in a supply crisis. It can thus be argued that multi-year periods (which are not assessed or defined in the scope of this report) of below average rainfall / runoff are the primary drivers of supply shortfalls (Bruce and Burger, 2019).

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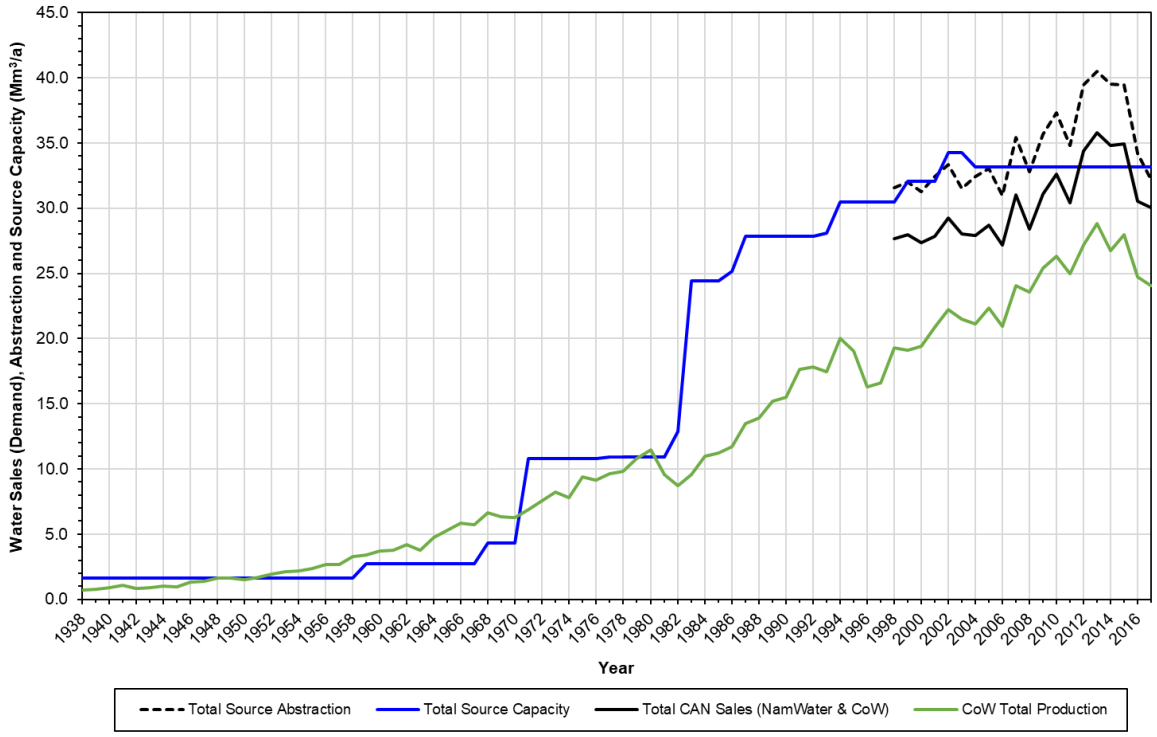

Figure 6.3: Historical Water Sales, Abstraction and Source Capacity in Windhoek and the Central Area of Namibia (Bruce and Burger, 2019)

Notes:

1. Total Source Capacity represents the long-term sustainable capacity of sources supplying the CAN, per the assumptions and approach outlined in Bruce and Burger (2019), including the 95% safe yield of the combined 3-Dam system of 20 Mm^3/a. This represents the "theoretically available" source potential per established yield values and does not provide an indication of the variability of the resources, particularly surface water availability.
2. CoW Total Production represents the water production from various sources in Windhoek only as a proxy for demand / use (CoW data). After 1998, the CAN totals for sales and abstraction include Windhoek and the other CAN users (the Swakoppoort, ENWC Canal and Waterberg Area Nodes, as well as Okahandja, the eastern and other users on the Von Bach Dam node) (Data from NamWater and the CoW).
3. The true value of the Windhoek Managed Aquifer Recharge Scheme is not reflected in this figure, which depicts only the long-term sustainable use of the groundwater resource. High rates of groundwater abstraction, based on conjunctive use of groundwater, much greater than the rates of natural recharge, have taken place from the Windhoek Aquifer, as well as from the Karst area aquifers near Grootfontein during drought periods to limit shortfalls, which is not depicted. In the case of the Windhoek Aquifer, which is used as a "water bank", this water needs to be replenished in order to be available again in the future.

6.2.2 Current Source Capacity Available to the Central Area of Namibia

The mix of normal, non-drought conditions, sustainable yield of the sources available to the CAN provided under the Water Augmentation Study (LCE-SCE JV, 2017) was updated with more recent (2017[37]) production data from the City of Windhoek for semi-purified irrigation water and reclaimed potable water via the New Goreangab Reclamation Plant.

[37] The city of Windhoek data is for calendar years.

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Since the main focus of this Feasibility Study is long-term water supply planning (for 2050), for a 30-year project horizon, water resources will be assessed and their utilisation proposed on the basis of "long-term sustainable supply capacity". In terms of groundwater sources, this implies abstraction at rates less than or equal to the rates of natural recharge.

Table 6.1: Water Resources Available to the Central Area of Namibia

Aquifer / Area	Scheme	Normal Period Yield (Mm^3/a)	Reference / Remark
Karst Area I	Brandwag Boreholes	0.009	LCE-SCE JV, 2017
	Kombat Boreholes	2.64	Normal yield taken as the natural recharge of 2.64 Mm^3/ indicated by NamWater's Geohydrology Division under the WAS (LCE-SCE JV, 2017)
Karst Area II	Berg Aukas Mine	1.60	Normal yield taken as the natural recharge of 1.60 Mm^3/a indicated by NamWater's Geohydrology Division under the WAS (LCE-SCE JV, 2017)
Seeis	Windhoek Airport	0.09	SCE-Aurecon JV, 2011
Windhoek	WMARS (Current Extent)	0.50	Refer to the notes below.
Subtotal: Aquifers Linked to the System		**4.84**	**Total groundwater resources**
Other Resources		**Yield or Capacity (Mm^3/a)**	**Reference / Remark**
Surface Water: 3-Dam System		**20.00**	95% assured yield from the conjunctive use of the 3 CAN dams (CAJVC, 2004c and, SCE-Aurecon JV, 2011)
Direct Reclamation (NGWRP)[1]		6.59	Production for calendar 2018 per the CoW
Semi-Purified Irrigation (Windhoek)		1.89	Production for calendar 2018 per the CoW
Subtotal: Other Resources		**28.48**	**Total surface water and unconventional resources**
Total CAN Water Resources		**33.32**	

Notes:

1. Abbreviations:
   a. WAS: Water Augmentation Study
   b. WMARS: Windhoek Managed Aquifer Recharge Scheme
   c. NGWRP: New Goreangab Water Reclamation Plant
   d. GWWTP: Gammams Waste Water Treatment Plant
2. In the long-term modelling analyses, the long-term abstraction (yield) of the Windhoek Aquifer is used as 0.5 Mm^3/a, to maintain infrastructure and to build-up the water bank and reserves for drought periods. Natural recharge from rainfall is assumed to be 1.73 Mm^3/a (per Zhang et. al., 2002). Neither of these values reflect the true value of the Windhoek Managed Aquifer Recharge Scheme.
3. The yield values are those applicable at the source and do not take into account treatment losses or the losses in the transfer systems to the major demand nodes. Particularly in the case of the Karst Area groundwater sources, high losses from the ENWC Canal are incurred and therefore the volumes of water which actually reach the demand nodes is much lower than those indicated.

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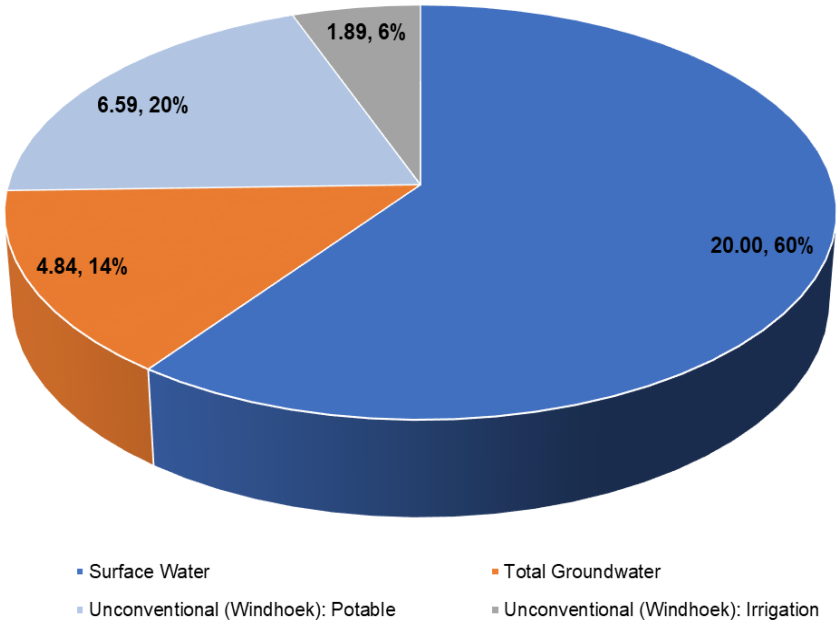

Figure 6.4: Water Resources Available to the Central Area of Namibia (Normal Yield Values; Mm^3/a and Percentage of Total)

Notes:
1. Normal period, non-drought resource availability (sustainable use). Values updated from LCE-SCE JV, 2017.
2. For surface water sources, the 95% assured safe yield for the combined use of the 3-Dam system of 20 Mm^3/a is shown. Refer to the text for considerations regarding the yield of the CAN dams.
3. Unconventional water resources in Windhoek consist of direct potable reclamation (taken as the 6.59 Mm^3 produced during calendar 2018 (CoW data) and semi-purified water for irrigation use (taken as the 1.89 Mm^3 produced during the 2018 calendar year; CoW data).

Under normal, non-drought conditions, surface water from the Von Bach, Swakoppoort and Omatako Dams constitutes the major portion (60%) of the water resources available to the CAN. The importance of unconventional sources[38] is highlighted by the fact that this category comprises a quarter (26%) of the water available to the CAN as a whole (though in reality to Windhoek only), a greater portion than is available from the sustainable use of groundwater resources (14%).

It should also be noted that the yield values indicated are those applicable at the source and do not take into account treatment losses or the losses in the transfer systems to the major demand nodes. Particularly in the case of the Karst Area groundwater sources, high losses from the ENWC Canal are incurred and therefore the volumes of water which actually reach the demand nodes is much lower than those indicated

[38] Conventional water sources are considered to be surface water (rivers and dams) and groundwater sources. Unconventional water sources are sources other than these, including desalination, water re-use, recycling and reclamation, artificial recharge of aquifers and water demand management through the conservation of water by reducing unit consumption and wastage.

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Of further concern is the fact that the majority of the supply to the CAN is from surface water resources, which are subject to the highest losses (evaporation) and the greatest variability (LCE-SCE JV, 2017). The three periods of supply shortages experienced in the CAN since the completion of the Von Bach Dam, 1980-82, 1994-96 and most recently 2015-17, were caused by below average rainfall/runoff, thus a lower supply from surface water sources than indicated by the quoted 95% yield values.

NamWater has conducted silt surveys for the three CAN dams, but has only processed the data for the Von Bach Dam (surveyed in 2011), resulting in an approximately 1 Mm^3 reduction in storage capacity compared with the volume use previously. NamWater has not yet revised the yields of the Von Bach Dam or the combined 3-Dam system to correspond with this reduced volume. For these reasons, and for those noted above, it is recommended that the silt surveys be processed and the volumes of the Omatako and Swakoppoort Dams be re-evaluated, following which the yield values for three dams individually and on a combined basis, be updated.

Below average rainfall/runoff in 2019/20 has the potential to produce another supply shortage in the CAN (as of April 2019). If climate change effects do result in greater future variability in rainfall and thus runoff, the resulting variability in the majority portion of the supply mix will create major difficulties for water supply in Namibia.

The drought or emergency yield of groundwater resources is not considered in terms of the long-term sustainable yield of the CAN resources, as abstraction at these rates is not sustainable over the long-term. During drought periods, the use of surface water sources which are constrained or unavailable is typically replaced with the emergency use of groundwater (LCE-SCE JV, 2017).

6.3 Resource Analysis

6.3.1 Surface Water Sources and Hydrological Conditions in the Central Area of Namibia (Von Bach Dam)

6.3.1.1 The Von Bach Dam

The Von Bach Dam constitutes the central node in the CAN water supply system, and the dam receives transfers from both the Swakoppoort and Omatako Dams, in addition to natural inflow from the upper Swakop River catchment. Von Bach Dam has therefore been analysed as being both representative and a summary of the hydrological conditions in the CAN (the latter since the dam levels in Von Bach include the transfers from the other two dams).

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6.3.1.2 Rainfall and Runoff

There is generally a much poorer correlation between rainfall and runoff than would be expected; 2000/01 and 2002/03 (increased rainfall yet lower runoff relative to the preceding year[s]) and 2012/13 (rainfall but no runoff) serving as examples **Figure 6.5**. This is most likely due to the timing, sequencing and intensity of rainfall events and antecedent conditions, which factors probably influence rainfall / runoff correlation more in arid environments than elsewhere. No rainfall / runoff model has yet successfully been developed for the CAN dams, most likely for these reasons (Bruce and Burger, 2019).

The three major drought occurrences in the CAN of 1980-82, 1994-96 and 2015-17 resulting from below average rainfall/runoff in the preceding years are encircled in red in **Figure 6.5**.

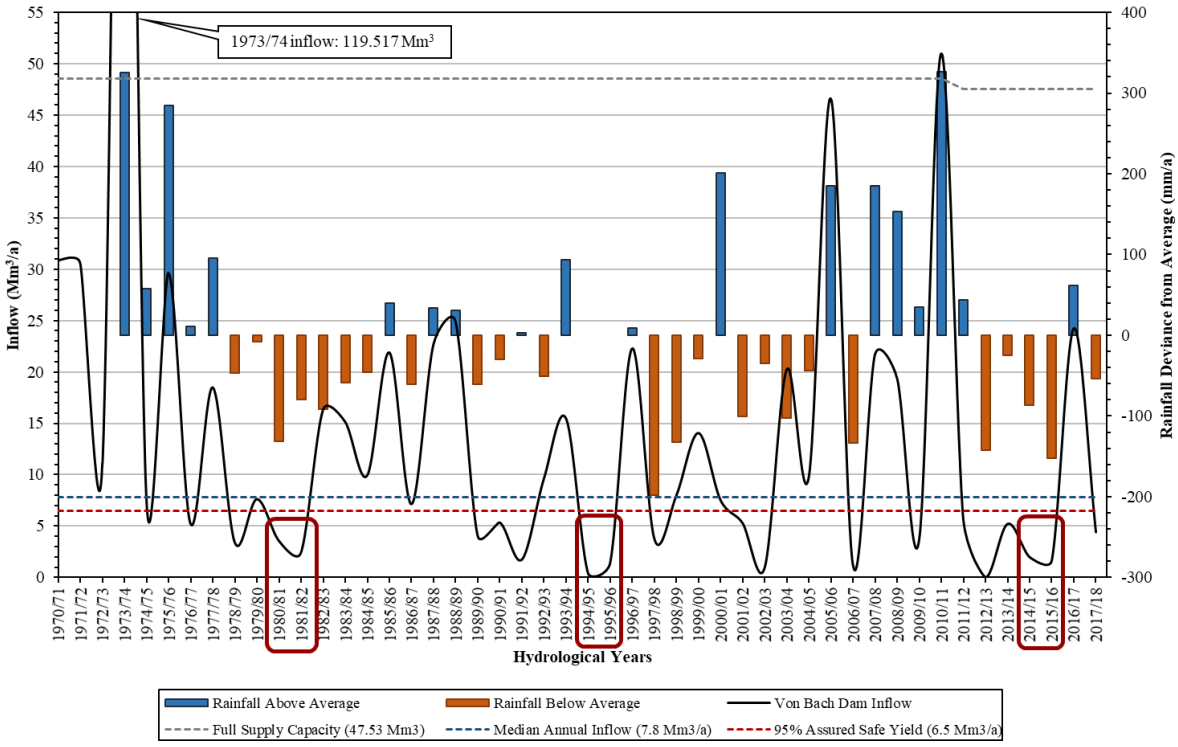

Figure 6.5: Runoff (Mm³/a) into and rainfall (mm/a) on Von Bach Dam (Bruce and Burger, 2019)

Notes:

1. Hydrological data from NamWater. Rainfall data not available for 1970/71, 1971/72, 1994/95 and 1995/96.
2. Full supply level previously 48.56 Mm³ based on a 1970 survey (SCE-Aurecon JV, 2011) which was updated to 47.525 Mm³ (applied to 2011/12) based on a silt survey conducted by NamWater in 2011 (NamWater, 2017b).
3. The major drought occurrences of 1980-82, 1994-96 and 2015-17 resulting from low inflows are encircled in red.

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6.3.1.3 Content of the Von Bach Dam

An analysis of the content of Von Bach Dam (**Figure 6.6**) shows how supply in the CAN is largely based on periodic events of good inflows (in such events the inflows are much larger than the transfers from the other dams), with dam levels (content) declining steadily between these events.

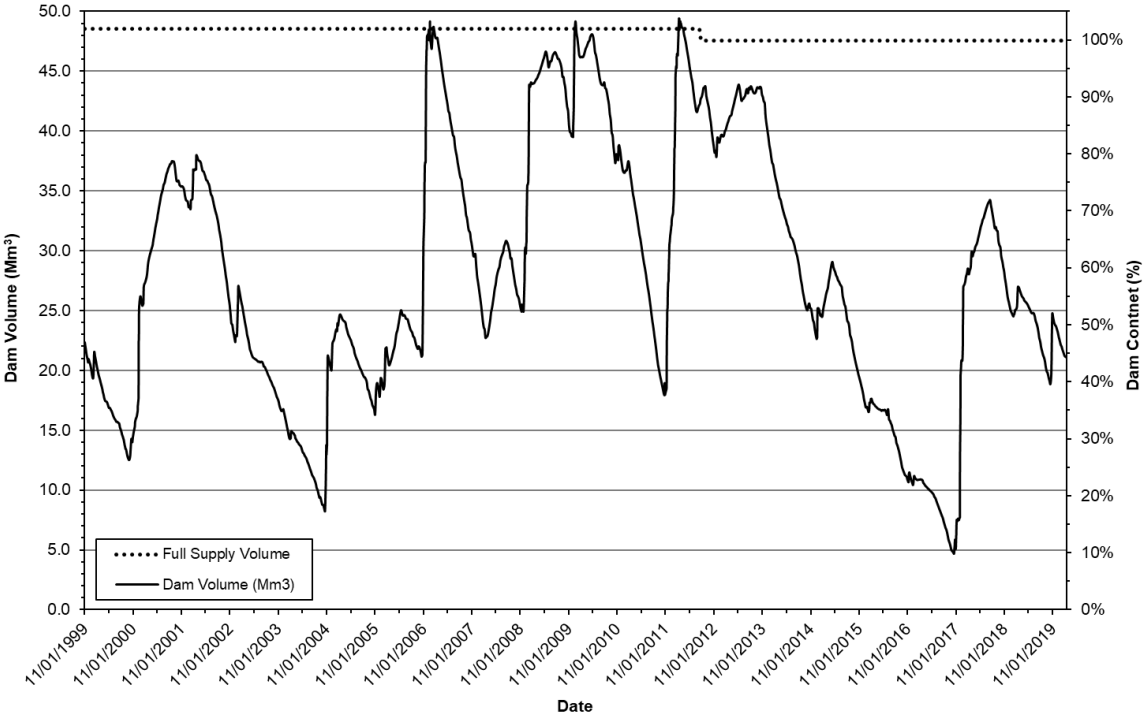

Figure 6.6: Volume (Mm^3) and Content (%) of Von Bach Dam

Notes:

1. Hydrological data between January 1999 and April 2018 from NamWater under the CAN Medium Term Project (LCE-SCE JV, 2019). Data from 09 April 2018 onwards compiled from NamWater's weekly Dam Bulletins.
2. Full supply level previously 48.56 Mm^3 based on a 1970 survey (SCE-Aurecon JV, 2011) which was updated to 47.525 Mm^3 based on a silt survey conducted by NamWater in 2011 (NamWater, 2017b). No exact date in 2011 for this silt survey is however available. The updated volume of 47.525 Mm^3 was therefore applied to 2011/12, i.e. from October 2011 onwards.

In 2005/06, the Von Bach dam spilled for only the second time in its history, 32 years after the first occurrence in 1973/74. A mere five years later, in 2010/11 (April 2011), following an historic rainy season, the dam spilled for the third time. Therefore, between 2005/06 and 2011/12, surface water was relatively abundant, shown by these events and high dam levels, as rainfall was above average for 6 of the 7 years. The relative abundance of surface water is what supported the high rates of water use during this period (**Figure 6.3**), when water use was essentially unrestricted (after Bruce and Burger, 2019). The high rates of water use are evident by the steeper drop in content of the dam between April 2006 and April 2007, over the course of 2010 and between December 2012 and February 2014, than was the case between August 2014 and December 2016.

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In the former instances, water use was essentially unrestricted, whilst there was a growing awareness of a water supply shortage in 2015, followed by the issue of the CoW's Drought Response Plan in November 2015 and a Water Demand Management (**WDM**) and savings campaign by the CoW during 2016, which served to reduce water demand in the Capital during 2016, resulting in a less rapid drawdown of the dam level (content).

After spilling in April 2011, the content of Von Bach Dam essentially declined steadily during a period of below average rainfall (**Figure 6.5**), including the first ever occurrence of no natural inflow into the dam in 2012/13, to reach an historic (since 1999) low of 10% some five and a half years later, at the end of December 2016. Windhoek only narrowly avoided a crisis similar to Cape Town's thanks to good rains in January to March 2017 (Bruce and Burger, 2019). However, in the period since, the dam content has again declined steadily.

Apart from low rainfall / runoff being the mode of failure of water supply in the CAN, supply is vulnerable to increasing periods of time between significant inflow events, as the 2011 – 2016 period shows. Should climate change result in more variable hydrological conditions, and the intervals between "good" rainfall/runoff years increase, this would jeopardise supply security in the CAN.

6.3.1.4 Water Quality and the Swakoppoort Dam

The water quality of the Swakoppoort Dam is known to be poor, as there are a large number of scattered obnoxious industries which lie within the catchment area of the dam, which contribute to significant loads of phosphate and nutrients in the run-off to the dam. As a result, the Chlorophyll concentrations in the Swakoppoort Dam can be classified as Eutrophic (significant 20 to 30 µg/ℓ in 2012) or Hypertrophic (serious >30 µg/ℓ) for the period 2009 to 2014. Approximately 80 to 100% of the algae in Swakoppoort Dam, the raw water at the withdrawal point or the raw water at the Karibib Water Treatment Plant (between February 2014 and February 2017), were blue-green algae[39]. After February 2017 there is limited data on the algae in the Swakoppoort Dam. In January 2018 however, blue-green algae comprised 93% of the total algae count of 21 367 (LCE-SCE JV, 2019).

The TDS of the Swakoppoort raw water was constantly below 400 mg/ℓ after previous rainy seasons, from May 1997 until May 2011. From May 2011 onwards, the salinity increased steadily to 1 769 mg/ℓ in April 2017. Since water from Swakoppoort Dam is pumped over to Von Bach Dam, the latter has also been affected by the deteriorating water quality in Swakoppoort Dam. As a result of the chemical deterioration of the water quality in Von Bach Dam, as well as the deterioration of the reclaimed water quality, recharging of the Windhoek Aquifer had to stop in May 2013, when the Von Bach Dam was still 70.6% full.

[39] Cyanobacteria are a class of bacteria which, because of their colour, are also called blue-green algae, which survive in a wide variety of habitats, but particularly in aquatic habitats. They are able to reproduce explosively under certain conditions, resulting in algal blooms, which can have the appearance of blue-green paint or scum (LCE-SCE JV, 2017).

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The poor chemical quality of the available water has therefore negatively affected the security of supply to the CAN.

Concerns with poor and generally deteriorating quality of the water in the Swakoppoort Dam have been noted in an number of relatively recent studies, including the Bulk Water Master Plan for the CAN, (SCE-Aurecon JV, 2011), a risk assessment of the Von Bach – Windhoek Supply Scheme (LCE, 2015), an assessment of the Karibib water treatment plant (by WCE in 2015), under the WAS (LCE-SCE JV, 2017) and NamWater's CAN Medium Term Options Project (LCE-SCE JV, 2019) among others. Previous assessments have highlighted problematic levels of Dissolved Organic Carbon, algae (including blue-green algae or cyanobacteria) and Chlorophyll a. The high concentration of nutrients (agricultural runoff, storm water, sewage, discharge from abattoirs) in the runoff to Swakoppoort Dam, large amounts of sunlight and warm temperatures, stratification and stagnant water provide ideal conditions for cyanobacterial blooms (LCE-SCE JV, 2017).

Proposals for the treatment of the Swakoppoort Dam water with Dissolved Air Flotation (DAF) date from 2011 (SCE-Aurecon JV 2011) at least. Prior to the DAF, oxidation with Potassium Permanganate, adsorption of the remaining cyanotoxins with Powder Activated Carbon, Coagulation and Flocculation should be considered. The treatment of the Swakoppoort Dam water is the subject of a separate feasibility study by NamWater, the results of which are not yet available[40].

If the sources of pollution into the Swakoppoort Dam are not controlled, it is possible that the dam may become polluted to such an extent that by 2050 water treatment with RO may be required. This would be due to densification within the catchment area, particularly in Windhoek, as well as more storm water runoff and increased effluent volumes from several overloaded wastewater treatment plants in the catchment area, which would result in a further deterioration of water quality in the Swakoppoort Dam. The further reclamation of water in Windhoek should therefore be encouraged as a means by which the further pollution of the Swakoppoort Dam can be reduced (instead of {treated} effluent being discharged, to eventually reach the Dam, it is reused).

6.3.1.5 Yields of the 3-Dam System

6.3.1.5.1 Inter-basin Transfer Schemes

The Von Bach Dam has the most favourable evaporation characteristics (0.10 m^2 per cubic metre stored at FSL[41]) of the three dams, with the Omatako Dam the least favourable (0.36 m^2 per cubic metre stored at FSL). Those of the Swakoppoort Dam (0.12 m^2 per cubic metre stored at FSL) lie between those of the Von Bach Dam and the Omatako Dam, though closer to the former.

[40] The exact scope of the assessment is also not known.

[41] Using a surface area and volume prior to the silt survey update, for an equitable comparison with the other two dams.

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By transferring water from the Omatako and Swakoppoort Dams to the Von Bach Dam when there is space available in the latter (normally when the Von Bach Dam is below 90% full), the evaporation losses can be reduced such that the combined individual 95% assured safe yield of the 3 dams can be increased by approximately 7 Mm^3/a from 13 Mm^3/a to 20 Mm^3/a[42] (IWRMPJVN, 2010c and SCE-Aurecon JV, 2011).

6.3.1.5.2 Currently Available Values and Considerations

With the modelling analyses conducted for the CAN under previous assessments[43], the design goal typically followed by NamWater is one based on a 99% likelihood that annual shortfall magnitudes will be no greater than 15% of the annual demand for each year of the planning horizon (LCE-SCE JV, 2017). This design goal for the CAN was developed under the 2004 Water Augmentation Study (after CAJVC, 2004c) and has been used since. Being unable to use the CA-Model, the assessments proposed for this study must rely on the use of “stand-alone” yield values for the surface water sources and safe yields or natural recharge values for the groundwater sources in the CAN in order to derive the total capacity of the existing sources.

Unfortunately, stand-alone values for the 99% safe yields of the CAN dams are not available; only the 95% yield values are available in this format. Whilst the *99% security of supply for the CAN* (including all resources) is not the same as the *99% safe yields of the CAN dams*, the latter can at least be regarded as conceptually similar to the former. Also, if a *99% security of supply for the CAN* is considered overall for all resources, it is not unreasonable to disaggregate this requirement as a 99% security / yield applied to each of the individual water resources making up the supply system, thus in this case, to the 3-dam system.

The 95% safe yield figure of 20 Mm^3/a for the 3-dam system is believed to have been established under the 2004 Augmentation Study (CAJVC, 2004c) and would thus be 16 years old (2020). The 99% yield values, though not available, will be substantially less than the 95% yield values, as yield values decrease with increasing probabilities (surety) of supply[44].

[42] Note that this is prior to the silt surveys conducted for the 3 CAN dams and the revision of the volume and stage-area and stage-volume curves for the Von Bach Dam. These values have not been updated with the updated values and characteristics of the Von Bach Dam and should thus be treated as indicative only.

[43] The 2004 and 2017 Augmentation Studies, the 2011 BWMP, the 2016 GCF funding application and the 2019 CAN Medium Term assessment.

[44] Yield curves are also not available for the CAN Dams, but these are typically non-linear, and markedly so at higher exceedance probabilities, where yield volumes drop off sharply as exceedance probabilities increase above 90-95% and above (De Jager, 2019).

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Further consideration of the 95% yield values for the CAN dams should also consider:

1. Silt surveys of the dams have been conducted, but only processed for Von Bach Dam, resulting in an approximately 1 Mm^3 reduction in storage capacity compared with the volume use previously. The yield of the Von Bach Dam has not been revised. With a reduced volume and adjusted stage-area and stage-volume curves following the silt survey (NamWater, 2017b), the yield of the Von Bach Dam is likely to be lower than previously. Whilst NamWater has not processed the survey data for the Swakoppoort and Omatako Dams, similar results and thus also lower yield values can be expected for these two dams individually and thus for the 3-dam system overall as well;

2. The yield values available for the individual CAN dams are believed to at least be contemporary with or pre-date the 95% safe yield figure of 20 Mm^3/a for the conjunctive use of the dams, which is believed to date from the 2004 Augmentation Study. These yield values should therefore all be updated, which is likely to result in lower values, since it is known that the firm yield decreases as the number of years of analysis increases (De Jager, 2019). Yield values applicable a further 30 years into the future at the end of the Project Horizon of 2050 can be expected to be lower still. Alternatively, if not updated, the 2004 yield values would be 45 years old at the end of the Project Horizon and thus of very questionable accuracy;

3. A safe yield of 95% represents a 5% probability of failure in any given year, which corresponds to a recurrence interval of failure of 20 years. There is a 79% probability of failure for a recurrence interval event of 20 years within the 30-year Project Horizon (2020 to 2050).

Therefore, should they be updated as recommended, revised 95% yield values are expected to be lower than the currently available values, and lower still in 2050. The 99% yield values will be lower than the 95% values at each timeframe (current and future).

6.3.1.5.3 Revised Yield Values

A simplified yield analyses was conducted for this Study using the latest version of the CA-Model used by NamWater, in order to estimate the yields of the 3-dam system. In brief, the methodology was based on the following:

- Only one demand node was activated, namely Windhoek, and at a constant draft / demand for a 33 year period (equivalent to the period 2018 to 2050). All other demand nodes were set to zero and all other supply sources were set to zero;
- Three target draft values were tested; 20, 15, and 10 Mm^3/a;
- From the *Von Bach to Windhoek transfer* files generated by the CA-Model, the percentile values equivalent to 99%, 98%, 95% and 90% were abstracted per year. Mean and median values are also included for reference purposes.

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The results of these analyses, shown in **Table 6.2**, indicate that 10 Mm^3/a can be supplied with approximately 99% surety and 15 Mm^3/a can be supplied with approximately 95% surety. The 3-dam system can only yield 20 Mm^3/a on average (mean), possibly at near-90% surety. It is therefore clear that the 3-dam system cannot yield 20 Mm^3/a at either 99% or 95% surety.

Table 6.2: Results of a Preliminary Yield Analysis for the 3-Dam System

Statistic Measure	Average Values for 2018 – 2050 per Target Draft		
	20 Mm^3/a	**15 Mm^3/a**	**10 Mm^3/a**
Mean	20.69	16.00	10.82
Median	21.70	16.28	10.85
99%	6.19	7.07	10.67
98%	7.75	9.81	10.85
95%	12.18	15.87	10.85
90%	19.47	16.28	10.85

Notes:
1. The Target Draft refers to the volume of water desired from the dam. This is initially estimated (hence the term “target”) and revised through iterative analysis or graphical methods.

By making allowance for the fact that the silt surveys of the Swakoppoort and Omatako Dams have not been analysed, and are likely to result in lower volumes and increased surface areas for these dams, and hence lower yields, the Consultant recommends that the following yield values be considered for the 3-dam system:

1. 99% safe yield of 10 Mm^3/a;
2. 95% safe yield of 15 Mm^3/a.

It is however recommended that a more detailed yield assessment be conducted for the 3-dam system, particularly once the silt surveys of the Swakoppoort and Omatako Dams have been analysed and the area-height and volume-height relationships have been updated.

6.3.1.6 Water Quality provided by the Von Bach Water Treatment Plant

The water treated at the VBWTP and supplied to the downstream “Von Bach Node”, the largest demand node in the CAN, consists of groundwater from the Karst Area, surface water from the Swakoppoort and Omatako Dams which is transferred to Von Bach Dam, as well as water from the dam itself. The water treated at the VBWTP is that supplied for consumption (domestic and other) and, if of sufficient quantity and quality, for artificial recharge of the Windhoek Aquifer.

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A 22-year perspective on the product water quality of the VBWTP which uses mostly conventional unit processes[45] shows how the water quality deteriorated markedly between 2013 and the end of 2016 (refer to **Figure 6.7**) as the dam levels dropped (refer to Figure 6.6), improving again when the CAN dams received significant inflows in early 2017. Thereafter, as dam levels have again dropped, the water quality has deteriorated, indicating an inverse correlation between water quality and dam levels. The near-identical variation shown by the selected parameters indicates how TDS is a measure considered to be broadly representative of "water quality".

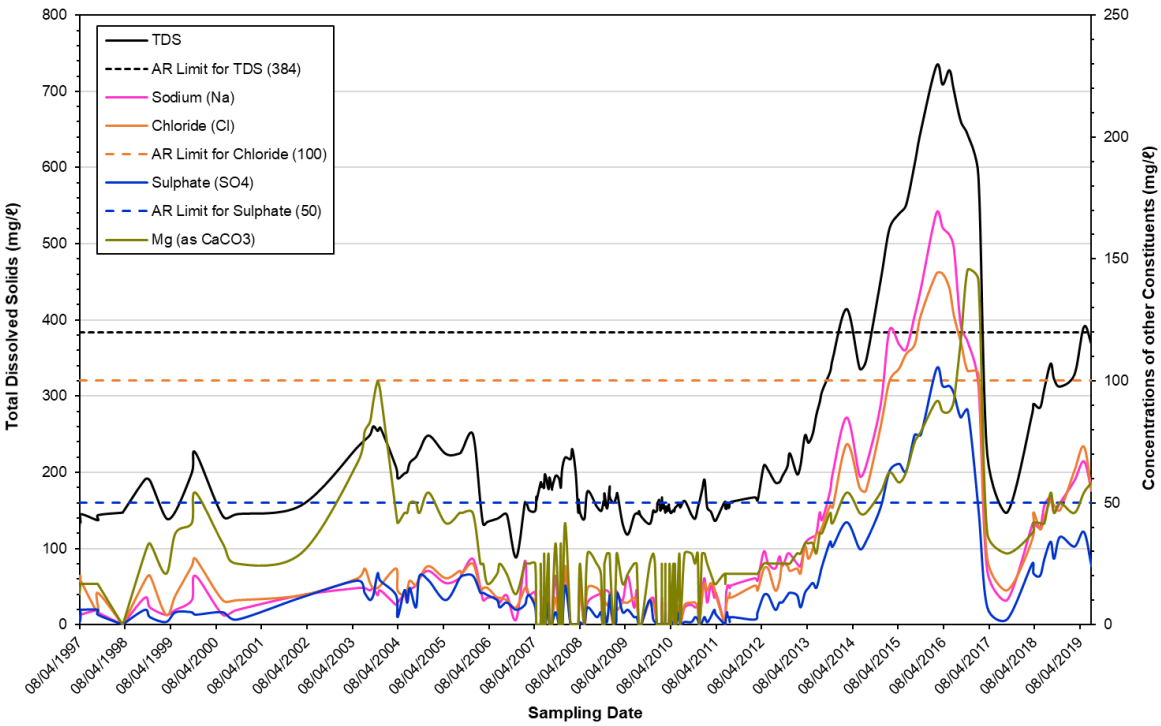

Figure 6.7: Selected Parameters Indicating the Quality of the Product Water from the Von Bach Water Treatment Plant

Notes:
1. Water quality data from NamWater.
2. TDS = Total Dissolved Solids. AR Limit derives from the 60 mS/m limit recommended for the artificial recharge of the Windhoek Aquifer (WAJVC, 2005), converted to 384 mg/ℓ using the "640 scale" (EC < 5 dS/m; per Bauder et al., 2011). In instances where the prevailing EC level in the groundwater of the injection area is above 60 mS/m, a maximum limit of 70 mS/m was proposed (WAJVC, 2005), equivalent to 448 mg/ℓ.
3. The water quality recommendations for artificial recharge of 100 mg/ℓ for Chloride (as Cl) and 50 mg/ℓ for Sulphate (as SO_4) derive from WAJVC, 2005.

[45] Powder Activated Carbon dosage as and when required in the raw water pipeline at the abstraction tower, coagulant and potassium permanganate dosing at hydraulic jump near outlet of the plug flow reactor, distribution box to three parallel treatment streams, flocculation canals before clarification (northern settlers and southern settlers), intermediate chlorination before the sand filters which may change to intermittent chlorination, rapid sand filtration, clear water wells, stabilisation with sodium hydroxide, chlorination.

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The values for TDS, Chloride (as Cl) and Sulphate (as SO_4) recommended for artificial recharge of the Windhoek Aquifer in 2005 (by WAJVC) are also indicated in **Figure 6.7**. Apart from low dam levels limiting the availability of water for artificial recharge, the water quality did not meet the recommended parameters between 2013 and early 2017 (full details in the Design Criteria Report). Following the identification of the Windhoek Managed Aquifer Recharge Scheme as the best scheme for water supply augmentation to the CAN in the medium-term in 2004 (CAJVC, 2004a), large-scale artificial recharge could only take place after the completion of NamWater's new and larger pump stations on the Von Bach – Windhoek transfer scheme in 2014 (prior to this, there was insufficient capacity in the Von Bach – Windhoek transfer scheme to transfer water for consumption in Windhoek and artificial recharge, particularly during peak demand periods).

Figure 6.7 shows that by 2014 the water quality had deteriorated beyond the accepted or recommended levels to allow artificial recharge. The relative abundance of water (refer to **Figure 6.7**) of acceptable quality (refer to **Figure 6.6**) between 2004 and 2013 which was not utilised for artificial recharge represents a lost opportunity regarding the optimal use of water resources in the CAN. Luckily, the exceptional rainfall season of 2010/11 filled the Windhoek Aquifer, which water was then available during the 2015-17 drought, which helped avert a major crisis.

If dam levels in the CAN remain "low" in future, it is likely that the surface water quality will not be suitable for artificial recharge without advanced treatment. This is one of the reasons why it has been proposed that a RO treatment step be added to treat some or all of the reclaimed water at the NGWRP / Wingoc (ratio to be determined) to a quality suitable to allow this to be used for artificial recharge of the Windhoek Aquifer (refer below). These proposals are however still under consideration by the TCE, NamWater and the CoW and are not yet finalised or approved. Treating only the volumes of water needed / to be used for artificial recharge will be more economical than treating all the water produced by the VBWTP to this more stringent standard (the water quality parameters for artificial recharge are more stringent than those for potable use in order to prevent pollution of the Windhoek Aquifer – refer to the Design Criteria report).

6.3.2 Windhoek Aquifer

6.3.2.1 Geology and Hydrogeology

The Windhoek Aquifer is located within the Windhoek basin, which consists of three geological environments. The southern part of the area is underlain by quartzites of the Auas Formation of the Damara Sequence. These quartzites form the highest mountains in the area (the Auas Mountains), which form the southern boundary of the Windhoek basin. In the central, south-eastern and south-western areas, metasediments of the Kuiseb Formation of the Damara Sequence conformably overlie the Auas quartzites.

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This area is characterized by quartz-biotite schists with interbedded micaceous quartzites of the Kleine Kuppe and Wasserburg Members of the Kuiseb Formation, which form hills and less prominent peaks (e.g. Kleine Kuppe). The hills and mountains in the northern parts of the Windhoek basin are underlain by the schists of the Kuiseb Formation with minor interbedded micaceous and pure quartzites (CAJVC, 2004b).

The hydrogeology of the area is dominated by the quartzite and schist horizons, and the extensive system of faults and fractures that is prevalent throughout the Windhoek Aquifer. The quartzites, being brittle, are highly fractured as a result of folding and faulting and have well developed secondary porosity and permeability (SCE-Aurecon JV, 2011).

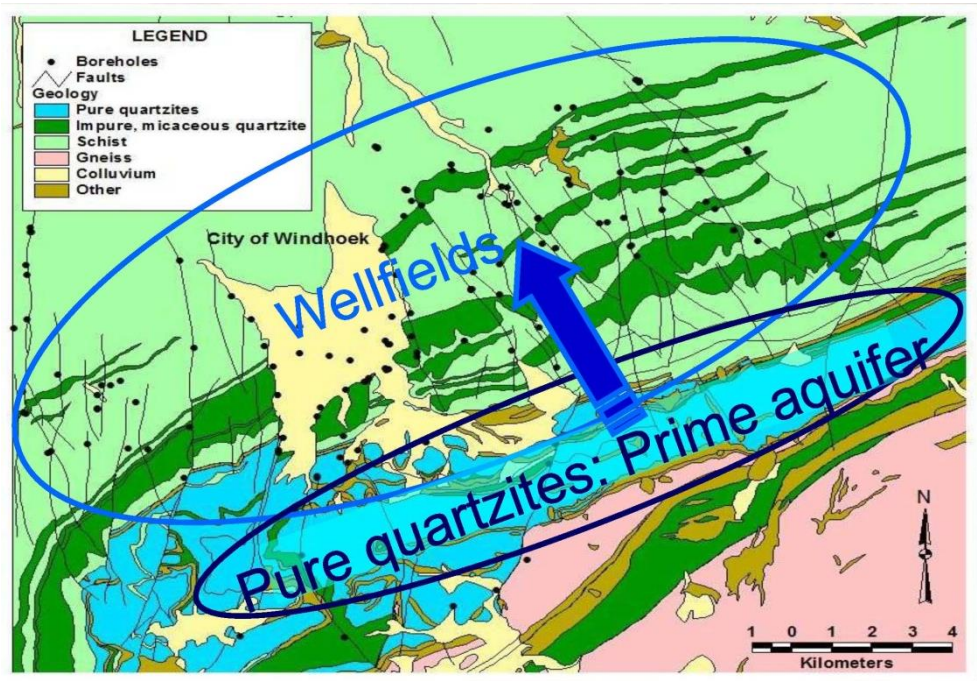

Figure 6.8: Hydrogeology of the Windhoek Aquifer

6.3.2.2 Aquifer Recharge

The sustainable yield of the Windhoek Aquifer without artificial recharge is equivalent to the aquifer's average annual natural recharge. This has been estimated to be 1.73 Mm^3/a (Zhang et al., 2002).

6.3.2.3 Water Banking in the Windhoek Aquifer

Water banking (artificial recharge) in the Windhoek Aquifer was identified in the "*Feasibility Study on Water Augmentation to the Central Area of Namibia*" as the best scheme for water supply augmentation to the CAN in the medium-term (CAJVC, 2004a). All the studies done to date have confirmed the high potential of the Windhoek Aquifer Recharge Scheme if it is linked to a sizable "water bank".

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This 2004 Feasibility Study on Water Augmentation concluded that apart from water banking in the Windhoek Aquifer being the most cost-effective option, the project would bring the following additional benefits, (SCE-Aurecon JV, 2011 and LCE-SCE JV, 2017):

1. The project can be developed in phases according to supply and demand;
2. The size of future augmentation schemes can be downsized significantly;
3. Supply sources that were regarded as non-viable due to low annual yields may become viable to keep the "water bank" full. Even savings through WDM will free up water for injection;
4. Upgrading of bulk infrastructure can be postponed if the "water bank" is filled during off-peak periods and abstraction occurs during peak periods; and,
5. The environmental impacts are minimal compared to the other alternatives.

Following the finalisation of the 2004 Feasibility Study on Water Augmentation to the Central Area of Namibia, the CoW in 2004 appointed consultants to submit a detailed assessment of the groundwater situation and the quality of water to be used for artificial recharge of the Windhoek Aquifer, which project became known as the Windhoek Managed Aquifer Recharge Scheme (**WMARS**).

The wellfield areas are based primarily on historical water level and geological information, and are presented in **Figure 6.9**. The existing boreholes are mostly situated in the Central Area, Southern Area 1, Southern Area 2 and the NE Area except for few in the Northern SW Area.

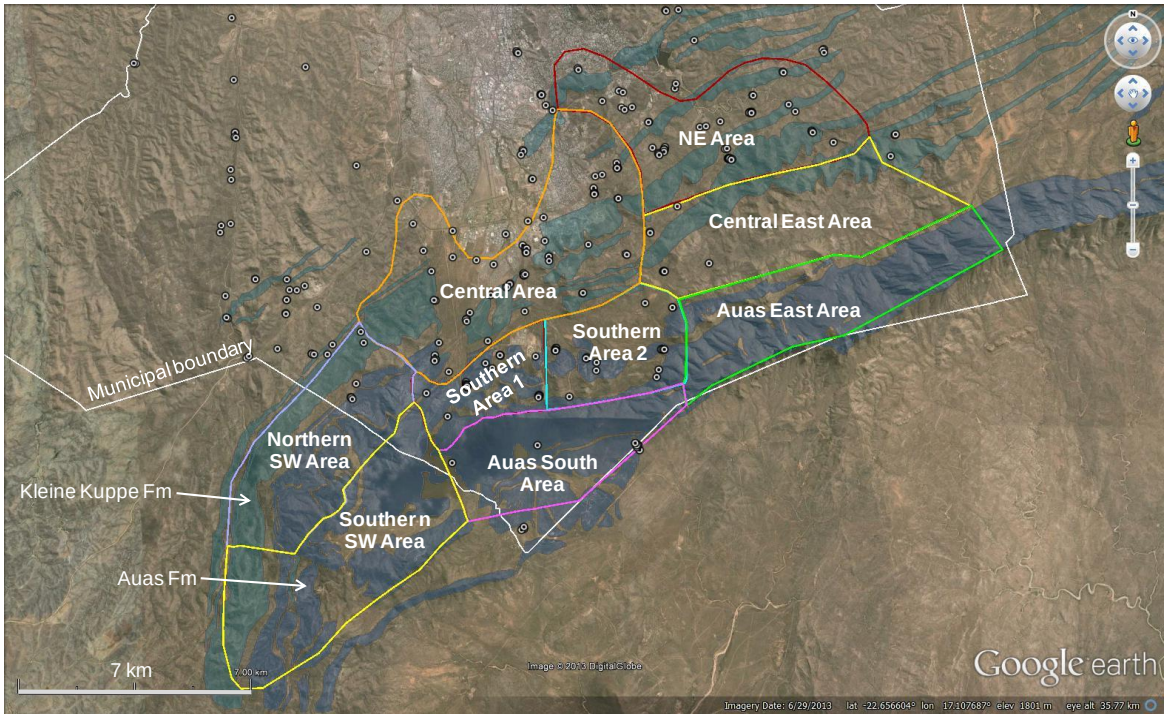

Figure 6.9: Windhoek Wellfield Areas (with Boreholes – Dots) (LCE-SCE JV, 2017)

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Based on detailed assessments conducted for previous projects of the MAWLR and NamWater, it is estimated that with existing infrastructure, 41 Mm^3 can be withdrawn from storage, and the best estimate of the future recoverable storage potential is 89 Mm^3 (once sufficient infrastructure has been installed, with this figure rounded up to 90 Mm^3; LCE-SCE JV, 2019).

6.3.2.4 Abstraction from and Artificial Recharge of the Windhoek Aquifer

Following the identification of the WMARS project as the best scheme for water supply augmentation to the CAN in 2004 (CAJVC, 2004), artificial or managed recharge of the aquifer first occurred in 2008, and thereafter up to 2012, and again in 2017 following good rains and significant runoff into the CAN dams in early 2017. Until 2018, 21% of the natural recharge rate of the aquifer was artificially recharged. In total, some 3.23 Mm^3 was artificially recharged into the Windhoek Aquifer over the last 10 years, which represents only 1.86 years' of average natural recharge from rainfall. The low recharge volumes are related to bad quality water from Swakoppoort Dam as well as the fact that the boreholes were utilised most of the time to augment supplies because the water demand exceeded the safe supply of the water sources in the CAN (LCE-SCE JV, 2019).

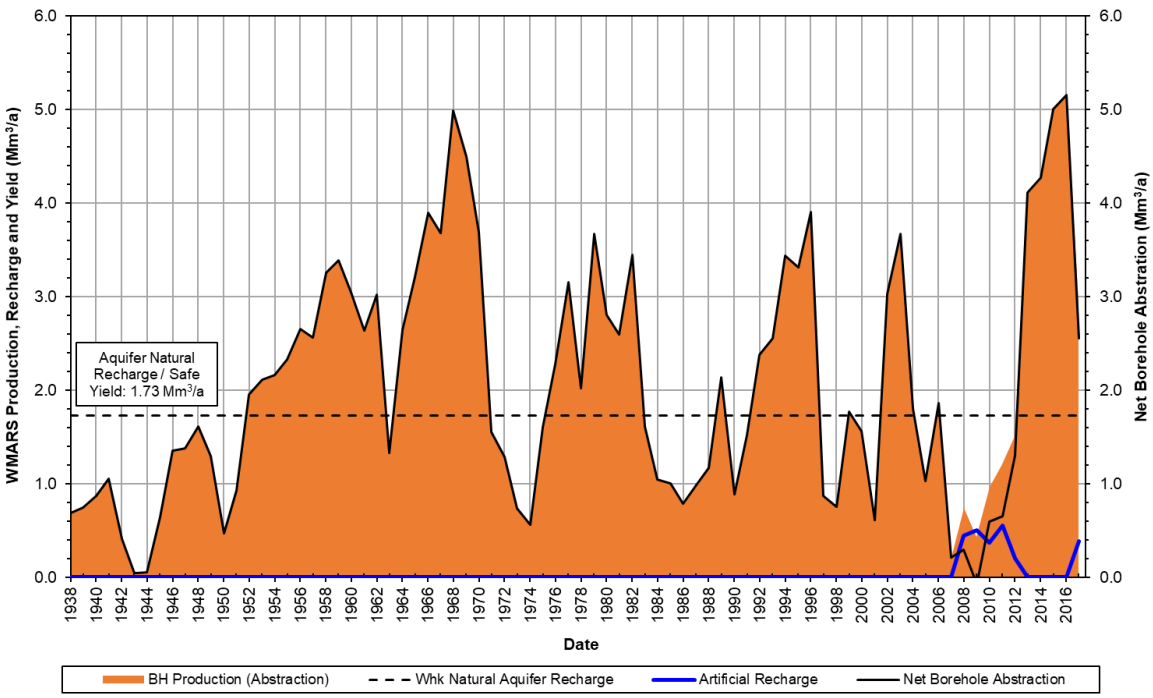

Figure 6.10: Production from, Recharge and Yield of the Windhoek Aquifer (LCE-SCE JV, 2019)

Notes:
1. Data provided by the City of Windhoek under NamWater's CAN Medium Term Options Project.
2. The accepted natural recharge and therefore the sustainable yield of the aquifer is 1.73 Mm^3/a. Refer to the text.
3. Net Borehole Abstraction = Borehole production or abstraction less artificial recharge.

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Net abstraction from the aquifer (production or abstraction less recharge) has been positive every year except 2009 when slightly more water (0.074 Mm3) was recharged than abstracted, and has been above the natural recharge rate of the aquifer for 41 years of the 80 for which data is available.

In particular, high rates of abstraction from the Windhoek Aquifer have occurred after 2013 as the levels in the CAN dams have dropped following several years of below average inflows (LCE-SCE JV, 2019).

Despite high levels of abstraction from the Windhoek Aquifer, particularly during the 2015-17 drought in the CAN, water levels in many of the boreholes have proved resilient, as shown in **Figure 6.11** for Borehole 12/12B, which is a deep borehole drilled in 2006/07. Despite high rates of abstraction (130 – 160+ m^3/h), the water level in this borehole has remained relatively constant. Under the CAN Medium Term Options Project, this was shown to be the case for other deep boreholes in the Windhoek Aquifer as well, suggesting that the assumptions regarding stored volume and recharge of the aquifer are conservative.

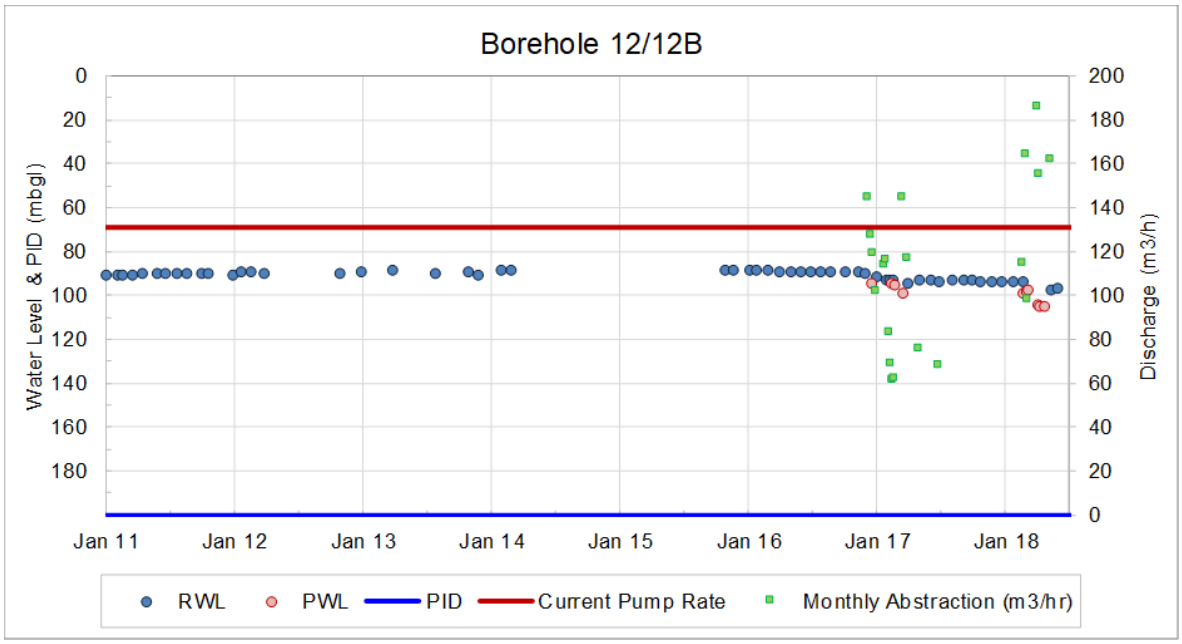

Figure 6.11: Water Levels and Abstraction for Borehole 12/12B in the Windhoek Aquifer (LCE-SCE JV, 2019)

6.3.2.5 Water Quality

6.3.2.5.1 Quality of the Abstracted Water

The water quality of the Windhoek Aquifer varies between the different boreholes, due to the complexity of the geology, the depth (and date) of the boreholes, and which boreholes and groups of boreholes have been used for artificial recharge and which for production, and at what rates, and is thus overall complex.

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In general, the water quality of the Windhoek Aquifer is good, excellent in the case of some boreholes and groups and generally poses no health concerns. Some specific considerations include:

1. In the boreholes drilled between 2005 and 2008:
   a) The water from all the boreholes is aggressive (Langelier and Ryznar) and corrosive and blending with other water sources as well as stabilisation before introduction into the CoW network for distribution to end consumers is needed;
   b) Most of the borehole water is hard except for boreholes at 12/5 which are moderately hard and borehole BH 7/4 B which is very hard;
2. In the boreholes drilled in 2016/17:
   a) Some boreholes shoed high to very high turbidity values;
   b) Most of the boreholes exceed the Iron and Manganese levels of the NWQS, although the strict requirements make compliance for borehole water almost impossible All the manganese levels were below the WHO guideline for health standards which may not be higher than 0.4 mg/ℓ for manganese. Depending on the degree of dilution, the elevated levels of iron may result in taste effects and the staining of plumbing and utensils at household level. Before dilution takes place within the distribution system, deposition of iron could reduce flow rates;
   c) The maximum annual production capacity to prevent the occurrence of brown water in the water network of Windhoek caused iron and manganese is in the order of 9 to 9.5 Mm^3/a, based on tests conducted by the CoW.

The CoW in March 2018 put out a tender for consultancy services to address the water quality concerns (turbidity, iron and manganese precipitation) as well as heat dispensation associated with high abstraction rates from the aquifer. This tender has not yet been awarded.

6.3.2.5.2 Quality of Injection Water

An investigation into the water quality requirements for artificial recharge of the Windhoek Aquifer found that the high levels of organic compounds and disinfection by-products in the water supplied to Windhoek "*may result in unknown effects when recharging….and may threaten the long-term sustainability of artificial recharge*" (WAJVC, 2005). The Rand Water / South African Guidelines (as applicable at that time) were investigated as "modern" drinking water standards, together with various aspects relating to the quality of the water supplied by NamWater, the New Goreangab Water Reclamation Plant (NGWRP; reclaimed water) and the hydrochemistry of the Windhoek Aquifer, along with other considerations.

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This 2005 investigation recommended that the Rand Water (95 percentile values) and the South African (Class 0 or 95 percentile values; as applicable at that time) water quality guidelines be adopted as the general guidelines for injection water, with some modifications proposed on an interim basis, including lower limits for Dissolved Organic Carbon (**DOC**), Electrical Conductivity (**EC**), Sulphate and Nitrate and Nitrite (measured as Nitrogen) (WAJC, 2005).

This 2005 investigation into the water quality requirements for artificial recharge of the Windhoek Aquifer recommended that in general, the Rand Water (95% percentile values) and the SANS 241:1999 specifications (as at the time) for Class 0 (95% percentile values) be adopted as the "*general guideline*[s] *for the injection water*" (WAJVC, 2005). Specific amendments to these guidelines were proposed for 6 parameters or determinants, as shown in **Table 6.3**.

Table 6.3: Specific Recommendations for Water Quality Limits for Artificial Recharge of the Windhoek Aquifer (WAJVC, 2005)

Determinant	Unit / Symbol	Rand Water Guidelines (95%)	Recommendation for Artificial Recharge
Dissolved Organic Carbon	mg/ℓ	5	4
Assimilable Organic Carbon	Growth rate/h	0.15	0.15
Electric Conductivity	mS/m	70	60*
Chloride	mg/ℓ Cl	100	100
Sulphate	mg/ℓ SO_4	200	50
Nitrate and Nitrite	mg/ℓ N	6	5

* The Electric Conductivity (EC) may be adjusted upwards to a maximum of 70 mS/m in areas where the prevailing EC level in the groundwater of the injection area is above 60 mS/m (WAJVC, 2005).

It was recommended that these guidelines be revisited after 2 years of intensive data collection and evaluation after further pilot injection in the Phase 1b boreholes of the Windhoek Aquifer (WAJVC, 2005).

To the Consultant's knowledge, these guidelines have not yet been reviewed, although the CoW did intend to, under Procurement Ref. SC/RP/COW-30/2018, appoint consultants to establish and verify the water quality parameters for abstraction from and artificial recharge of the Windhoek Aquifer. The closing date for bids on this tender was 20 April 2018 and to date (June 2019) the CoW had not yet awarded the contract.

Under considerations of costs and cost-effectiveness, it is recommended that the more stringent requirements for artificial recharge of the Windhoek Aquifer should apply only to the volumes to be recharged and not to all the water to be treated / supplied under this Project.

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6.3.2.6 Completion of the Windhoek Managed Aquifer Recharge Scheme

A detailed report, funded by KfW, on the feasibility of the WMARS in terms of the requirements for funding from the Green Climate Fund (**GCF**) was completed at the end of June 2016 (Van der Merwe, 2016). The United Nations Development Programme (**UNDP**) was subsequently identified to prepare and submit the project for GCF consideration. The resulting submission was made to the GCF by the UNDP (as an accredited agency) in June 2017.

The updated cost estimate for the completion of the WMARS project submitted to the GCF, was N$ 679.831 million, which included price escalation for implementation over a 3-year period (US$ 51 619 676). Increasing the estimate of N$ 679.831 million with 10% for escalation, alternatively applying an exchange rate of 1 US$ = 14.5 N$ to the US$ 51 619 676 estimate, gives an estimate of approximately N$ 747.814 million in current (2018/19) terms for the completion of the WMARS project (LCE-SCE JV, 2019).

6.3.2.7 Previous Assessments and Yield of the Windhoek Aquifer

It is important to note that the full completion of the WMARS project was assumed as a medium-term initiative, prior to the completion of the Okavango – Grootfontein supply scheme under the WAS. The implementation of supply from the Okavango River was thus analysed as being cumulative to the full implementation of the WMARS project (LCE-SCE JV, 2017).

The full benefit or value of the WMARS project is difficult to quantify in straightforward terms, since it is analysed using the CA-Model and expressed in terms statistical values, and is moreover dependant on the availability of water for the recharge of the aquifer. Without further direct potable reuse and the development of the WMARS project, the maximum shortfall volume (99 percentile value) was estimated to be approximately 42 Mm^3/a by 2030. With further direct potable reuse and the development of the WMARS project, the maximum shortfall volume (99 percentile value) was estimated to decrease to 28 Mm^3/a by 2030 (Van der Merwe, 2016), indicating how the full development of the WMARS project could lead to the downsizing of outside augmentation requirements.

The benefit of the WMARS scheme is believed to most prominent in the medium term, decreasing into the long-term, as the water demands of Windhoek increase relative to the size of the water bank. In the short-term, and as long as it remains the case, the full benefit of the WMARS scheme is limited by the availability of water for recharge (water banking).

Modelling analysis conducted under the 2011 BWMP suggest that if the WMARS Project is extended to provide abstraction capacity of 19 Mm^3/a less the natural recharge of 1.73 Mm^3/a, the benefit of the scheme is approximately 7.13 Mm^3/a, net of the natural recharge.

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In order to quantity the benefit of the WMARS scheme, the output files generated by the CA-Model with the modelling analyses conducted under the CAN WAS (2017) were analysed. The best estimate derived from this assessment is approximately 5 Mm^3/a overall benefit for the WMARS project in terms of a "stand-alone" supply value. It should be noted that the scenarios analysed under the CAN WAS (2017) were cumulative, and assumed the WMARS scheme (Scenario 4), additional reclamation (Scenario 6) and supply from the Okavango River (Scenario 7).

However, a shortcoming with the CA-Model is that supply from the Okavango River is triggered by an "emergency" condition, which is defined as a water level in Von Bach Dam below 40%. At this same level, the emergency groundwater supply routine is activated (if so selected) and water banking or artificial recharge is halted. Thus, by the time supply from the Okavango River is activated, artificial recharge no longer takes place, which reduces the longer-term benefit of the WMARS scheme. A further shortcoming in the CA-Model is that it cannot accommodate artificial recharge of and abstraction from the Windhoek Aquifer in the same year; only one or the other for any given year.

There is therefore considerable uncertainty regarding the benefit of the WMARS scheme, which is an aspect which should be investigated more accurately once NamWater has replaced the CA-Model with a more flexible numerical planning / yield model. For the time being, it is proposed that 5 Mm^3/a be adopted as the overall benefit for the WMARS project in terms of a "stand-alone" supply value, whilst acknowledging the considerable uncertainty surrounding this value.

6.3.3 Reclaimed Potable Water

6.3.3.1 Potable Water Reclamation in Windhoek

The reclamation of water does not affect primary sources such as surface reservoirs or groundwater. Another benefit of reclamation is the lowering of the peak demands on NamWater's bulk water supply infrastructure. If water was not reclaimed in Windhoek, the bulk supply from Von Bach Dam would need to be increased at an earlier date to cater for the increased demand and higher demand peaks of the City's residents (LCE-SCE JV, 2017).

The New Goreangab Water Reclamation Plant (NGWRP) supplies purified water drawn from the effluent of the Gammams Wastewater Treatment Plant (GWWTP) (mainly residential sewage effluent) directly into the potable water network of Windhoek (this is therefore Direct Potable Reuse; **DPR**).

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The plant is located on the western extremity of Windhoek, below the Goreangab Dam, and was commissioned in 2002, with a design capacity of 21 000 m³/d (7.5 Mm³/a[46]). The NGWRP is owned by the CoW and operated, under contract, by the Windhoek Goreangab Operating Company (**Wingoc**) (LCE-SCE JV, 2017).

During the 2017 calendar year, the NGWRP produced 16 300 m³/d (5.957 Mm³/a), which increased to ±18 037 m³/d (6.59 Mm³/a) during the 2018 calendar year, or 26% of the total supply of potable water to Windhoek.

An oil spill at the Namibia Dairies plant in Avis on 03 February 2019 resulted in the CoW closing down the GWWTP and the NGWRP which adversely impacted on water supply to the City, since 25% of the supply constituted reclaimed water from the NGWRP (Erastus, 2019a). Operation of the NGWRP resumed on 08 March 2019 again (Erastus, 2019b). This is the first known major incident at the NGWRP since its commissioning in 2002 (±17 years), The actual reliability of supply from the NGWRP is however a more complex matter which is beyond the scope of this Study.

6.3.3.2 Previous Proposals for Additional Potable Water Reclamation in Windhoek

Proposals for additional DPR in Windhoek were analysed as a medium-term scenario in the CAN WAS (2017) and found to be advantageous, particularly in combination with the full completion of the WMARS project. Under that assessment, additional reclamation of 11.8 Mm³/a was investigated (7.6 Mm³/a for the full capacity of Wingoc, plus 4.2 Mm³/a of additional reclamation, which could later be expanded in modular fashion as required; LCE-SCE JV, 2017).

6.3.3.3 Proposals for Increased Efficiencies and Output of the Current Reclamation Facility

Several proposals to increase the efficiency and hence output of the NGWRP were put forward under NamWater's Medium Term Options project, including replacing the raw water inlet butterfly valve with a pinch valve or a knife valve, changing the SCADA system to change the frequency and interval of the hopper desludging and de-scumming of the DAF units, installing 5 SUTRO weirs in the inlet of each sand filter, changing the pipeline from the ozone contact tank to the BAC filters and installing 16 purpose-made SUTRO weirs to even the flow distribution amongst the granular carbon filters. By introducing these measures, the targeted production should increase by approximately 0.5 Mm³/a at least, to 6.5 Mm³/a (LCE-SCE JV, 2019).

[46] Including provision for a shutdown of 7 to 8 days per year for scheduled maintenance. The best performance and water quality is achieved with continuous runs at a constant rate.

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Wingoc has indicated that the output of the NGWRP has been and is adversely affected by WDM measures implemented in Windhoek (particularly during the 2016/17 drought period). If changes are made to the GWWTP, to address the shortfall in influent or feed water to the NGWRP, which occurs over week-ends from around mid-night on Saturday night until around mid-morning on Mondays, and during the December / January holiday period, it may be possible to obtain a further 0.5 Mm^3/a of reclaimed water from the NGWRP, thus 7.0 Mm^3/a in total (LCE-SCE JV, 2019).

6.3.3.3.1 Proposals for Additional Treatment of the Reclaimed Water for Artificial Recharge

The manifestation of rising Total Dissolved Solids (TDS) with the reclaimed water has been noted as one of two problems associated with Direct Potable Reclamation in Windhoek (WHO, 2017b). Within the cycle of water use and reuse, salts build up over a period of time, because there is no specific treatment process by which these are removed[47]. With the "input" water into the system from the VBWTP not able to meet the requirements for artificial recharge (refer above), the reclaimed water will not be able to either.

In order to be able to use reclaimed water for artificial recharge of the Windhoek Aquifer, the salt content would need to be lowered, which would require a Reverse Osmosis (RO) treatment step (WHO, 2017b) at the NGWRP / Wingoc. Whilst RO is problematic in an inland location, due to the need to dispose of the brine in an environmentally responsible manner, either full or partial (with blending with surface water) RO treatment of the reclaimed water should enable it to meet the requirements for artificial recharge of the Windhoek Aquifer. This is advantageous in that only the water needed / to be used for artificial recharge will require "advanced" treatment, which will be more economical than treating all the water supplied to Windhoek by NamWater to this more stringent requirement. With very little artificial recharge having taken place in recent years, due to infrastructure shortcomings and recurring water shortages (refer to **Figure 6.10**), it is imperative that some water is injected back into the aquifer in order to avoid the depletion of this resource which would adversely impact on the supply security to the CAN.

If RO membranes are added at the NGWRP, it is estimated that up to 7.00 Mm^3/a could be made available for artificial recharge of the Windhoek Aquifer. This constitutes a "substituted supply"; i.e. the 7.00 Mm^3/a produced by the extended NGWRP / Wingoc (possibly with some blending of surface water) would be used to recharge the aquifer instead of being consumed in Windhoek (as currently) and "replaced" with the consumption of 7.00 Mm^3/a of surface water, provided by NamWater, whilst sufficient surface water is available. In the short-term, this would lead to savings in evaporation losses from the CAN dams, owing to the increased utilisation of surface water, whilst in the longer-term, this would contribute to an improved security of supply and more beneficial use of

[47] Essentially the only process step which effectively removes salinity (TDS) is Reverse Osmosis (RO) (WHO, 2017b), which is not employed with the basic potable water supply by NamWater (i.e. at the Von Bach Water Treatment Plant), with wastewater treatment (at the Gammams Waste Water Treatment Plant) or with reclamation (at the New Goreangab Water Reclamation Plant or Wingoc).

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the WMARS project, which would otherwise be limited without artificial recharge of the Windhoek Aquifer.

The proposal for the RO treatment of reclaimed water dates from 2016 (Lithon et al., 2016a), and has been investigated, though not in detail, under the CAN Medium Term Options Project. That assessment recommended a full feasibility study into the water quality requirements and possible RO portions and blending ratios which would be required for this concept (LCE-SCE JV, 2019), but such a study is still to be initiated.

Therefore, the above proposals are still under consideration by the TCE, NamWater and the CoW and are not yet finalised or approved.

6.3.3.3.2 Current Proposals for Additional Potable Water Reclamation in Windhoek

In August 2015 the City of Windhoek (CoW) invited tenders for consulting services for determining design parameters for the planned Gammams Advanced Water Reclamation Plant (GAWRP), which was envisaged as an additional reclamation plant (i.e. in addition to the NGWRP), and which has since been referred to as “DPR 2”, denoting the second direct potable water reclamation facility, after the NGWRP / Wingoc. After an initial design phase, the original intention was to pilot a selection of treatment processes / trains for which the CoW sought funding from KfW. The current (mid-2019) intentions are to proceed with the design of a plant based largely on the proven and validated process of the NGWRP. Whilst it has been estimated that ~4.0+ Mm^3/a of additional potable water could be reclaimed in the short to medium term by reconfiguring the wastewater / DPR configuration of Windhoek (LCE-SCE JV, 2019), this can be expected to increase in line with future water use. However, these proposals for the reconfiguring the wastewater / DPR configuration of Windhoek are still under investigation, thus not yet finalised and are not yet approved by the CoW.

6.3.3.3.3 Proposals for Future Potable Water Reclamation in Windhoek

A study in Australia has found that DPR was cheaper and thus more favourable than providing semi-purified water and the installation of a dual pipe network and cheaper and thus more favourable than seawater desalination (Law, 2018). Similar results are expected in Windhoek / Namibia, particularly relative to the supply of desalinated water to Windhoek, some 350 km distance-wise and 1 700 m elevation-wise from the coast. It is therefore clear that DPR will be implemented in Windhoek on the basis of costs / economy, as it will unquestionably be cheaper (and require less energy) to maximise the use/reuse of water close to the source rather than transferring it from far away at great cost.

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However, there are no currently available plans for DPR in Windhoek which extend to 2050, the Planning Horizon for this Study. In order to estimate the volumes of reclaimed water which may be available across the Project Horizon, it is proposed that different scenarios are put forward, using different percentage-values of reuse. Three scenarios are proposed, namely:

1. 35% Reuse: This corresponds with the current restrictions on the blending ratio of reclaimed / potable water, due to restrictions on the Dissolved Organic Carbon (**DOC**; < 1 mg/ℓ) which originates from treated wastewater and which is not completely removed with the current processes at the NGWRP / Wingoc. This is considered a lower-case value, as DPR treatment will in future most likely incorporate some membrane filtration, likely RO, which would remove the DOC;

2. 45% Reuse: With RO as part of any future DPR treatment process, the current DOC restrictions on the blending ratio fall way. Whilst the ultimate aim may be to reclaim up to 50% of all potable water supplied (refer below), this scenario is considered to be a more realistic target, allowing for factors such as: Not all development / water use will fall within the catchment area of the DPR plant, there may be a slightly higher than current portion of industrial water use (not suitable for reclamation) and that efficiencies may not match the values assumed;

3. 50% Reuse: With RO as part of any future DPR treatment process, the current DOC restrictions on the blending ratio fall way and as much water can be reclaimed as possible. This is the maximum blending ratio currently in use in the world, in Wichita Falls, Texas, where reclaimed water is blended into surface water prior to conventional water treatment. The further conventional treatment of reclaimed water is unlikely to be implemented in Windhoek, due to cost considerations and the fact that the current conventional treatment of surface water takes place 65 km way from Windhoek, and this likely represents an upper bound for reclamation in Windhoek.

6.3.4 Semi-Purified Irrigation Water

Between 1990 and 1992 a dual pipe system was installed in Windhoek to distribute semi-purified irrigation water for the restricted irrigation of sports fields, parks and cemeteries in the City. In 2002, the Old Goreangab Water Reclamation Plant (OGWRP) was integrated into this system to supply filtered and chlorinated water for unrestricted irrigation through the dual pipe system.

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The provision of semi-purified irrigation water can be seen as a substitute for potable water as it does not impinge on the primary surface water and groundwater sources providing water to Windhoek. Water for semi-purified irrigation is obtained from Goreangab Dam and treated sewage effluent via the GWWTP. In 2017 (calendar year), the OGWRP produced 1.344 Mm^3 of semi-purified water for distribution via the dual pipe system in Windhoek, which increased to 1.894 Mm^3 production in 2018 (calendar year).

It is proposed that semi-purified water not be considered separately in terms of the supply capacity available at the end of the Project Horizon, under the assumption that this will be included in the higher rates of DPR (i.e. total reclamation = DPR + semi-purified) or that semi-purified water will be phased out and replaced with DPR[48].

6.3.5 Northern Groundwater Sources and System

6.3.5.1 Current and Previously Available Data and Analyses

NamWater supplies groundwater from the Karst I Aquifer and Karst II Aquifers into the ENWC Canal via the Kombat Mine and Brandwag Boreholes and Berg Aukas Mine schemes respectively. This water gravitates via the canal as far as Omatako Dam, from where it is pumped to Von Bach Dam. Large volumes of water are abstracted from the ENWC Canal at the Waterberg Off-take for supply to Okakarara and the Waterberg Water Supply Area further to the northeast and east.

The nomenclature used by NamWater's CA-Model refers to the Northern Users as all users and the sub-system (supply and demand) to the north of the Von Bach Node, therefore the Karst groundwater supply, the ENWC Canal, Omatako Dam and the Omatako – Von Bach transfer system.

The most recent supply and demand modelling for the CAN was conducted in mid-2018 under the CAN Medium Term Options project of NamWater, in a manner similar to that done previously for the CAN WAS. Groundwater supply from the northern aquifers in particular, was investigated via two (sub-) baseline options:

- Scenario 1a: Groundwater abstraction at sustainable rates, i.e. abstraction is less than or equal to recharge rates, using the same recharge / sustainable abstraction rates as for the Okavango River feasibility study (CAN WAS);
- Scenario 1b: Analyses with the emergency supply routine of the CA-Model activated, which allows the possible and prolonged use of groundwater at rates above those which are sustainable over the longer-term, using the same emergency abstraction rates as for the Okavango River feasibility study (CAN WAS).

[48] In consideration of the results of a study in Australia, which found that Direct Potable Reuse was cheaper and thus more favourable than the option of providing semi-purified water and the installation of a dual pipe network (Law, 2018). Similar results are expected for applications / conditions in Namibia.

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The results of the modelling carried out for NamWater's CAN Medium Term Options assessment showed shortfalls in the supply of the Northern Users for both the (sub-) baseline options investigated. Shortfalls for the Northern Users (north of the Von Bach node) indicate that the groundwater sources upstream of Omatako Dam fail to sufficiently provide the corresponding demands and / or users between Omatako and Von Bach do not receive sufficient supply from either the upstream groundwater supply or from Omatako Dam itself.

These shortfalls are relatively small (~0.15 – 0.16 Mm^3/a by 2034/35) and the expectation is that these can be addressed by reducing losses from the ENWC Canal and by increased efficiencies in particularly the Waterberg Water Supply Area (increased billing efficiencies, debtors' controls, more accurate recordings {water meter replacements}, and reduced NRW). Nevertheless, these results indicate that the sustainable use of the Karst groundwater sources will not be sufficient to supply the users north of the Von Bach Dam by the end of the Project Horizon (2050).

Table 6.4: Normal and Emergency Abstraction Rates from the Karst I and Karts II Aquifers from Different Assessments

Scheme and Aquifer	Abstraction Values (Mm^3/a) Used for the CAN Medium Term Options Study[1]		Abstraction Values (Mm^3/a) Used for the Okavango River Feasibility Study[2]	
	Normal / Natural Recharge	Emergency	Normal / Natural Recharge	Emergency
Kombat Mine (Karst I)	2.64[5]	5.4[6]	2.64[5]	3.81[7]
Brandwag (Karst I)	0.009	1.48	0.009	1.48
Berg Aukas Mine (Karst II)	1.60[5]	5.20[6]	1.60[5]	5.20[7]

Notes:
1. NamWater's CAN Medium Term Options Project (LCE-SCE JV, 2019).
2. The Water Augmentation Study of the Central Area of Namibia (CAN WAS) (LCE-SCE JV, 2017).
3. Normal period abstraction is normally set equal to the natural recharge values for long-term sustainable supply.
4. The Emergency abstraction indicates higher rates of abstraction which are permissible over shorter periods, during "emergencies".
5. Natural recharge rates for the Karst I and Karst II Aquifers were provided by NamWater under the CAN WAS (LCE-SCE JV, 2017).
6. Emergency abstraction rates for the Karst I and Karst II Aquifers were provided by NamWater under the CAN Medium Term Options study (LCE-SCE JV, 2019).
7. Emergency abstraction rates for the Karst I and Karst II Aquifers as per permit-approved values, which rates were at or close to the installed capacities at that time (per NamWater) (LCE-SCE JV, 2017).
8. The Berg Aukas Boreholes are not shown, as they supply water to Otjituuo and the area towards Elandspan and not into the greater CAN system.

The assessments conducted for both the CAN WAS and the CAN Medium Term Options studies indicated that without reuse and WDM measures, the demand of Otjiwarongo will surpass the sustainable capacity of the Otjiwarongo Marble Aquifer before 2050 (by 2035 in the latter case; LCE-SCE JV, 2019), following which supply to the town will need to be augmented from outside sources.

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This would most likely be via a pipeline supplying water from the ENWC Canal, south of the Waterberg Off-take, which would thus place additional demand on the Karst Aquifers.

Under the CAN WAS, water supply to Otjinene was investigated, and it was found that the demands may likely exceed the safe yield of the current groundwater supply before 2043, and therefore that Otjinene would require water augmentation before 2050. The Otjinene Water Supply Scheme is located in the Okavango – Epukiro Basin, with the boreholes supplying the town boreholes drilled into Kalahari sediments which overlie sediments of the Damara Sequence. The drilling success (defined as the percentage of boreholes yielding more than 1 m^3/h) is less than 25% in fractured aquifers beneath thick unsaturated Kalahari layers [as in Otjinene]. The most difficult areas to find groundwater are those to the north and east of Otjinene (after Christellis and Struckmeier, 2001). It may therefore not be possible to rely on groundwater sources to supply Otjinene in the future (LCE-SCE JV, 2017), in which case supply augmentation may need to be via the Waterberg Water Supply Area schemes, which would rely at least in part on groundwater from the Karst Aquifers.

It is therefore likely that before 2050, groundwater from the Karst area would need to supply not only the existing consumers, for which sustainable supply is likely to be inadequate, but additional centres such as Otjiwarongo and Otjinene as well. For these reasons, the northern groundwater sources have not been included in the supply capacity available to the Von Bach Node and it is proposed that for the purposes of planning at the end of the Project Horizon (2050), groundwater from the Karst Area will be used to supply users north of Omatako Dam, as currently, with no transfer further to the south under normal conditions. Infrastructure capability should be provided to be able to transfer groundwater from the Karst Area to Von Bach Dam under emergency conditions (as currently). It should further be noted that this proposal is aimed primarily at estimating infrastructure requirements (mainly the transfer pipeline) for the end of the planning horizon and does not impact on operational aspects of supply in the short- and medium-term. Should desalinated water supply be implemented, this will likely be in a phased manner, with supply increasing over a period of time and therefore not immediately curtailing the supply of Karst groundwater south of Omatako Dam.

6.3.5.2 Revised Recommendations for the Yield and Operation of the Karst Groundwater Sources

NamWater has appointed specialists to construct numerical groundwater models for the Berg Aukas and Kombat Mines, in order to derive updated and more accurate estimates of the normal / natural recharge and / or sustainable use of these key groundwater sources. Preliminary results from the groundwater model for the Berg Aukas Mine indicate that an abstraction rate of 4.66 Mm^3/a may be sustainable for up to 10 years (Jacobs, 2019). This however has not yet been approved by NamWater.

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A numerical groundwater model for the Kombat Mine is still in the early phase of development. It is possible, as indicated by the preliminary results of the modelling of the Berg Aukas Mine, that more groundwater may be available from the Karst Area I and Karst Area II Aquifers on a sustainable basis than previously thought (to be confirmed).

Should additional groundwater supply be able to be harnessed sustainably and / or the demands of current and potential existing consumers not grow as projected, and surplus water is available to the north of Omatako Dam, this could be supplied to currently undeveloped areas to the east of the Waterberg Water Supply Area, where there is the potential to develop grazing areas and farming units up to the border with Botswana. There may also be the potential to develop conservancies which are located in the northern and north eastern Otjozondjupa Region and eastern Omaheke Region.

It is therefore highly unlikely that there will be a problem of too much water; should additional water be available from the Karst Area I and Karst Area II Aquifers, a demand for it can easily be established.

6.3.5.3 Abenab Mine and Remnant Dyke / Karst III Aquifer

The Karst Area IV covers a large area to the north of Grootfontein and to the north and east of Tsumeb, which area includes the Remnant and Tsumeb Dykes and the Abenab mine to the east of Tsumeb. This area is known to have a potentially significant groundwater potential, and could be combined with the groundwater abstracted from the Karst Area III located to the north of Grootfontein and some 10 km south of Abenab Mine, for the supply of water to the CAN via the ENWC Canal.

NamWater is busy investigating water supply from the Abenab Mine / Karst III Aquifer as a medium-term and / or emergency supply option following their own development proposal / feasibility investigation in 2014 (NamWater, 2014). Previous investigations into the use of the Abenab Mine Karst Area IV Aquifer have focussed on the latter scenario, which, based on the Tsumeb Groundwater Study (undertaken by GKW and Bicon and reported on in 2002), proposed 12 Mm^3/a as an unsustainable or emergency abstraction rate which could be maintained for a maximum of 3 years, after which 12 years would be needed for the aquifers to recover (LCE-SCE JV, 2017). There is however some uncertainty regarding whether this is still possible, given other groundwater use in the area, as well as possible environmental concerns. Different abstraction scenarios can unfortunately not be re-assessed using the groundwater model setup under the Tsumeb Groundwater Study, which although it was submitted to NamWater under that project, no longer appears to be available.

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If an abstraction rate of 36 Mm^3 (12 Mm^3/a over 3 years) is distributed linearly over the 15-year cycle, a possible sustainable abstraction rate of 2.4 Mm^3/a can be derived. Considering that this water would be pumped into the ENWC Canal near its start outside Grootfontein, and considering the high losses incurred along the canal, as well as the evaporation losses from the Omatako and Von Bach Dams, the portion of 2.4 Mm^3/a which would eventually reach Windhoek, the largest demand node in the CAN, is not considered to be very significant in the context of the water demand in 2050. Given the shortfalls expected in the ENWC Canal system and the possibility of having to supply additional demand areas or nodes in future from the Canal in future (refer above), it is considered unlikely that any significant (if any at all) volumes of water would reach Windhoek if groundwater is supplied into the Canal at this rate.

However, water supply from the Abenab Mine / Karst III Aquifer is one of the possible medium-term options identified under Phase 1 of the CAN Medium Term Options Study and which is thus due for further investigation under Phase 2 of that project, with results not expected before the end of calendar 2019. The possible supply of water to the CAN from the Abenab Mine / Karst III Aquifer is therefore under investigation and details are not yet available regarding the likely contribution to water supply in the Von Bach Node. This option is believed by NamWater to offer a significant supply potential in the medium-term, possibly to bridge the period during which a long-term supply option is being implemented.

Unfortunately the performance of an aquifer can only be established over a period of time, by monitoring abstraction from, recharge of and water levels in the aquifer. Thus, any greater certainty regarding the sustainable use of the Abenab Mine / Karst III Aquifer can only be obtained after some years of larger-scale abstraction from the resource.

The Abenab Mine / Karst III Aquifer was investigated as one of the possible scenarios or alternatives for medium-term supply in the Okavango River feasibility study, but was found to be less favourable than the full development of the WMARS project and even less favourable than the full development of the WMARS project with additional reclamation for artificial recharge (LCE-SCE JV, 2017). For these reasons, the water supply from Abenab Mine was not considered or incorporated into the final results of the Okavango River feasibility study.

Since the Abenab Mine / Karst III Aquifer supply was not considered under the final results of the Okavango River feasibility study, and due to the uncertainty regarding the long-term use of these resources (considering the Project Horizon of 2050), which is still under investigation, this option has not been quantified in terms of the long-term supply for 2050, but is proposed in terms of medium-term supply.

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6.3.6 Alternative Options for Supply Augmentation to the Central Area of Namibia

Under the Assessment and Selection of the Most Feasible Medium-Term Water Supply Alternatives for the Central Area of Namibia (the *CAN Medium Term Options* project), NamWater assessed the options available for the augmentation of water supply to the CAN. The outcomes of Phase 1 of that assessment (initial shortlisting of options) can be summarised as follows (LCE-SCE JV, 2019):

- Short-Term Options: In the short-term (±5 years), supply to Windhoek can be improved by:
  - Intensifying Water Conservation / Water Demand Management (WC/WDM) measures;
  - Better utilisation of the water from the “hot boreholes” which do not form part of the WMARS project. Abstraction from these BHs does not appear to influence the levels in the water bank in the short term (an additional 1.5 Mm^3/a);
  - Upgrades to the New Goreangab Water Reclamation Plant (NGWRP):
    - Several minor changes were investigated to increase production from 5.96 Mm^3/a in 2017 to 6.5 Mm^3/a or even 7 Mm^3/a (refer above). Production of 6.59 Mm^3/a was already achieved in 2018 (calendar year), suggesting that the NGWRP is operating very close to optimally;
    - If RO membranes are added at the NGWRP, it is estimated that up to 7.00 Mm^3/a could be made available for artificial recharge of the Windhoek Aquifer. This constitutes a “substituted supply”; as explained above;
- Medium-Term Options (approximately 5 to 15 years): In the medium term, supply to Windhoek can be augmented by up-scaling and further developing existing options / schemes and increasing water (re)use efficiency, namely by:
  - Construction of a second Direct Potable Reclamation Plant (“DPR 2”) in Windhoek to provide additional volumes of potable reclaimed water:
    - In the shorter-medium term, increased volumes of treated effluent for reclamation can be provided by increasing the efficiency of the Gammams Waste Water Treatment Plant (GWWTP), and increasing the efficiency and capacity of the Otjomuise Waste Water Treatment Plant (OWWTP) (the latter to be confirmed with a feasibility study for the substitution of effluent volumes from the GWWTP for reclamation at the NGWRP);
    - In the longer-medium term, increased volumes of treated effluent for reclamation can be provided by increasing the capacity of the Gammams Waste Water Treatment Plant (GWWTP);
  - Increasing the injection and abstraction capacity of infrastructure in Windhoek associated with the WMARS project and drilling additional deep bore-

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holes, to be able to access larger volumes for emergency supply and to allow larger volumes of recharge when surface / reclaimed water is available;

- Supply from Abenab Mine / Karst III Aquifer: This supply option is currently under investigation by NamWater with the intention that it be implemented, following a development proposal / feasibility investigation by NamWater in 2014 (NamWater, 2014) (refer also above);

- Long-Term Options (25+ years): Long-term options for the supply of water to the CAN which are under consideration by NamWater include the supply of water from the following:
  - The Okavango River;
  - The C(K)unene River;
  - Neckartal Dam;
  - Desalinated seawater.

The supply of water to the CAN from the Okavango River was the subject of an engineering feasibility study undertaken by the MAWLR between 2013/14 and 2017 (LCE-SCE JV, 2017). The environmental and social feasibility study into the supply of water from the Okavango River has not been completed.

The supply of water from the Kunene River and Neckartal Dam was analysed at a high level under NamWater's *CAN Medium Term Options* project, where it was found that both options are long-term options (as opposed to medium-term options) and would require further analyses and investigations to confirm their suitability for long-term supply to the CAN, including the possible / observed correlation with the hydrological conditions in the CAN (LCE-SCE JV, 2019).

The supply of desalinated seawater to augment the existing supply to the CAN, as a long-term supply option, is the focus of this Study, which is also to be compared with the supply to the CAN of water from the Okavango River under a later phase or component of this Study.

All of these short- to medium-term options are still to be further investigation under Phase 2 of NamWater's *CAN Medium Term Options* project and are still under consideration by the TCE, NamWater and the CoW and are not yet quantified, finalised or approved at this juncture.

In terms of proposals for additional reclamation, different options have been prepared on the basis of differing percentages of the potable water supply rather than in outright volumetric terms.

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6.3.7 Summary of the Resource Analyses and Supply Scenarios

Different options have been put forward for the utilisation of the different resources available to the Von Bach Node in the CAN, as follows:

- The Windhoek Managed Aquifer Recharge Scheme:
  - Long-term abstraction is limited to the natural recharge of the Windhoek Aquifer, 1.73 Mm^3/a (Zhang et al., 2002) if the WMARS project is not fully developed or completed and / or there is insufficient water available for the recharge of the aquifer once it has been depleted in the short- to medium-term;
  - If the WMARS project is fully developed / completed, and sufficient water is available for artificial recharge, for example from DPR, the best estimate of the overall benefit of the scheme is believed to be 5 Mm^3/a;
- Surface water sources from the 3-Dam System;
  - Abstraction of 20 Mm^3/a proposed by NamWater, which is believed to be at 95% assurance (NamWater), per the 2004 CAN WAS (CAJVC, 2004c)[49];
  - Abstraction of the approximately 99% safe yield of 10 Mm^3/a as estimated by the Consultant, which best approximates the goal of 99% security of supply usually adopted by NamWater, and that adopted with previous feasibility studies, including for comparison with the Okavango River feasibility study;
- Water reclamation in Windhoek:
  - Additional reclamation of 11.80 Mm^3/a in the short- to medium-term, as assumed with the Okavango River feasibility study;
  - Low supply scenario: Reuse of 50% of the potable supply to Windhoek, as an upper bound of what may be possible for water reclamation, with additional RO treatment;
  - Likely supply scenario: Reuse of 45% of the potable supply to Windhoek as a more realistic target than 50%, with additional RO treatment;
  - High supply scenario: Reuse of 35% of the potable supply to Windhoek according to the current blending restrictions with largely unchanged treatment processes to this currently utilised.

Overall, these various options result in 16 supply scenarios for the CAN, varying between 24 Mm^3/a and 42.0 Mm^3/a for the capacity of the existing and locally available sources.

[49] This scenario and value was specifically requested by NamWater and is in this form not supported by the Consultant.

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Table 6.5: Summary of Options for the Utilisation of Existing and Locally Available Sources in the Central Area of Namibia for 2050

Resource	Options	Scenario	Yield / Benefit (Mm^3/a, %)	Comment and Notes
Windhoek Managed Aquifer Recharge Scheme	Natural recharge	WMARS 1	1.73	Zhang et al., 2002
	Alternative benefit	WMARS 1	5.0	Best estimate of overall benefit of WMARS
Surface Water: 3-Dam System	95% Yield	SW 1	20.0	Yield values per 2004 CAN WAS. Option requested by NamWater
	Reduced Yield	SW 2	10.0	Consultant's proposal
Water reclamation in Windhoek	Fixed capacity: Medium Term	Reuse 1	11.80	Proposal for additional medium-term reclamation under the Okavango River feasibility study
	Reuse: Low Scenario	Reuse 2	50%	Upper bound of water reclamation, which may not be achievable (?)
	Reuse: Likely Scenario	Reuse 3	45%	More realistic target for total water reclamation in Windhoek
	Reuse: High Scenario	Reuse 4	35%	Current restriction on the blending ratio for DPR due to the DOC limit.

Notes:
1. Refer to the text for explanations.
2. DOC = Dissolved Organic Carbon.
3. DPR = Direct Potable Reclamation.

6.4 Consumption Analyses

6.4.1 Water Demand Nodes in the Central Area of Namibia

According to the configuration of sources and schemes in the CAN (**Figure 6.2**), the following demand nodes are defined:

1. The Eastern National Water Carrier System, which is a raw water supply system consisting of two sub-sections;
    1. The Grootfontein – Omatako Canal;
    2. The Omatako – Von Bach Pipeline;

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2. The Von Water Treatment Plant (VBWTP), which includes supply to the following:
    1. Windhoek and other industries;
    2. The online users between Von Bach and Windhoek, including Brakwater and Elisenheim;
    3. The “Airport System”: Otjihase Mine and the Hosea Kutako (Windhoek International) Airport, including to the surrounding developments such as Finkenstein, Herbothsblick, Kapp’s Farm, Sungate Mixed Use Development and Sonnleiten Nature Estate;
    4. Okahandja;
    5. Resorts and Others, which includes the Gross Barmen and Von Bach Dam Resorts and the Von Bach – Gross Barmen and Gross Barmen – Rüdenau Nord pipeline schemes;
3. The Von Bach – Swakoppoort Pipeline, which is a raw water supply consisting of three sub-sections:
    1. The Swakoppoort – Von Bach Pipeline,
    2. The Swakoppoort – Okongava Pipeline,
    3. The Okongava – Navachab Pipeline
4. The Karibib Water Treatment Plant (**KWTP**), which supplies potable water to the Karibib Municipality as well as to users along the pipeline to the Karibib Airport and to the reservoir on the farm *Spes Bona* (Cost Centre: Karibib Boreholes) as well as to Otjimbingwe and the surrounding areas.

The “Von Bach Node” or the supply by and downstream of the VBWTP constitutes by far the greatest portion of water demand in the CAN (85% of the total on average over the period 1998 to 2017 (calendar years); Bruce and Burger, 2019).

On this basis, and considering that desalinated water is likely to be provided to the Von Bach Node and not to users upstream of Von Bach Dam, at least initially, the demand assessment will focus on this demand node and Windhoek, which is by far the single largest water user in the CAN.

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6.4.2 Historical Water Consumption in the Central Area of Namibia

Water sales by NamWater and "production" by the CoW (being the volumes of water supplied to Windhoek residents from various sources) are typically analysed as a proxy for "water demand", as shown in **Figure 6.12**.

The broader historical perspective of water supply to Windhoek and in the wider CAN, is that of steadily increasing demand over time, as could be expected of a still-developing nation. The growth in water demand in Windhoek is broadly similar to that of the population in the capital, though this has been influenced by enforced savings during drought periods and demand recoveries thereafter. Since about 2002 however, the rate of growth in water demand in Windhoek has lagged behind that of the population, indicating a general decrease in per capita consumption. This is in part due to the large influx of people into Windhoek who reside in informal settlements and who are supplied with water via from communal water points, and who thus have low rates of per capita consumption. This may be one of the reasons why the increase in Windhoek's population did not precipitate an earlier shortage in supply (Bruce and Burger, 2019).

In 2013/14, NamWater increased their tariffs sharply as a result of the new pump stations constructed on the Von Bach – Windhoek scheme, whose largest customer is the CoW, and due to the phasing in of the revaluation of their assets, which were earlier valued at historical costs and not on replacement value. As a result, demand was lower than in 2012/13, showing that tariffs are one of the key drivers influencing the water demand.

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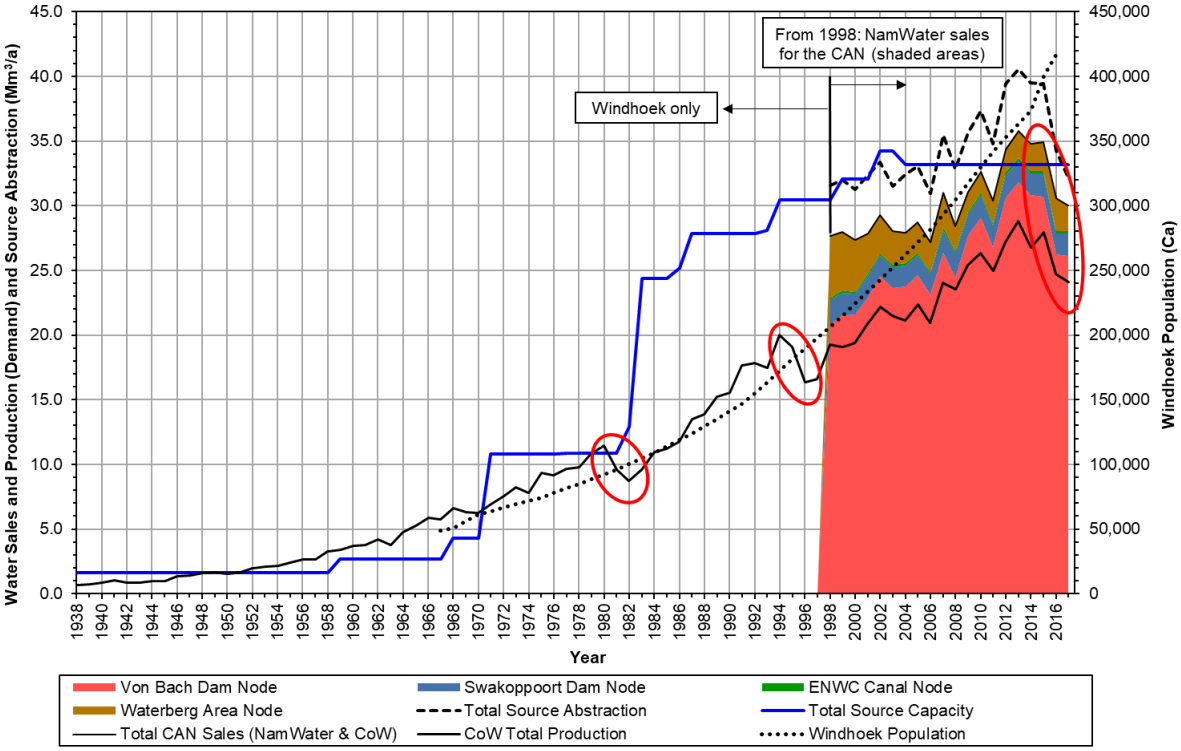

Figure 6.12: Water Sales and Estimated Abstraction Volumes for Windhoek and the Central Area of Namibia (Mm^3/a) (Bruce and Burger, 2019)

Notes:

1. The shaded data represents NamWater's sales data for the Central Area of Namibia, compiled for calendar years (Source: NamWater).
   a. The production volumes of the CoW sources (boreholes in the Windhoek Aquifer, potable reclaimed water and semi-purified water) were added to NamWater's sales to the CoW in the sales for the "Von Bach Dam Node" to provide the total "demand" of this node.
   b. The "ENWC Canal Node" represents the off-take volumes from the ENWC Canal and includes supply to the Okakarara – Ombinda / Elandspan portion of the Waterberg Water Supply Area. The sales data for this area are known to be problematic (LCE et al., 2017) and were therefore adjusted to better align with the outflow volumes from the Waterberg Purification Plant.
   c. The "Total Source Abstraction" represents the estimated volumes of abstraction from the various sources used by NamWater, being the addition of transfer and treatment losses to the sales data as appropriate to the various infrastructure components and demand nodes.
2. The "CoW Total Production" represents the volumes of water supplied from the various sources utilised by the CoW, excluding artificial recharge (Source: CoW).
3. The difference between the "Von Bach Dam Node" sales of NamWater and the "CoW Total Production" of the CoW is the supply to other users downstream of the Von Bach Dam, including Okahandja, users to the east of Windhoek up to the Hosea Kutako Airport, those along the pipeline between Von Bach and Windhoek and others.
4. Population of Windhoek: Source: City of Windhoek. The population of the CAN includes the smaller towns of Okahandja, Okakarara and Karibib, as well as other smaller centres, whose population numbers are not available from census data. Windhoek is by far the dominant demand centre in the CAN and its population growth is deemed representative for the purposes of these analyses.
5. The major drought occurrences of 1980-82, 1994-96 and 2015-17 resulting from low inflows are encircled in red. These correspond with the same occurrences highlighted in Figure 6.5.

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6.4.3 Categories or Types of Water Use in the Central Area of Namibia

From NamWater's sales database, for the sales of 20.1 Mm^3/a for FY 2018, 88% of sales were to municipalities, representing 17.9 Mm^3/a. Of this 88%, 90% (16.2 Mm^3/a) was sold to the Municipality of Windhoek itself (also refer to **Section 6.4.4** for a breakdown of consumption types within the City itself). Clearly therefore, Windhoek dominates supply in the CAN. Mining consumption represents 6% of sales (1.2 Mm^3/a), though this is almost exclusively from sales to the Navachab Gold mine (raw water). Industrial use is the third largest consumer group, representing 3.8% of sales (0.76 Mm^3/a), though mostly to the Von Bach – Windhoek supply node (almost 80% of total industrial sales). The remaining consumption groups represent only 1.5% of consumption. The CAN (as defined) had a total of 208 active sales points for FY 2018, 55% of these private consumers, although water use by these consumers represents 0.4% of consumption in the CAN.

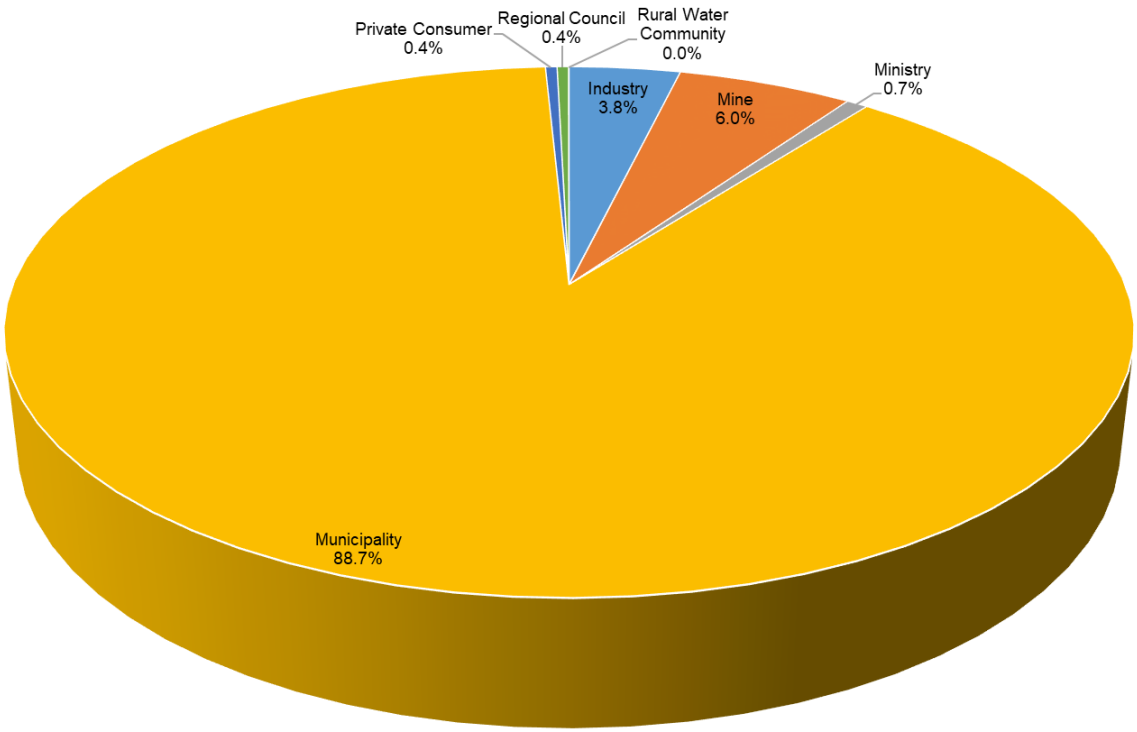

Figure 6.13: Water Use Categories within the CAN per NamWater Sales Data for FY 2018

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6.4.4 Water Demand and Use in Windhoek

6.4.4.1 Water Supply to Windhoek

Windhoek is capital city of Namibia and is located in the geographical centre of the Country. The area was first settled in 1840 due to the availability of groundwater in the area, which is reflected in the traditional names for Windhoek; Ai//gams (Nama: *hot springs*) and Otjomuise (Otjiherero: *place of steam*). Home to 325,858 people in 2011 (NSA, 2012a), Windhoek's population has grown at rates substantially greater than the national average, due in part to increasing rates of urbanisation, as the city is the commercial, economic, political and administrative hub of the country. The CoW currently estimates that there are 433 166 people in Windhoek, of which some 120 000 to 140 000 reside in informal settlements.

Windhoek is supplied with surface (from the 3-dam system) and groundwater (from the Karst Aquifers) via the Von Bach Water Treatment Plant by NamWater, with groundwater from the Windhoek Aquifer by the CoW and with reclaimed potable water from the NGWRP by Wingoc. Semi-purified water from the OGWRP is supplied by the CoW for restricted irrigation.

6.4.4.2 Historical Water Use in Windhoek

Windhoek was grown at rates well above the national average since independence (**Section 2.2**), as Namibians and others have been drawn to the Capital, and the rate of urbanisation has increased (**Section 2.2.4**). As could therefore be expected, the water demand of the City has grown steadily over time.

Total water production or supply, including semi-purified water, reached a peak of 28.817 Mm^3/a (27.216 Mm^3/a potable consumption) in 2013. From some 0.691 Mm^3/a in 1938, this represents an equivalent annual growth rate of 5.1% per annum over the period, which is greater than the population growth rate. This is likely due to the commercial development of Windhoek over this time, which has included the establishment of some wet industries, and the fact that for some years pre-2013, water demand was essentially unrestricted.

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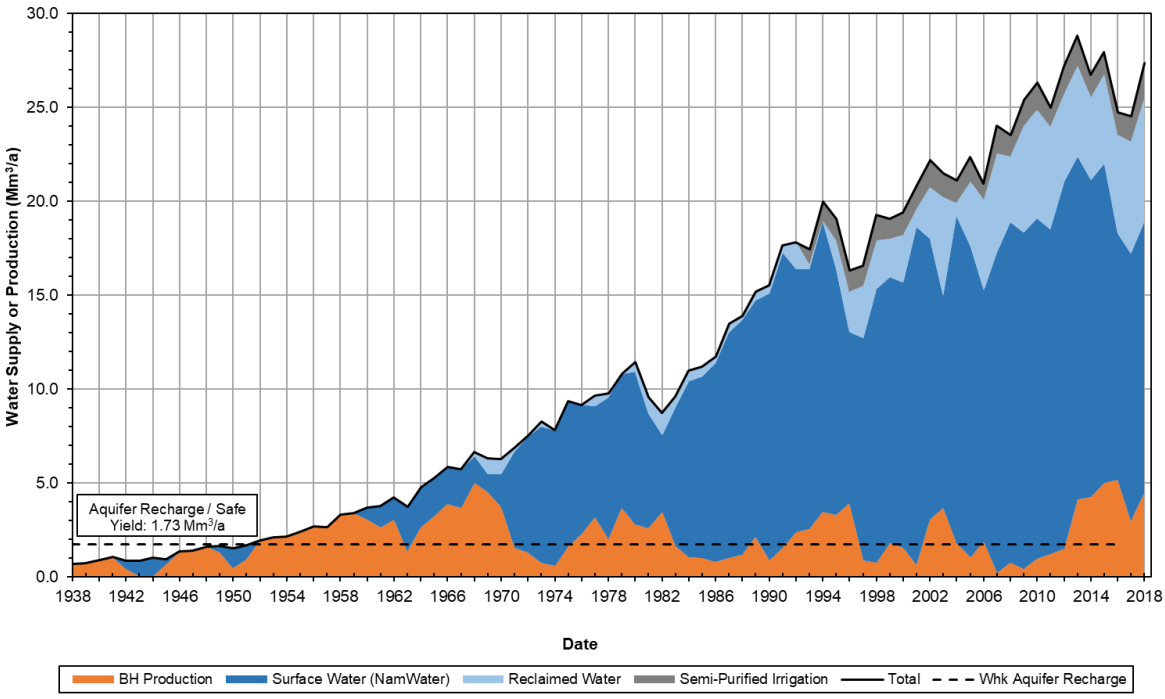

Figure 6.14: Windhoek Water Consumption per Source

Notes:
1. Source: City of Windhoek.
2. Figure updated from the version presented under the CAN Medium Term Options Study with updated production data received from the CoW.
3. Water use in Brakwater included and artificial recharge excluded per the data from the CoW.
4. Data for calendar years as provided by the CoW (annual data).

Data received from the CoW shows that since 1994, per capita consumption in Windhoek has declined, from 318 ℓ/c/d in that year to 173 ℓ/c/d in 2018 (including semi-purified irrigation water), indicating that over this period at least, water demand has grown at a lower rate than the population of the Capital. It could also be noted that large numbers of the people moving to the Capital, especially from the rural areas, are those using less than the average per capita consumption, thus contributing to the overall decline in per capita consumption.

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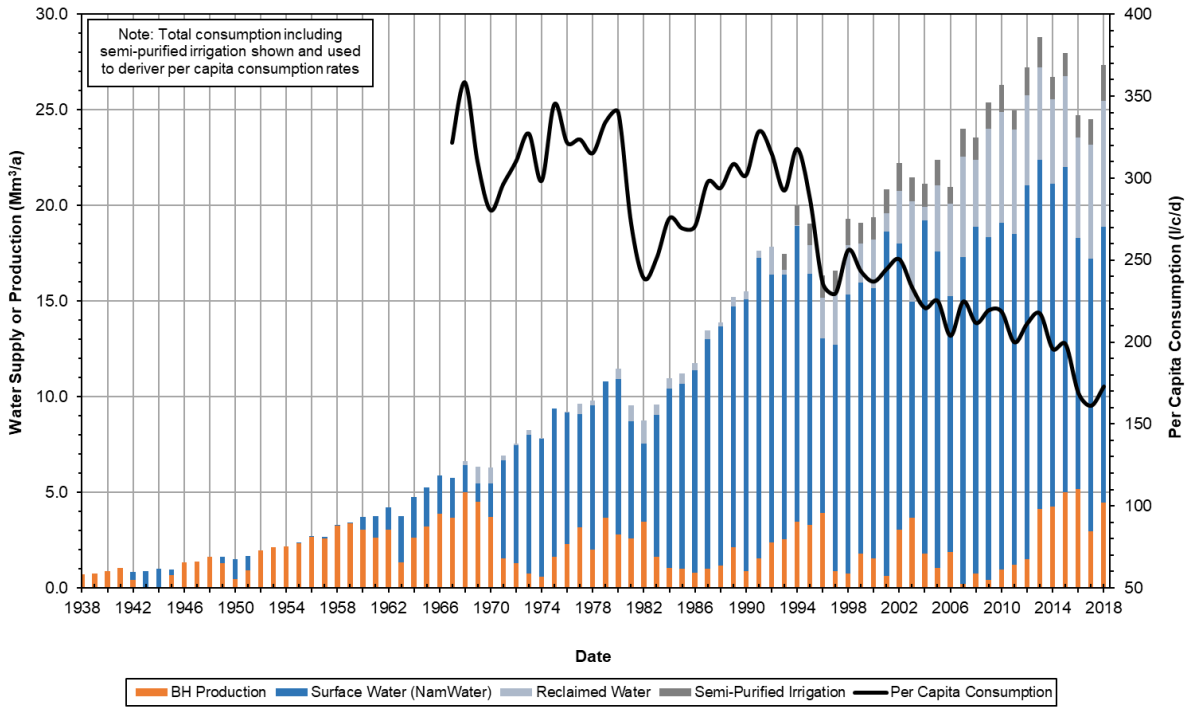

Figure 6.15: Windhoek Water Consumption per Source and per Capita

Notes:
1. Source: City of Windhoek.
2. Figure updated from the version presented under the CAN Medium Term Options Study with updated production data received from the CoW.
3. Water use in Brakwater included and artificial recharge excluded per the data from the CoW.
4. Data for calendar years as provided by the CoW (annual data).

6.4.4.3 Historical Water Use by Category

The data previously provided by the CoW does not indicate the category of water use, for example “business”, “residential”, “industrial”, etc. The erf zoning has therefore been used as a proxy for the category or type of water use. Since there are at least 17 zoning descriptions used by the CoW, for the for the purposes of categorising water usage, these have been grouped into the following categories: Business / Industrial / Public / Domestic-Residential and Other.

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Table 6.6: Windhoek Water Use per Defined Category (LCE-SCE JV, 2019)

Water Use Category	Annual Water Sales (m^3/a)			Portion of Total Sales (%)		Reduction 2015-2017	
	2015	2016	2017	2015	2017	(m3/a)	(%)
Business	2 588 471	2 485 310	2 193 970	11%	12%	394 501	15%
Industrial	2 276 961	1 907 964	1 803 118	10%	10%	473 843	21%
Public	3 634 197	3 143 900	3 114 428	16%	17%	519 769	14%
Domestic / Residential	13 811 023	12 305 285	10 839 156	59%	58%	2 971 867	22%
Other	933 521	829 207	833 784	4%	4%	99 737	11%
Totals	**23 244 173**	**20 671 666**	**18 784 456**	**100%**	**100%**	**4 459 717**	**19%**

Notes:
1. Data provided by the City of Windhoek.
2. Only potable water sales (excluding semi-purified) in the Windhoek area analysed, excluding outlying areas of Brakwater, Elisenheim, Nubuamis, etc., corresponding with the sales used for the water balance.
3. Data excludes accounts / erven with zero sales volumes.

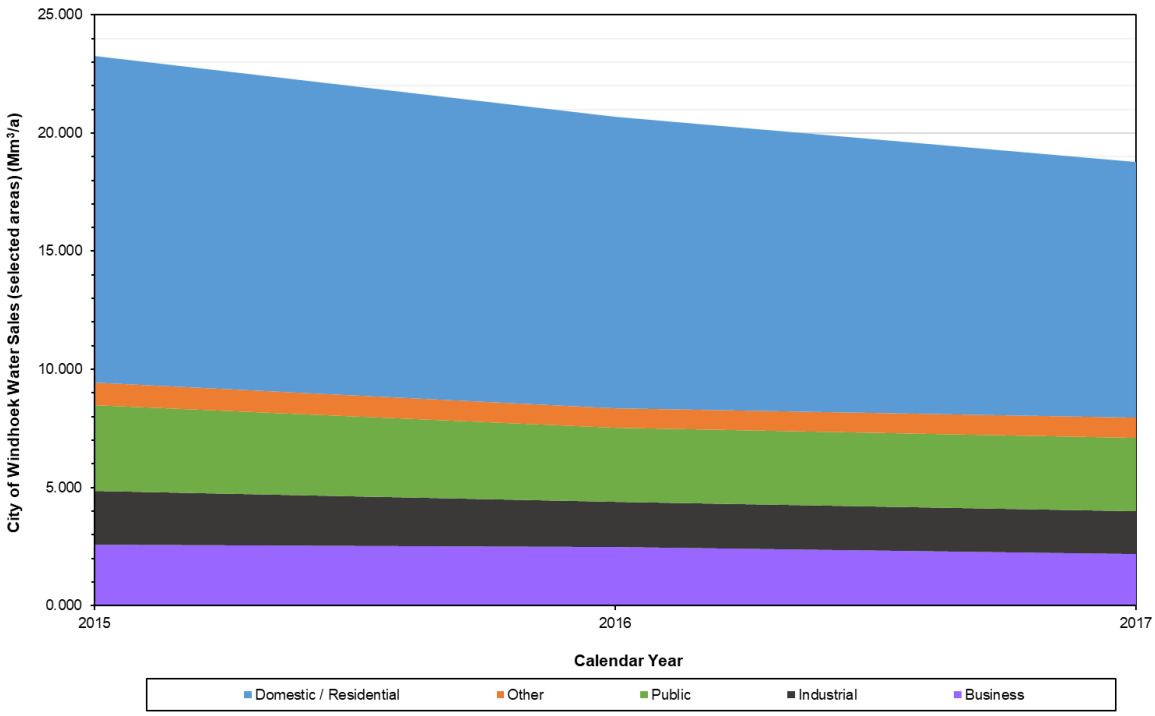

Figure 6.16: Windhoek Water Use per Defined Category (LCE-SCE JV, 2019)

Notes:
1. Data provided by the City of Windhoek.
2. Only potable water sales (excluding semi-purified) in the Windhoek area analysed, excluding outlying areas of Brakwater, Elisenheim, Nubuamis, etc.
3. Data excludes accounts / erven with zero sales volumes.
4. Water user per the erf zoning defined by the CoW, per the categories noted in the text.

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Residential water use can be seen to be the largest category (as analysed) of water use, using 10.839 Mm^3/a or approximately 58% of water in the "core" Windhoek area (as analysed) in 2017. It is interesting to note that overall and within each defined category of use, water consumption declined between 2015 and 2017 in response to the CoW's WDM campaign and drought initiatives, but that each category's portion of total sales remained more-or-less unchanged. On a percentage basis relative to 2015, domestic / residential water consumption decreased the most to 2017 (22%), followed closely by industrial water use (21%). All categories recorded reductions in consumption of more than 10%, with an overall 19% reduction in *sales* (for the defined areas) between 2015 and 2017. This is in the same order of magnitude as the 15% to 21% reduction in water *supply or production* over this period.

6.4.4.4 Previous Water Demand Projections

Water demand projections have been prepared for Windhoek on several occasions in the past, under a number of different studies and investigations. The more recent projections prepared under the 2011 CAN BWMP, including one for Vision 2030, are shown together with the 1999 and 2001 projections. The water demands resulting from the economic growth of 7 to 8% and the 1.5% densification of Windhoek envisaged under Vision 2030 were determined under the 2011 CAN BWMP and termed the "Vision 2030" demand projection (SCE-Aurecon JV, 2011).

The water demand projections from the CAN BWMP proved to be accurate up to 2015, after which supply became restricted during the drought conditions. The expected growth scenario from that study assumed a growth in demand of 4.1% per annum between 2001 and 2020, decreasing to 2.3% per annum thereafter (SCE-Aurecon JV, 2011). Whilst high probabilities of a shortfall in supply were calculated under the work of that study (SCE-Aurecon JV, 2011), the exact timing of the drought could not have been predicted.

Overall, it can be seen that the variability of demand / consumption in Windhoek, driven in a large part by climatic variability, makes the preparation of accurate water demand projections very difficult.

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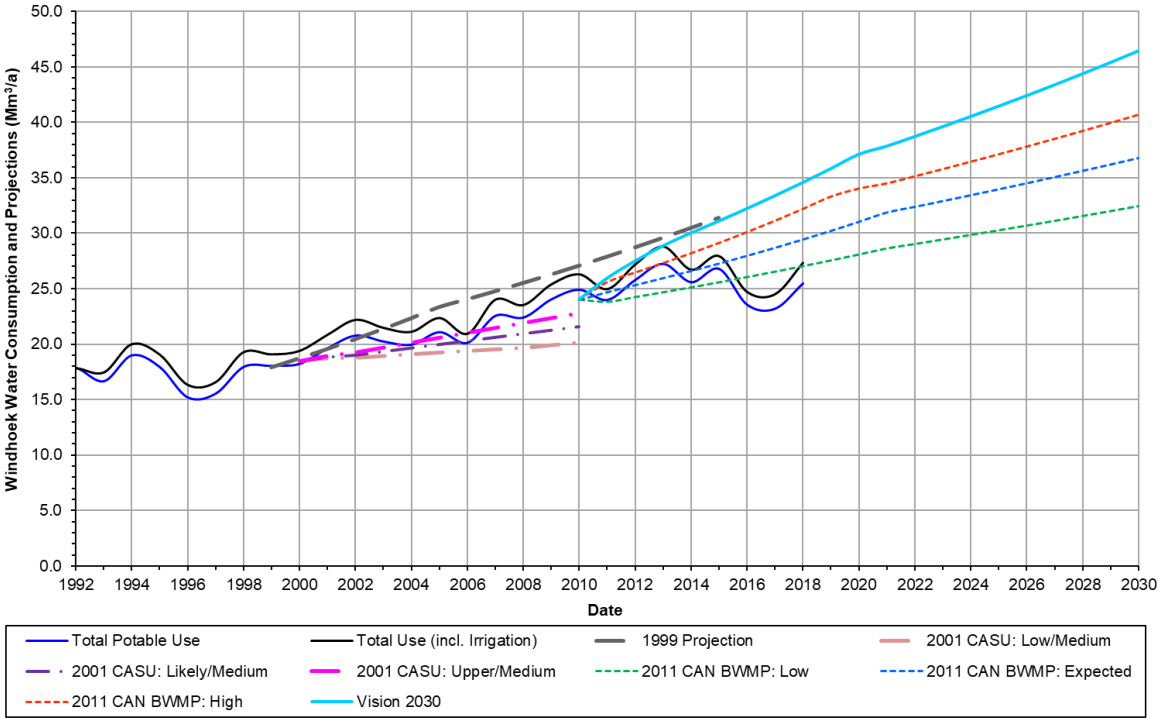

Figure 6.17: Windhoek Supply and Selected Previous Projections

Notes:

1. Figure updated from the version presented under the CAN Medium Term Options Study with updated production data received from the CoW.
2. 1999 Projection: Report for Namibia Water Resources Management Review (WCE, 1999).
3. 2001 CASU: The Central Area System Update Report (WTC, 2001). The low likely, likely and upper likely projections shown are those for medium weather conditions.
4. 2011 CAN BWMP: Low / Expected / High demand scenarios prepared under the Water Supply Infrastructure Development and Capital Replacement Master Water Plan for the Central Water Supply Area (SCE-Aurecon JV, 2011).
5. Vision 2030: Projection prepared under the 2011 CAN BWMP based on the 7 to 8% economic growth and 1.5% densification of Windhoek envisaged under Vision 2030 (SCE-Aurecon JV, 2011).
6. Refer to the earlier notes on the water consumption data.

6.4.5 Water Demand and Use in Okahandja

6.4.5.1 Water Supply to Okahandja

Known as the *Garden Town of Namibia*, Okahandja is located some 65 km to the north of Windhoek, but falls within the Otjozondjupa Region of Namibia. Okahandja was home to 22,639 people in 2011 (NSA, 2012a) and is administered by a Municipal Council.

Okahandja is primarily supplied with water from the Von Bach Dam, via the Von – Bach Okahandja Scheme, which consists of a base pump station at the VBWTP, a 3.7 km long pipeline, which leads to the Okahandja East ground level Reservoir, which is located on a hill overlooking the town.

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From this reservoir, water gravitates into the town's reticulation network through the bulk sales meter which demarcates the end of the NamWater scheme and the start of the Okahandja Municipality's responsibility (after SCE-Aurecon JV, 2011).

The Okahandja Municipality also owns and operated two boreholes in the bed of the Okahandja River which they use to supply water into the municipal reticulation network. Previous assessments determined that there are no records of production from these two boreholes (SCE-Aurecon JV, 2011).

6.4.5.2 Historical Water Use in Okahandja and Previous Projections

NamWater's sales under the Von Bach – Okahandja scheme (Code: OKJ) have shown some variation over time, although also a general increase between 2003/04 and 2015/16.

The Von Bach – Okahandja scheme (Code: OKJ) provides water to the Municipality of Okahandja and a few private consumers, many of them NamWater staff; the others are presumed to be located along the length of the pipeline. The sales from the full Von Bach – Okahandja scheme (Code: OKJ) are shown since these are the values used in previous assessments (the 2004 Augmentation Study and the Water Augmentation Study) and the configuration for which demand projections were prepared under these previous studies.

The AB InBev (previously SABMiller) brewery was completed in the latter part of 2014, which explains the increase in water use between 2013/14 and 2015/16.

A sharp reduction in demand occurred in 2016/17, most likely as a result of the drought. Some rebound in demand occurred in 2017/18.

The demand forecasts for Okahandja prepared in 2010 under the 2011 CAN BWMP assumed growth projections of 2.58% for the expected scenario and 3.5% and 1.67% per annum respectively for the high and low growth scenarios (SCE-Aurecon JV, 2011). These projections were in 2014 revised to weighted average values of 2.0% per annum, 2.9% per annum and 3.5% per annum for the low, likely and high likely scenarios under the WAS, based on the (at the time) imminent opening of the SABMiller brewery, expected industrial developments by the Namibia Development Corporation and planned housing projects for both low and middle income sectors.

The growth in water demand initially followed these 2014 projections closely, later in 2015/16 growing at a rate greater than assumed prior to the drought, after which demand dropped significantly.

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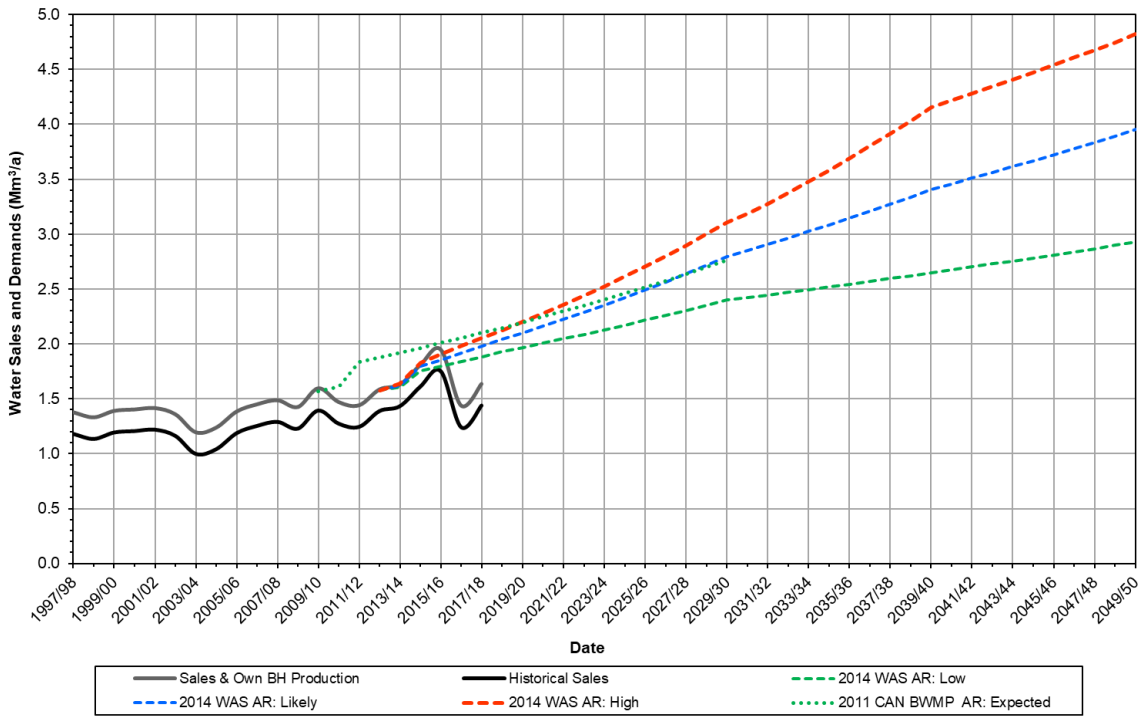

Figure 6.18: Water Sales from the Von Bach – Okahandja Scheme and Previous Projections

Notes:

1. Sales from the Von Bach – Okahandja scheme (Code: OKJ), approximately 99.8% of which are to the Municipality of Okahandja.
2. The actual production or abstraction from the municipal boreholes are not known, since abstraction records are not kept by the Okahandja Municipality. Estimates vary from 120 000 m^3/a to 194 300 m^3/a. During 2003 there were 2 boreholes in production, whilst for the 12 months preceding an assessment in 2013/14, only one borehole was in production (LCE-SCE JV, 2017). The upper estimate of 194 300 m^3/a has been used to represent own supply by the Okahandja Municipality. The abstraction requirements include this volume for supply from Von Bach Dam, under the assumption that the supply from the municipal boreholes is not reliable, but that provision must be made for this supply, since it has been factored into the demand. This therefore represents a conservative estimate for the demand by Okahandja.
3. 2011 CAN BWMP AR = Central Area of Namibia Bulk Water Master Plan of 2011 Abstraction Requirements including losses of 5% (SCE-Aurecon JV, 2011).
4. 2014 WAS = Abstraction requirements prepared in 2014 under the Water Augmentation Study, including losses of 5% (LCE-SCE JV, 2017).

6.4.6 Water Demand and Use in Karibib

6.4.6.1 Water Supply to Karibib

Karibib is a town located in the central eastern portion of the Erongo Region, which is administered by the Karibib Municipality. The town comprises two distinct townships; Karibib and Usab, with an informal settlement located near the latter (SCE-Aurecon JV, 2011).

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Karibib (and Usab) is supplied with water from the Swakoppoort Dam. This water is abstracted from the dam and pumped via the Okongava reservoir to the Karibib Water Treatment Plant, where it is purified and stored in the Karibib Terminal Reservoir, which is located on a hill overlooking the town. There are two pipelines from this reservoir, one which supplies water to the Spes Bona Booster Reservoir and one which supplies water to Karibib Town. The former pipeline also supplies water to users along the pipeline to the Karibib Airport / NDF Karibib.

6.4.6.2 Historical Water Use in Karibib and Previous Projections

NamWater's sales to the Karibib Municipality under the Karibib Purification scheme (Code: KUP) have shown some variation over time, although relatively little increase overall between 1997/98 (0.281 Mm^3) and 2017/18 (0.297 Mm^3).

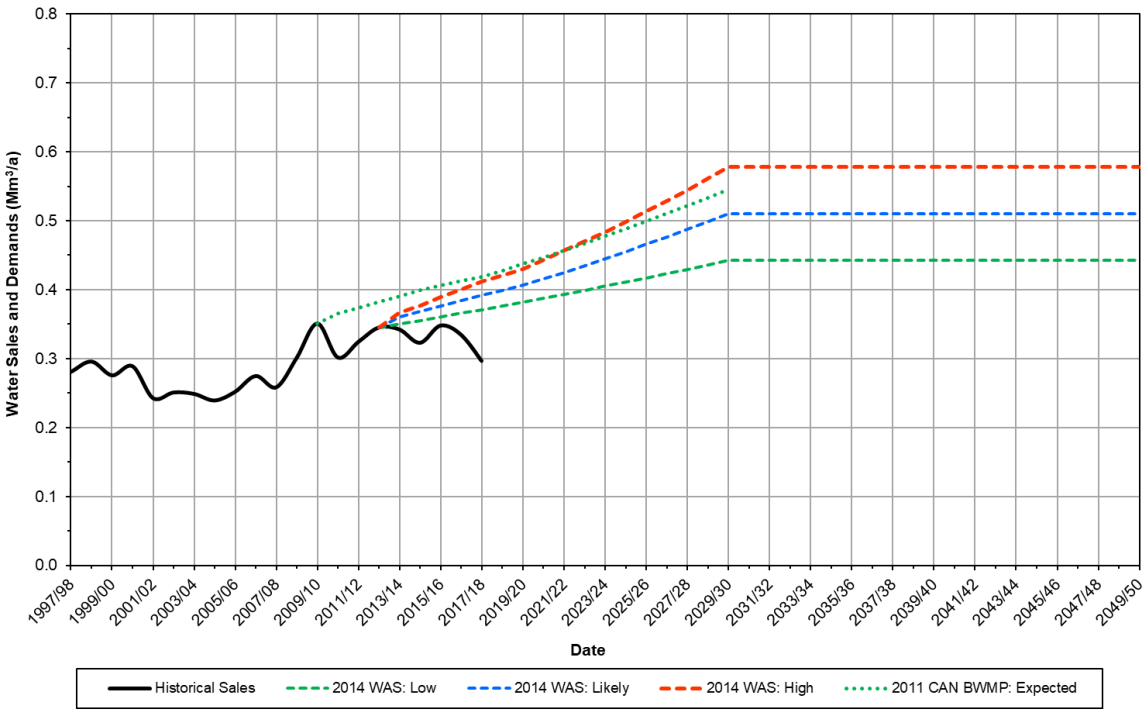

Figure 6.19: Water Sales to Karibib Municipality and Previous Projections

Notes:
1. Sales to the Karibib Municipality under the Karibib Purification scheme (Code: KUP).
2. 2011 CAN BWMP = Central Area of Namibia Bulk Water Master Plan of 2011 Expected water demands for Karibib town (SCE-Aurecon JV, 2011).
3. 2014 WAS = Water demands prepared in 2014 under the Water Augmentation Study (LCE-SCE JV, 2017).

The water demand of Karibib is largely influenced by development of the Navachab Gold Mine and development at the Karibib Airport by the NDF, which increases the development of houses and business in Karibib (LCE-SCE JV, 2017). Closure of the Navachab Gold Mine has been imminent several times in the past, after which the mine has continued operation for a number of years, which may explain some of the variation in water demand observed.

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It is interesting to note that water consumption (sales) did not increase as dramatically in 2016/17 as elsewhere in the CAN during the drought; instead the greater decrease in sales occurred in 2017/18.

The demand forecasts for Karibib prepared in 2010 under the 2011 CAN BWMP assumed weighted average growth projections of 2.2% for the expected scenario and 3.0% and 1.5% per annum respectively for the high and low growth scenarios (SCE-Aurecon JV, 2011). In 2014, the growth in water demand for the expected or likely scenario was revised upwards marginally to 2.5% per annum. At the time, the Karibib Mine's Technical Manager provided figures for new development contemplated by the mine until 2020. Proposals for the relocation of 330 families served with standpipes to fully serviced erven in Usab Extension 2 were also noted. At the time, it was expected that the Navachab Mine would close in 2030, after which the stagnation or even decline of Karibib was expected, given that there is no substitute for the mine in terms of the local economy. No growth in water demand after 2030 was therefore forecast for Karibib (LCE-SCE JV, 2017).

6.5 Benchmarking of Water Use Efficiency

6.5.1 Benchmarking of Non-Revenue Water

The assessment and benchmarking of NRW in the CAN towns was conducted as outlined in **Section 4.4.5.7**.

The water balance previously conducted for Windhoek indicated values similar to the 12% estimated by the CoW[50], which is below the approximately 14% "distribution losses" determined for 2008 by the audit of the CoW's finances (AG, 2013). The latter is however expected to be a "financial NRW" figure and not the volumetric NRW figure obtained from the IWA water balance. If NRW in Windhoek is indeed in the order of 12%, this would be "good" in terms of comparisons with regional and international cities.

NRW for the towns in the CAN is compared and benchmarked against the South African National and World Averages as obtained from McKenzie et al. (2012). Only Windhoek currently meets the target of 15% NRW recommended by the *Rapid Assessment of Desalination Options* (BCT and DME, 2016).

Significant improvements in water use efficiency are required in Okahandja in particular, where the estimated NRW (45%) is well above the South African and world averages and the target value of 15%. To a lesser, but still significant extent, there is also a need to improve water use efficiency in Karibib as well.

[50] In 2016, the CoW signed a memorandum of agreement with the City of San Antonio, Texas, regarding mutually beneficial cooperation and the exchange of knowledge and ideas on water management, energy polices and housing. Officials from San Antonio and those of the CoW worked together (no date provided) to prepare and estimate of the NRW in Windhoek, which was determined to be approximately 12%, as reported by officials of the CoW on 09 July 2018 under the CAN Medium Term Options Project of NamWater. No date was provided for the assessment (LCE-SCE JV, 2019).

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The Okahandja Municipality, although not knowing the figure, is aware that NRW is problematic, and this is reportedly a point of discussion between the Municipality and NamWater (Mr. Nunda, 2019, pers. comm., 25 March).

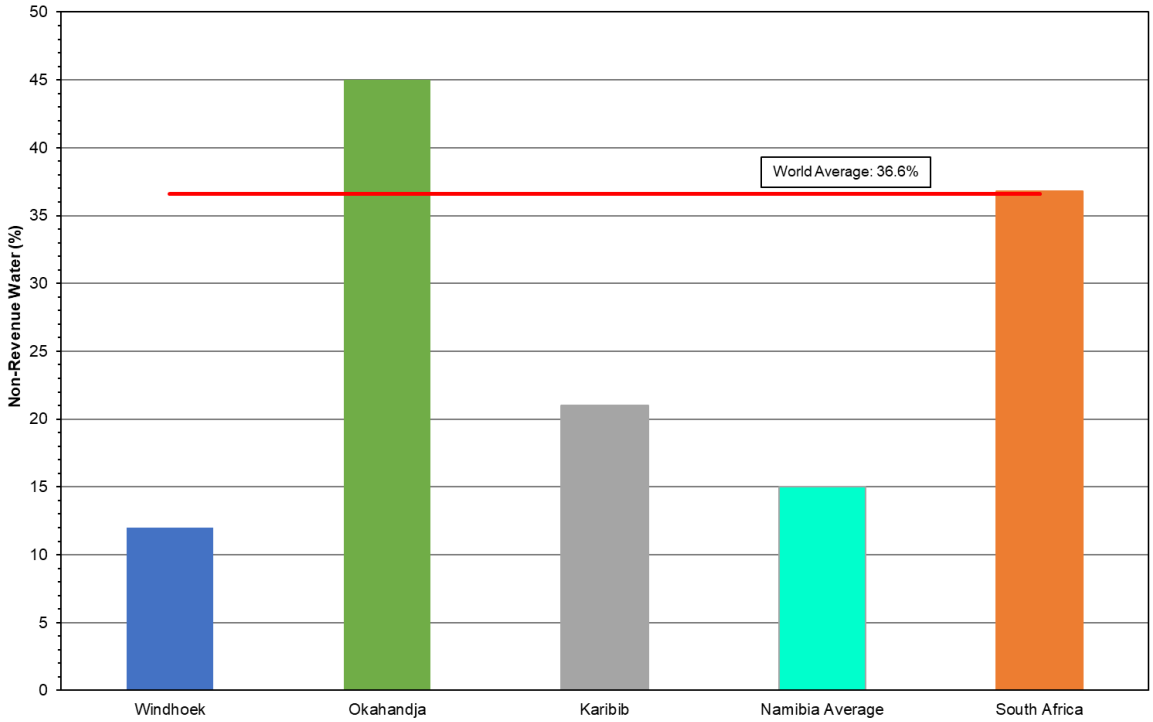

Figure 6.20: Benchmarking of Non-Revenue Water Consumption in the CAN Towns

Notes:
1. A value of 12% for Windhoek was adopted, as indicated by officials of the Municipality on 09 July 2018, which also corresponds with the NRW estimated from the attempted water balance.
2. The NRW values for Okahandja and Karibib could not be determined with certainty. The values proposed are based on proportion of unaccounted for leakage based on an assessment of the night flows and should be understood in this context (LCE-SCE JV, 2019).
3. Namibia average of 15% per NamWater (2017a). The derivation of this figure could not be ascertained and it is considered optimistic.
4. Average of 36.8% for South African municipalities per McKenzie et al. (2012).
5. World average of 36.6% per McKenzie et al. (2012).

6.5.2 Night Flows

NamWater provided average hourly outflows from their supply (terminal) reservoirs for Okahandja and Karibib, which are in both instances, the main storage reservoirs in each town and which could be analysed to determine the night flows.

In Windhoek, water from the Windhoek Terminal Reservoir is supplied to the various municipal reservoirs throughout the city, partially under gravity and partially under pumped transfer, which the CoW carries out during off-peak power periods to save on pumping costs. Flow balancing therefore occurs between the various reservoirs and pressure zones throughout the day, but particularly during the night when water use is much reduced and during off-peak power periods.

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There are no water meters which record the outflows from the various reservoirs into the separate pressure zones in Windhoek, or the flow balancing which occurs between the reservoirs, which means that an analysis of diurnal water demand patterns and night flows is not possible in Windhoek.

Table 6.7 summarises the night flow analysis for Okahandja and Karibib, based on the methodology described in **Section 4.4.5.7**.

Table 6.7: Night Flows and Unaccounted for Water in Okahandja and Karibib

Item	Unit	Okahandja	Karibib
Average daily flow rate	m^3/h	179.45	41.53
Minimum night flow (MNF)	m^3/h	113.6	12.8
Time of MNF	hours	3:00	3:00
Estimated normal night use	m^3/h	33.58	4.10
Unaccounted for leakage	m^3/h	80.02	8.70
Unaccounted for leakage	**% of daily flow**	**45%**	**21%**
Daily unaccounted leakage	m^3/day	1,840	200
Annual unaccounted leakage	m^3/a	672 191	73 120
Equivalent i.t.o. average monthly sales	Months	5.8	2.3

Notes:
1. NamWater data provided and analyses conducted under the CAN Medium Term Options project of NamWater (LCE-SCE JV, 2019).

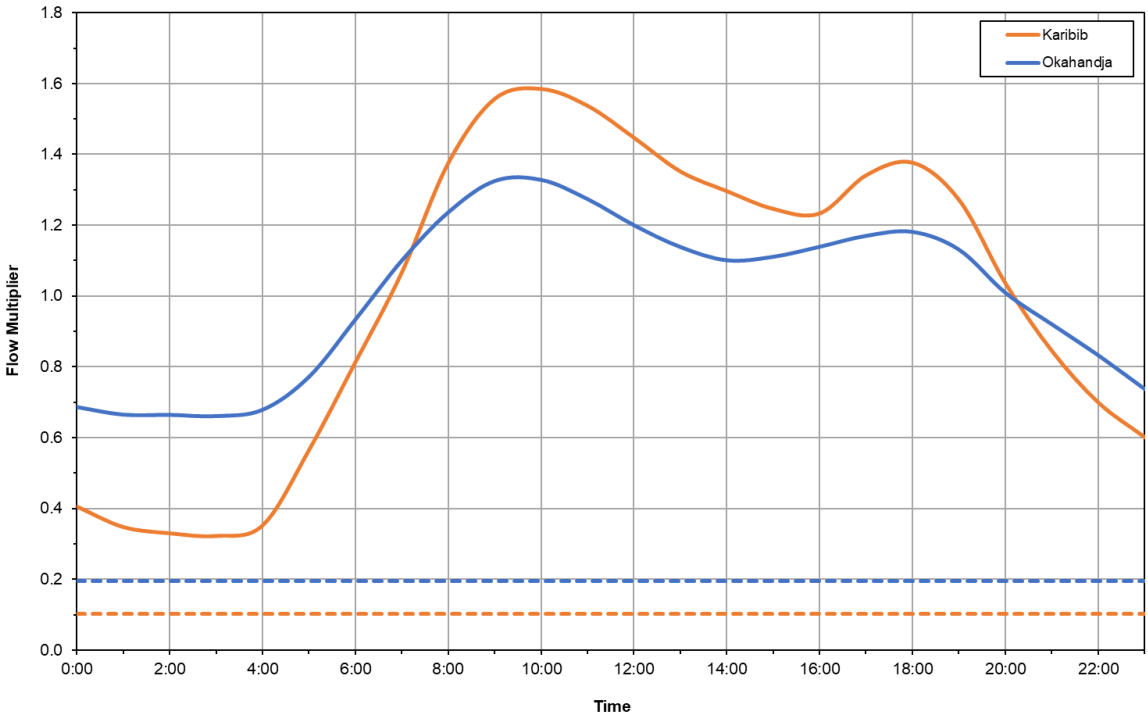

Figure 6.21: Average Daily Flows in Okahandja and Karibib

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Figure 6.21 illustrates the diurnal daily flow rates (normalised around the average hourly rate) of Okahandja and Karibib as well as their respective estimated normal night use values. The difference between the minimum daily and normal night use flows is the un-accounted-for leakage value.

6.5.3 Benchmarking of Per Capita Water Consumption

The assessment and benchmarking of NRW in the CAN towns was conducted as out-lined in **Section 4.4.5.7.3**.

A comparison of the per capita consumption values for the CAN towns is provided in **Figure 6.22**, and the estimated average for Namibia as a whole and the average for South Africa is provided in **Figure 6.23**.

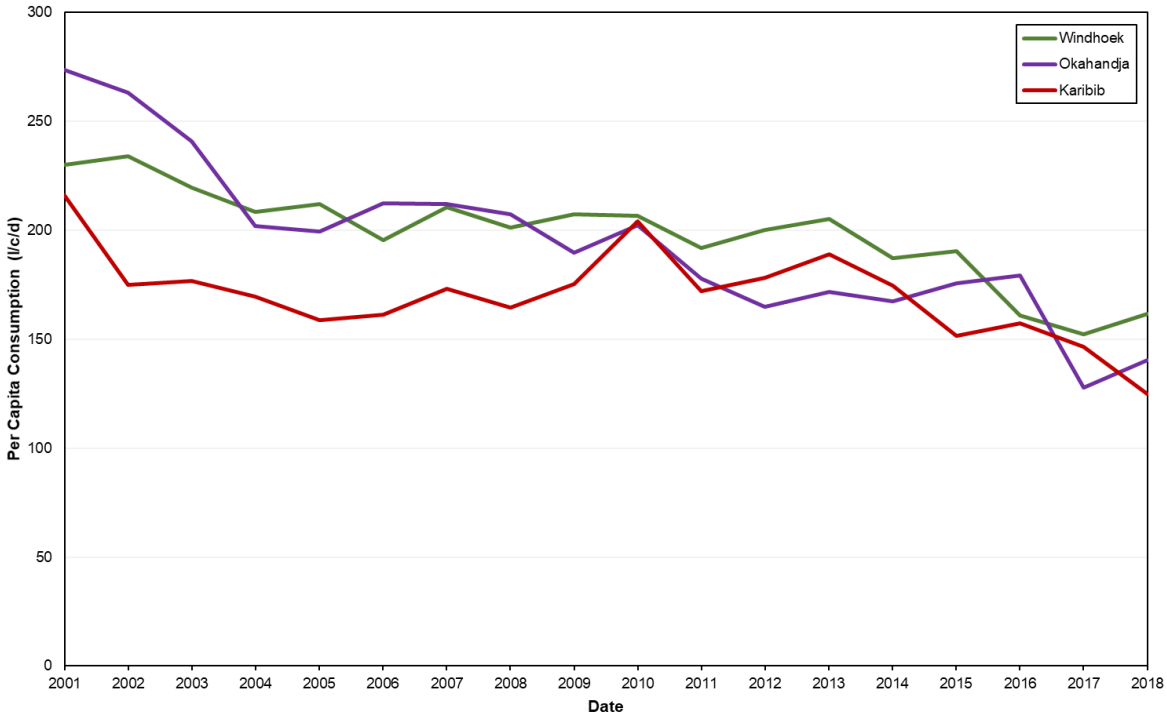

Figure 6.22: Per Capita Consumption in the Major Urban Centres of the CAN

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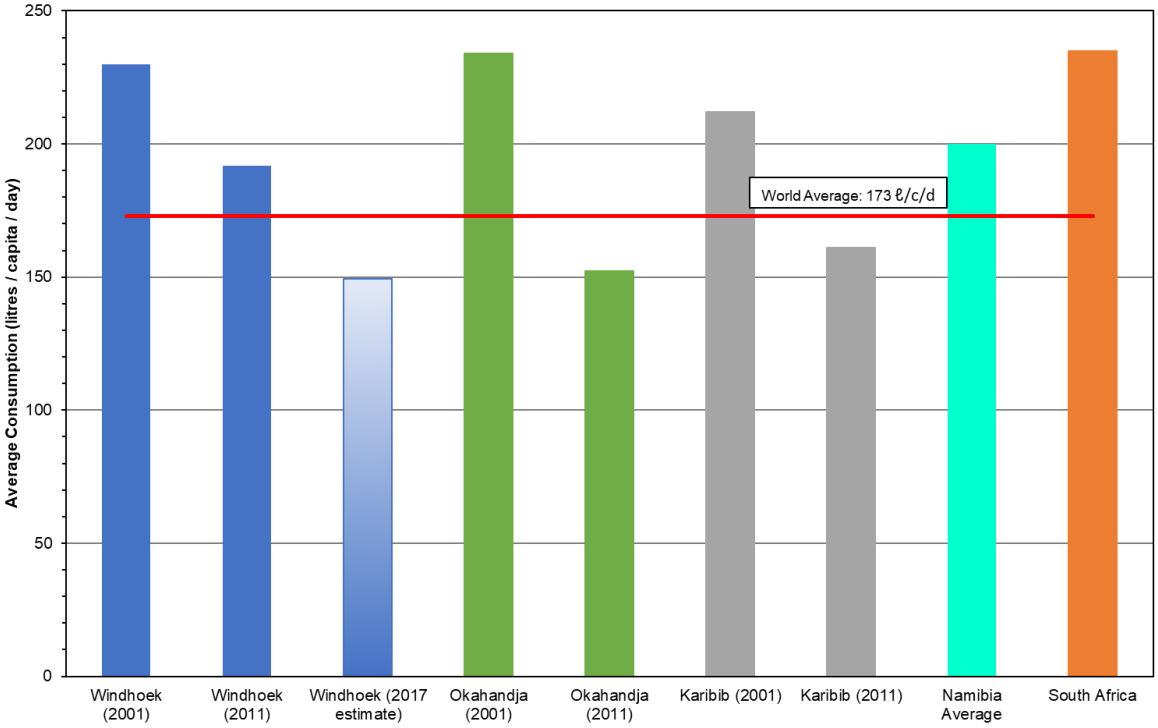

Figure 6.23: Benchmarking of Per Capita Water Consumption in the CAN Towns

Notes:
1. Windhoek estimate of 149 ℓ/c/d for the 2017 calendar year per the City of Windhoek.
2. Namibia average of 200 ℓ/c/d per NamWater (2017a).
3. Average of 235 ℓ/c/d for South Africa per McKenzie et al. (2012).
4. World average of 173 ℓ/c/d for South Africa per McKenzie et al. (2012).

In each of the three CAN centres, per capita consumption declined between 2001 and 2011, indicating that water use did not increase as much as the population totals did. In part, this is due to relatively higher population growth in the towns, as a result of rural – urban migration. The 2011 per capita consumption rates in the urban centres of the CAN are below the national average, as well as the South African and the world averages, which indicates relatively efficient water use.

Despite this, the high levels of NRW indicated by the previous benchmarking suggests that there is room for improvement in water use efficiency in the CAN.

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6.6 Water Demand Projections

6.6.1 Development Proposals

6.6.1.1 Windhoek

6.6.1.1.1 Developments in the Windhoek Basin and the Greater Windhoek Area

The Windhoek Basin refers to the pre-2011 extent of the municipal boundaries which extend to the south of the Luipardsvalley Army Base, and in the north to include Okuryangava, as shown in **Figure 6.24**. In December 2011 the municipal boundaries of Windhoek were extended by a significant distance to the north (to include the Brakwater area), to the south and to the east (to include the Finkenstein and Herbotsblick developments), as shown in **Figure 6.25**. The Elisenheim and Brakwater developments will obtain water from the Von Bach – Windhoek pipeline, whilst the Finkenstein and Herbotsblick developments will receive water via the Otjihase Mine pipeline.

During consultations with the CoW, it was noted that Groot Aub, the settlement to the south of Windhoek, which falls within the Greater Windhoek Area (post-2011), is not to be included in the water demand of Windhoek, as this settlement is to be supplied with groundwater. The distance of Groot Aub from Windhoek (some 54 km by road) is such that it is considered unlikely that the extension of bulk water supply will be economically viable or affordable for the residents of Groot Aub.

Development in the Windhoek Basin (refer to **Figure 6.24**) is restricted, mainly as result of the topography around the City; the groundwater exclusion zone is one of the limiting factors in the south, whilst the hilly topography limits expansion to the east (of Ludwigsdorf), south, west (of Rocky Crest) and north west. Due to the major shortage of medium and high income erven, private townships have mushroomed around the City, with the Elisenheim, Omeya, Finkenstein and Herbotsblick developments catering primarily to these markets. Prices for serviced erven are also lower on a per unit basis in these satellite townships than in Windhoek. The low income housing market is less well served, although the extensions underway in Rocky Crest and the Osona development, and the imminent Ongos / Monte Christo developments are aimed to serve sectors of this market (mainly the low to middle-income markets).

Within the Windhoek Basin, the CoW has identified some areas where further development can take place (refer to **Figure 6.24**), after which further development can be expected to be in the form of densification and gentrification. The developments around Maerua Mall (Feld Street in particular) and the Hidas and Olympia Shopping Centres provide examples of these trends.

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The CoW has indicated that further development is to take place to the north-west of the City; the Ongos / Monte Christo development, which is aimed at low to middle-income housing developments, whilst it can be expected that the Elisenheim and Osona (mainly residential and associated) developments will continue to expand, together with non-residential (industrial and other) development in the Brakwater area.

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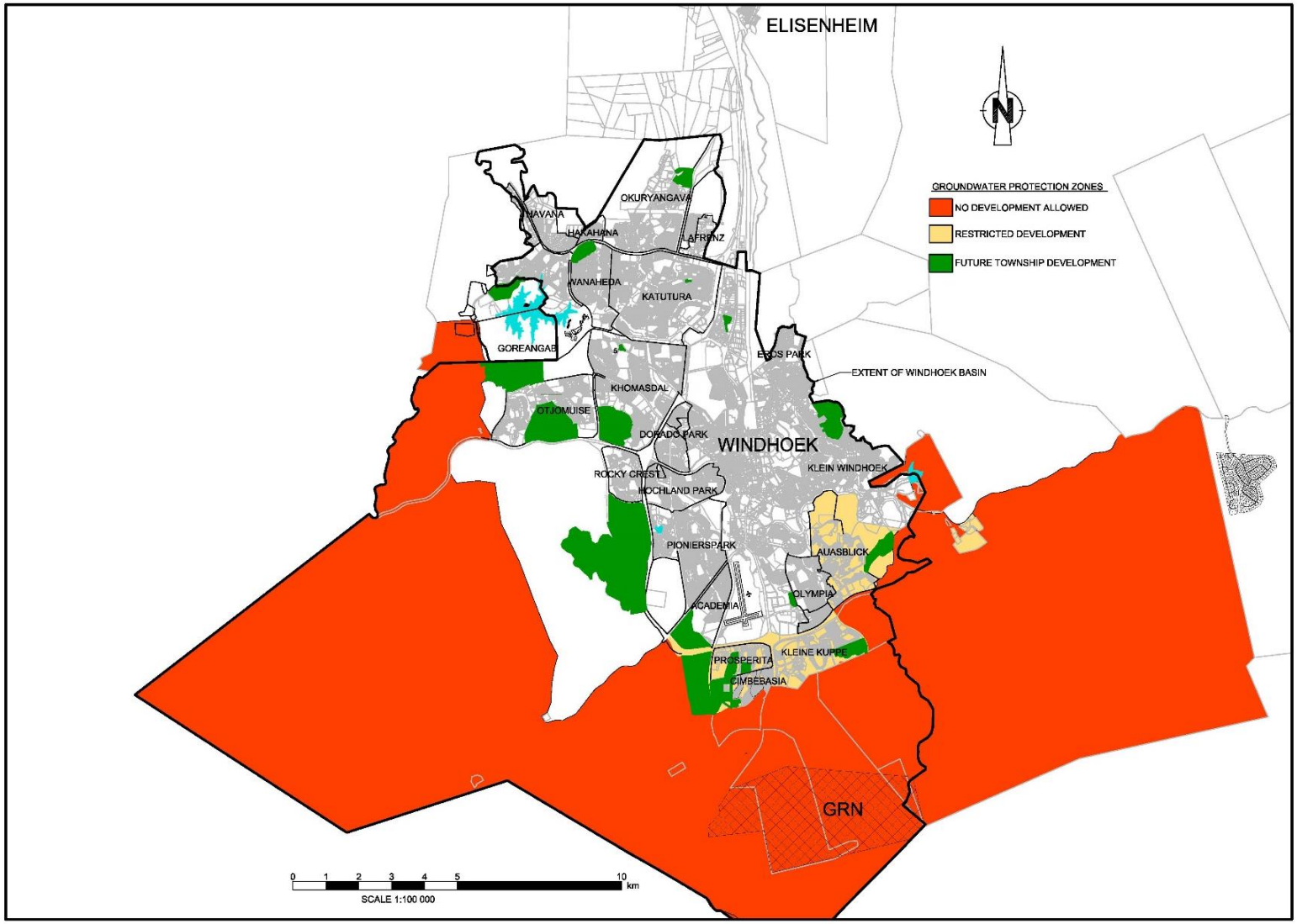

Figure 6.24: Extent of the Windhoek Basin (LCE-SCE JV, 2017)

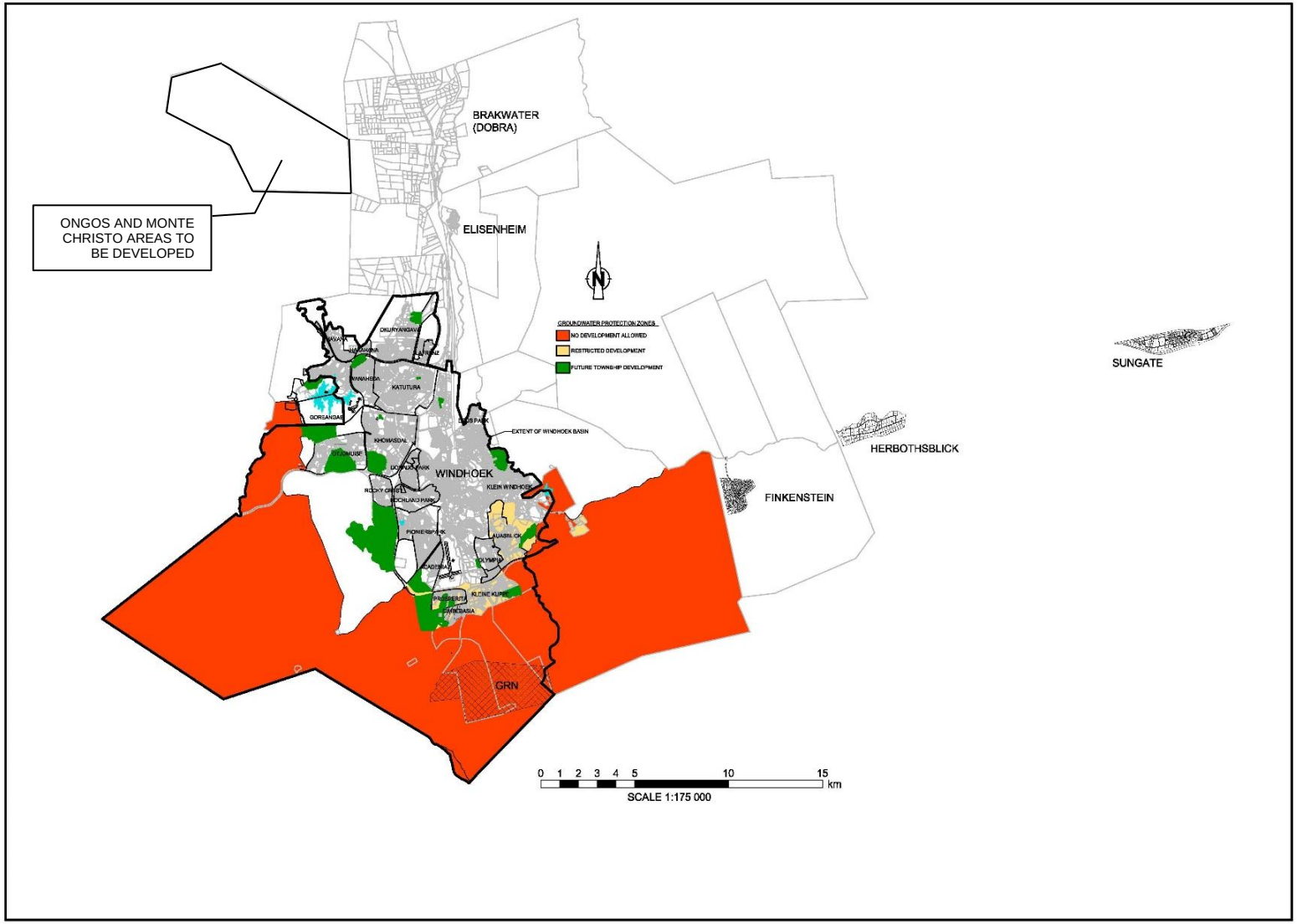

Figure 6.25: Extent of the Greater Windhoek Area (LCE-SCE JV, 2017)

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6.6.1.1.2 Ongos and Monte Christo Developments

The Monte Christo and Ongos farms are privately owned farms located to the north west of Windhoek which have been subdivided into smaller portions and, with the exception of Monte Christo North, sold off to private developers (Lithon et al., 2016a). Lithon et al. (2016) noted that a number of developers have commenced with preparing township layouts and preparing their applications to the CoW for approval. The developable land on the original Monte Christo and Ongos farms, being that with a slope less than 1:4 (25%) is approximately 12 500 ha, which is some 1.4 times the currently developed extent of Windhoek (8 650 ha; Lithon et al., 2016a). This indicates a very sizable developable area, although the development thereof may be complicated by the fact that the land does not belong to the CoW.

The average annual daily demand for the Ongos and Monte Christo developments was estimated to be 90 118 m^3/d (Lithon et al., 2016a), which is equivalent to approximately 33 Mm^3/a.

On 09 July 2019, the Ongos Valley Development revealed their plans for a N$ 4.3 billion housing project which aims to construct 30 000 housing units for low- to middle-income households in the next 15 to 20 years (Nakale, 2019b). Four business centres including 106 business plots, 48 institutional plots and 20% of the area dedicated to public and conservation open areas are also to form part of the development. The first phase of the development is envisaged to require an investment of N$ 1 billion to construct 4 500 houses (Nakale, 2019b).

In terms of the estimated water demand for the Ongos and Monte Christo developments, some key considerations include:

- It is clear from the assessment of the historical and current supply and demand in the CAN, that the current resources supplying the CAN do not have sufficient capacity to supply the approximately 33 Mm^3/a of additional water demand. Thus, whilst there is a demand for land and housing, and hence a need for further development in and around Windhoek, this cannot be supplied from existing water sources in the CAN and likely not from other sources within the interior of Namibia either;
- As a first-order assessment: Assuming 30 000 housing units are developed as indicated by the Ongos Valley Developers, six people per household and a generous consumption rate of 200 ℓ/c/d[51], the water demand could be estimated to be some 13 Mm^3/a including water use by businesses, industries, institutions, etc., indicating

[51] In 2018, per capita demand in Windhoek was 161 ℓ/c/d excluding semi-purified irrigation water, which included all consumption / water use in Windhoek (domestic as well as business, commercial, institutional and other water use), as well as NRW. On this basis, the 200 ℓ/c/d used for a first order assessment / illustrative purposes is very generous.

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that the 33 Mm^3/a water demand estimated by the master plan covering this area is likely to be very generous and unlikely to be realised in the medium-term;

- In the short-term, the depressed economy and economic outlook is unlikely to result in a rapid rate of development and uptake of new housing. The water demand of this development can therefore be expected to grow relatively slowly over a period of time.

6.6.1.1.3 Brakwater

Noting that development in the Windhoek basin is reaching its limits along the eastern, southern and western boundaries, the Brakwater Bulk Services Master Plan was prepared to cater for the foreseen expansion of Windhoek in a northerly direction (Lithon, 2010). This area consists mostly of privately owned plots which are expected to be subdivided in future (Lithon, 2010). The Brakwater Bulk Services Master Plan envisaged a 4.05% per annum probable population growth rate resulting in a probable maximum population of 184 000 inhabitants and 3 150 industries in 2119 (Lithon, 2010).

The estimated water demand of the dully developed Brakwater area is given as 45 000 m^3/d (Lithon, 2010), which is equivalent to approximately 16.4 Mm^3/a.

As with the Ongos and Monte Christo developments, it is likely that the development of the Brakwater area will not proceed as rapidly as initially estimated and that the full development and estimated water demand may take some time to be achieved.

6.6.1.1.4 Osona Village

The Osona Village, located west of the B1 highway between Windhoek and Okahandja, opposite the Osona Military Base, initially commenced as a housing development for “men and women in uniform” (NBC, 2016). The Government Institutions Pension Fund (**GIPF**) entered into partnership with Preferred Investment Property Fund under the Unlisted Investment Programme of the GIPF for the construction of houses (Lela, 2017), which, under later phases of the development, are available to the general public.

Correspondence with Knight Piésold Consulting Engineers and Mutschler Consulting Engineers who were and are involved with the Osona Village Development respectively, provided a design demand of 10 000 m^3/d for the full development, equivalent to 3.652 Mm^3/a.

6.6.1.1.5 Development in the Greater Windhoek Area

During consultations with the CoW, it was agreed that the growth in population, water demand and development of the Greater Windhoek Area should be examined holistically; i.e. that the Windhoek Basin, together with the Brakwater, Elisenheim, Ongos and Monte Christo and “airport” or “eastern” developments (Finkenstein, Herbothsblick, Sungate), be viewed as a single developmental area.

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Due to the relative shortage of available land in the Windhoek Basin, the CoW envisages that in terms of growth in Windhoek, for the high income and "lifestyle" developments, this will take place to the east (Finkenstein, Herbothsblick, Sungate) and south (Omeya; which is not included in the water supply and demand) of the City, that middle income developments will take place in Elisenheim, industrial developments in Brakwater and mid-to-lower income developments at Osona Village and the Ongos and Monte Christo areas.

Residents of these satellite townships are most likely to be working in Windhoek and thus these areas should be considered to be part of the "Greater Windhoek Area". The CoW also expects further densification in the Windhoek Basin, due to the relative shortage of developable land and the relative distance of the Ongos and Monte Christo areas from the city centre and southern industrial areas (residents may be unwilling to commute that far).

Overall, the Osona Village (3.65 Mm^3/a), Elisenheim (3.29 Mm^3/a), Brakwater (16.44 Mm^3/a), Ongos and Monte Christo (32.92 Mm^3/a) developments are expected to have water demands totalling 56.30 Mm^3/a once fully developed, according to the formal development plans and information available (refer above). This is more than double the 2018 water use in Windhoek (25.46 Mm^3/a for potable use; CoW), which, according the development plans, would constitute demand in addition to the future demand of the Windhoek Basin. It is however considered unlikely that the future water demand of Windhoek will reach over 80 Mm^3/a, and hence the CoW's position that the development of the Greater Windhoek Area should be viewed holistically. It is in any event clear from the assessment of the historical and current supply and demand in the CAN, that the current resources supplying the CAN do not have sufficient capacity to supply the approximately 56.30 Mm^3/a of additional water demand (should this be the case), and it is also likely that this cannot be supplied from existing water sources within the interior of Namibia either.

6.6.1.1.6 Formalisation of Communal Services

The Department of Housing, Property Management and Human Settlements and the Department of Urban and Transport Planning of the CoW have indicated that the City Council has resolved to formalise the provision of services in the informal settlement areas of Windhoek. In the initial stages, this will consist of increasing the coverage of services to reduce the distance people need to walk to get water from communal water points from 200 m to 100 m and thereafter to provide yard connections. The CoW expects that water consumption will increase from 20-30 ℓ/c/d for water collection at communal standpipes to ±100 ℓ/c/d for yard connections. These expectations are closely aligned with the findings of Uhlendahl et al. (2010) who found unit consumption rates of 21 ℓ/c/d at community taps, 29 ℓ/c/d at prepaid or public taps and 109 ℓ/c/d on serviced erven.

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Assuming that the CoW successfully implements the formalisation of services to a (currently estimated) population of some 130 000 in Windhoek's informal settlements, and this results in an increase in water demand of 70 ℓ/c/d (an increase from 30 ℓ/c/d at communal water points to 100 ℓ/c/d for yard connections), this would result in an additional water demand of some 3.3 Mm^3/a.

The view of the CoW is that this increase in demand will likely off-set some of the effects of the lower economic growth expected in the short- to medium-term.

6.6.1.2 Okahandja

The Okahandja Municipality was not able to make available any formal development plan, as they are in process of compiling this, having appointed consultants to do so. Previous development proposals are provided above.

6.6.1.3 Karibib

The Karibib Town Council was not able to make available any formal development plan, but indicated a large number of development projects / proposals in and around Karibib, including:

- A Woermann Brock supermarket development;
- Plans to service industrial plots and formalise ±350 plots in Usab (servicing);
- The Best Cheer marble works are set to expand;
- The Desert Lion Lithium Mine (although some uncertainty exists in this regard);
- A Chinese developer is expected to develop the Karibib Extension 3 as a housing development;
- A building materials manufacturing plant;
- A paper recycling plant.

It is often the case that prospective developments are not implemented at all, or not as originally envisaged, particularly in terms of time frames. Whilst Karibib is located on the Trans-Kalahari Corridor and there is therefore latent development potential, it is unlikely that the town will grow much above historical rates. In the short- to medium-term, it is likely that growth (or not) in the town will be more closely aligned with the fortunes of the Navachab Gold Mine.

6.6.1.4 Navachab Mine

The WAS for the CAN was conducted shortly after the mine was sold to a new owner, QKR, in 2013 and it was thought that the mine might close in 2030. However, QKR (the owners of the mine) have indicated that the current life of mine is expected to extend to 2061.

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Navachab Mine's agreement with NamWater was signed on the 27th of April 1988 and was valid for 30 years, therefore to 2018. Apparently, a new agreement is still being finalised between the mine and NamWater. The 1988 agreement made provision for NamWater to supply the mine with 4 500 m^3/d from Swakoppoort Dam, with a maximum of 5 000 m^3/d. The mine has averaged a monthly usage of 135 000 m^3/m (Wilhelm, 2019).

6.6.2 Water Supply and Demand Options

6.6.2.1 Expected Realistic Growth in Water Demand in Windhoek

During the various consultations carried out with the CoW, they indicated that their best estimate of the current realistic or ideal water demand for Windhoek is in the order to 26 to 26.5 Mm^3/a. They expect a realistic growth in water demand to be between 2.6% and 3.3% per annum, which is lower than the population growth rates experienced to date, as this has indeed been the case historically; the growth in water demand has been lower than the population growth rates. As noted above, the growth in water demand is to apply to the "Greater Windhoek Area", being Windhoek plus the outlying developments.

Overall, the CoW indicated that their estimate for the 2050 water demand for the "Greater Windhoek Area" to be in the order of 60 Mm^3/a.

Using the CoW's indications, a current (2019) realistic or ideal water demand of 26.25 Mm^3/a; the demand in 2050 would be 58.17 Mm^3/a using a 2.6% per annum growth rate or 65.63 Mm^3/a using a 3.0% per annum growth rate. It is however not clear to what area / demand configuration of Windhoek (including / excluding Brakwater & Elisenheim for example) the CoW's value of ± 26.25 Mm^3/a for 2019 or their estimate of 60 Mm^3/a for 2050 corresponds. By averaging the values obtained using different growth rates (58.17 Mm^3/a and 65.63 Mm^3/a as above), a value of ±62 Mm^3/a can be derived as an estimate of the 2050 water demand for the "Greater Windhoek Area". Given the uncertainties noted above, and the fact that this figure includes the water demands of the "airport subsystem" which are likely not included in the CoW's estimate, this is believed to correspond closely enough with the demand of 60 Mm^3/a indicated by the CoW.

To reach the targeted water demand in 2050 from the baseline used by the Consultant, a growth rate of ~3.1% is required, which is also considered reasonable.

6.6.2.2 Definition of the Von Bach – Windhoek Area

The Consultant has interpreted the water demands for the "Greater Windhoek Area" to in reality correspond with NamWater's Von Bach – Windhoek Scheme, due to the need to include the Osona Development which technically falls outside the "Greater Windhoek Area" depicted in **Figure 6.25** above.

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Water demand projections for the Greater Windhoek Area have been determined as follows:

Von Bach – Windhoek Scheme = Windhoek (as represented by supply to Terminal Reservoir)

+ Brakwater

+ Elisenheim

+ Ongos and Monte Christo

+ Osona Development

Termed "Major Developments" by the Consultant

+ Other small on-line users along the Von Bach – Windhoek Pipeline

+ Airport subsystem users (Finkenstein, Herbothsblick, etc.), excluding Otjihase Mine.

6.6.2.3 Current or Baseline Demand in the Windhoek Basin

Since water demand projections are to be prepared for different "areas" or developments – refer above – the Consultant has needed to split the historical water demands / use into the corresponding areas or "segments".

For example, the historical sales to Brakwater and Elisenheim need to be subtracted from the supply by NamWater since the demand projections for these areas are to be determined separately.

The Consultant used sales data from NamWater up to NamWater's FY 2018 (April 2017 to March 2018) for their Von Bach – Windhoek Scheme and from this, used the sales data at Terminal Reservoir (representing supply to the Windhoek Basin). An historical analysis was done by comparing NamWater's sales at Terminal Reservoir to the CoW's data for supply by NamWater and it was found that there is a relatively poor correlation, even allowing for different financial years:

- NamWater Terminal Reservoir Sales FY 2018: 13.13 Mm^3/a
- CoW data for supply from NamWater: Calendar 2017: 14.22 Mm^3/a
- CoW data for supply from NamWater: Calendar 2018: 13.93 Mm^3/a

Some of the discrepancy is believed to be due to water use in the Brakwater area which is billed separately by NamWater but which may be aggregated under "supply from NamWater" in the CoW's data. The data from the CoW cannot be disaggregated and thus the exact source of the discrepancies cannot be confirmed.

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Since NamWater's sales data to Elisenheim, the other on-line users and the airport system was used, the NamWater sales data for Terminal Reservoir was also used.

To derive an approximate value for the baseline (for projections) water demand for Windhoek; the Consultant applied the following:

- NamWater Terminal Reservoir Sales FY 2018: 13.13 Mm^3/a
- Windhoek Borehole Supply: CoW: FY 2017: 2.94 Mm^3/a
- Reclaimed Water (NGWRP Supply): CoW: FY 2017: 5.96 Mm^3/a
- **Total Windhoek Basin Demand: FY 2017/18: 22.03 Mm^3/a**.

These values exclude the Brakwater & Elisenheim areas which are added separately and exclude artificial recharge which is water which is not used consumptively (not part of Windhoek's "demand"). The Consultant used NamWater's FY 2018 as the baseline for projections across the whole project.

6.6.2.4 Rate of Development of the Major Developments around Windhoek

The Consultant initially used the water demand projections for the various "Major Developments" as contained in the applicable master plan reports approved by the CoW:

- Ongos and Monte Christo: 90 118 m^3/d (Lithon et al., 2016a), which is equivalent to approximately 33 Mm^3/a;
- Brakwater: 45 000 m^3/d (Lithon, 2010), which is equivalent to approximately 16.4 Mm^3/a;
- Osona Village: 10 000 m^3/d for the full development (Knight Piésold Consulting Engineers and Mutschler Consulting Engineers), which is equivalent to 3.652 Mm^3/a.

Due to the uncertainty regarding the rate of progression of these developments, and the current depressed economic climate and short- to medium-term outlook, it was initially assumed that they would be fully developed by 2050 (end of the Planning Horizon). It was further assumed that these developments would follow a "S-curve" which is typically that followed by new developments.

Following the consultations with the CoW who indicated a target water demand for 2050, the Consultant has "scaled" these demands by different percentages under different scenarios or options, to represent an "envelope" of possible water demands for these developments.

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6.6.2.5 Definition of the Water Demand Nodes and Configuration

The configuration or definitions of the demand areas or nodes used are as follows:

- Windhoek Basin: Corresponds with supply from Terminal Reservoir
- Major Developments = Brakwater + Elisenheim + Ongos and Monte Christo + Osona Development
- Other Online Users = Other users along the Von Bach – Windhoek Pipeline
- Airport System = All demand on the Booster 2 – Airport Pipeline system excluding Otjihase Mine.

The grouped configurations or demand areas are therefore as follows:

Total Von Bach – Windhoek Users: = Windhoek Basin

+ Major Developments

+ Other Online Users

+ Airport system, excluding Otjihase Mine

These configurations are illustrated in Figure 6.26.

Total d/s of Von Bach = Total Von Bach – Windhoek Users

+ Okahandja + Resorts (Goss Barmen & Von Bach) + Swakoppoort – Von Bach online demands + Otjihase Mine.

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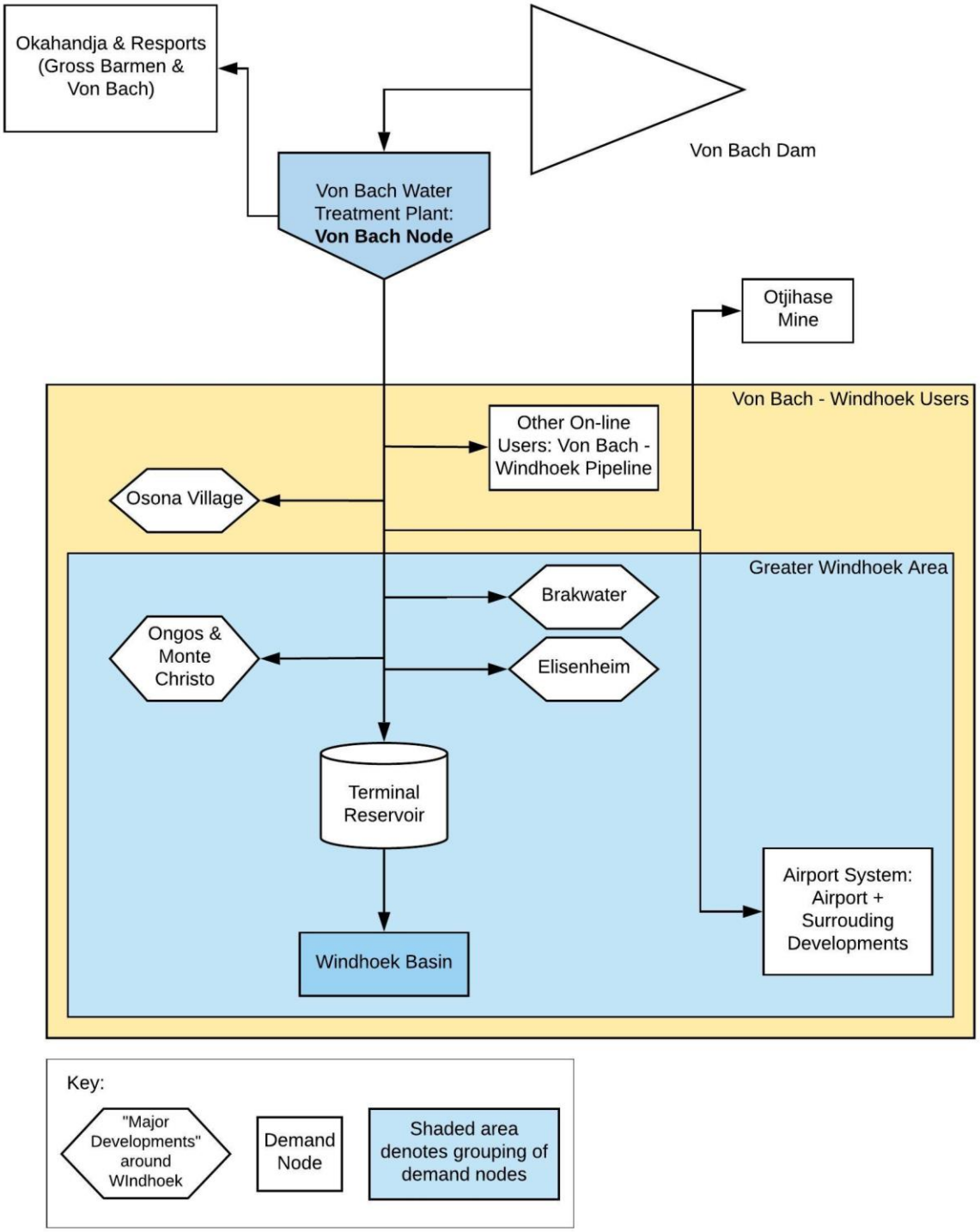

Figure 6.26: Schematic Layout of the Water Demand Nodes and Configuration

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For this desalination feasibility study:

Total CAN Demand = Total d/s of Von Bach + Swakoppoort System Demands (Karibib, Otjimbingwe, Navachab Mine & On-line users)

6.6.2.6 Water Demand Scenarios, Major Developments and Different Demand Nodes

Various water demand projections were produced under three scenarios; low likely, likely and high likely for the various existing consumers (Windhoek, Okahandja, etc). Four scenarios were put forward to cater for different extents of final development of the "major developments" around Windhoek. This has resulted in twelve overall demand options for the CAN (as defined for this Study) for 2050, giving a broad range of water demands; between 40.67 Mm^3/a and 91.64 Mm^3/a, as detailed in **Appendix 2**.

6.6.2.6.1 Major Developments Around Windhoek

The water demand projections for the "Major Developments" which derive from targeted water demand of ±62 Mm^3/a for the "Greater Windhoek Area", per the CoW's recommendations (refer above), are provided in **Table 6.8** and are illustrated in **Figure 6.27a**.

Table 6.8: Client's Recommendation for the Water Demands of Major Developments Around Windhoek (Likely Scenario)

Item		**Water Demands (Mm^3/a) Per Development and Total**			
		Osona Village	**Brakwater and Elisenheim**	**Ongos and Monte Christo**	**Total**
Reuse %[1]		Not Applicable	Not Applicable	15%	Not Applicable
Water Demands[2] (Mm^3/a)	2018	0.00	0.48	0.00	0.48
	2020	0.01	0.49	0.02	0.52
	2025	0.05	0.71	0.39	1.15
	2030	0.30	2.04	2.52	4.85
	2035	0.85	4.96	7.06	12.88
	2040	1.31	7.36	10.56	19.23
	2045	1.45	8.09	11.37	20.92
	2050	1.46	8.18	11.19	20.83

Notes:
1. Reuse only applicable to Ongos and Monte Christo, where direct potable reuse was suggested (Lithon et al., 2016a). The extent of reuse varied per the extent of the development.
2. The water demands presented in this table already incorporate the effect of reuse (only applicable for Ongos and Monte Christo).

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Table 6.9: Client's Recommendation for Water Demands Downstream of the Von Bach Water Treatment Plant (Likely Scenario)

Item			Water Demands (Mm^3/a) and Other Values Per Node and Total								
			Okahandja	**Resorts[1]**	**Swakop-poort - Von Bach[2]**	**Von Bach - Windhoek (online)[3]**	**Airport Users[4]**	**Otjihase Mine**	**Windhoek Basin[5]**	**Major Devel-opments[6]**	**Total**
Growth Rate (% p.a.)	Short Term	2018-2023	4.0%	Not applicable	Not applicable	5.0%	Not applica-ble	Not applica-ble	3.0%	Not applicable	Not applicable
	Medium Term	2023-2035	3.0%			3.5%			2.0%		
	Long Term	2035-2050	2.0%			1.0%			1.0%		
Non-revenue water (%)		2018	14.5%			0.0%			15.0%		
		2050	12.0%			0.0%			12.0%		
Water Demands (Mm^3/a)		2018	1.63	0.07	0.09	0.53	0.27	0.02	22.03	0.48	25.12
		2020	1.77	0.10	0.10	0.58	0.30	0.25	23.32	0.52	26.94
		2025	2.09	0.14	0.14	0.72	0.72	0.30	26.89	1.15	32.15
		2030	2.42	0.14	0.15	0.88	1.22	0.30	30.11	4.85	40.07
		2035	2.78	0.15	0.16	1.03	1.70	0.30	33.06	12.88	52.06
		2040	3.07	0.15	0.16	1.09	1.86	0.30	34.56	19.23	60.42
		2045	3.39	0.15	0.16	1.14	2.00	0.30	36.13	20.92	64.19
		2050	3.74	0.16	0.16	1.20	2.16	0.30	37.77	20.83	66.32

Notes:

1. "Resorts" includes the Gross Barmen and Von Bach Dam Resorts and the Von Bach – Gross Barmen and Gross Barmen – Rüdenau Nord pipeline schemes
2. The Swakoppoort – Von Bach node refers to the on-line users supplied by this pipeline which are accounted for under the Von Bach Node in the methodology followed by NamWater.
3. These are the on-line users along the Von Bach – Windhoek Pipeline, excluding the Major Developments and the Airport Subsystem.
4. These include the Hosea Kutako (Windhoek International) Airport, including to the surrounding developments such as Finkenstein, Herbothsblick, Kapp's Farm, Sungate Mixed Use Development and Sonnleiten Nature Estate, but exclude the Otjihase Mine which is added separately as a non-domestic type of user.
5. Water demands for the Windhoek Basin, being the area supplied from Terminal Reservoir.
6. Major Developments as defined, with water demands from **Table 6.8**.

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6.6.2.6.2 Water Demands for the Von Bach Node

The water demand projections for the Von Bach Node or those downstream of the VBWTP, consisting of the Client's recommendations for the water demand projections of existing consumers and those of the Major Developments around Windhoek, are provided in Table 6.9 and are illustrated in

Figure 6.27b (for the existing consumers only). The total projected demands for 2050 for the Von Bach Node are approximately 66.32 Mm^3/a, consisting of existing consumers (45.5 Mm^3/a) and the Major Developments (20.83 Mm^3/a).

6.6.2.6.3 Water Demands on the Swakoppoort Dam Node

The Client's recommendations (likely scenario) for the water demands on the Swakoppoort Dam, which consist of Karibib and Otjimbingwe (potable water), Navachab Gold Mine and on-line users (raw water), are provided in Table 6.10 and are illustrated in

Figure 6.27c. The total projected demands for 2050 for the Swakoppoort Dam Node are approximately 2.44 Mm^3/a.

Table 6.10: Client's Recommendation for the Water Demands on the Swakoppoort Dam Node (Likely Scenario)

Item			**Water Demands (Mm^3/a) and Other Values Per Node and Total**		
			Swakoppoort Raw Water (Okongava and Navachab)	**Karibib WTP (including Otjimbingwe)**	**Total**
Growth Rate (% p.a.)	Short Term	2018-2023	Not applicable	3.0%	Not applicable
	Medium Term	2023-2035		2.1%	
	Long Term	2035-2050		0.8%	
Non-revenue water (%)		2018		10%	
		2050		10%	
Water Demands (Mm^3/a)		2018	1.26	0.43	1.69
		2020	1.50	0.46	1.96
		2025	1.64	0.51	2.15
		2030	1.65	0.56	2.22
		2035	1.68	0.61	2.28
		2040	1.70	0.63	2.33
		2045	1.73	0.65	2.38
		2050	1.77	0.67	2.44

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6.6.2.7 Total Water Demands for the Central Area of Namibia

A summary of the water demands recommended / selected by the Client for the CAN (as defined for this Study) is provided in Table 6.11 and are illustrated in **Figure 6.27d**.

Table 6.11: Client's Recommendation for the Total Water Demands in the CAN

Item		Water Demands (Mm^3/a) Per Node and Category and Total				
		D/S of Von Bach WTP	**D/S of Swakop-poort Dam**	**Mining Water Demand**	**Non-Mining Water Demand**	**Total**
Water Demands (Mm^3/a)	2018	25.12	1.69	1.28	25.53	26.81
	2020	26.94	1.96	1.75	27.16	28.91
	2025	32.15	2.15	1.93	32.35	34.29
	2030	40.07	2.22	1.95	40.33	42.28
	2035	52.06	2.28	1.97	52.37	54.34
	2040	60.42	2.33	2.00	60.75	62.75
	2045	64.19	2.38	2.03	64.55	66.58
	2050	66.32	2.44	2.07	66.70	68.77

Notes:
1. The Mining Water Demand in the CAN includes the water demand of the Otjihase Mine and that of the Swakoppoort Raw Water component; Okongava and Navachab Gold Mine (QKR) per the option selected by NamWater.

The Client's recommended water demands for 2050 of 68.77 Mm^3/a falls slightly above mid-way within the range of water demands for the CAN (as defined) between 40.67 Mm^3/a (minimum or lowest of the scenarios) and 91.64 Mm^3/a (maximum or highest of the scenarios) which results from the overall combination of scenarios and options.

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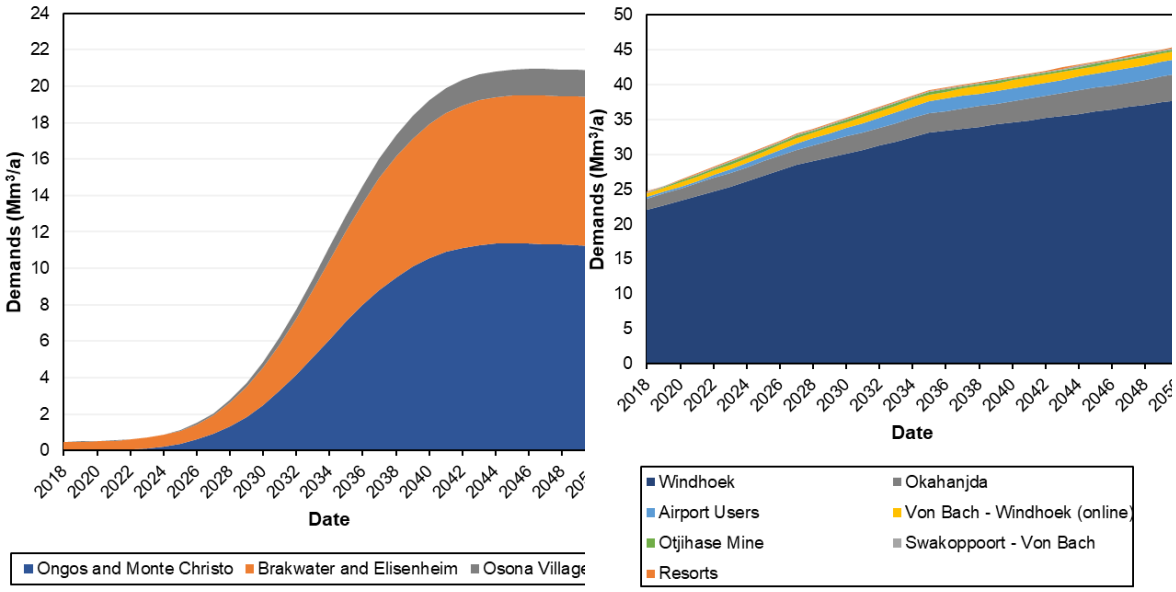
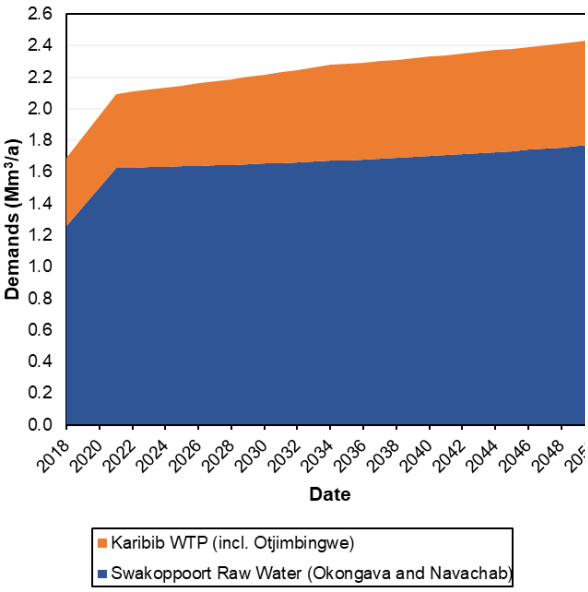
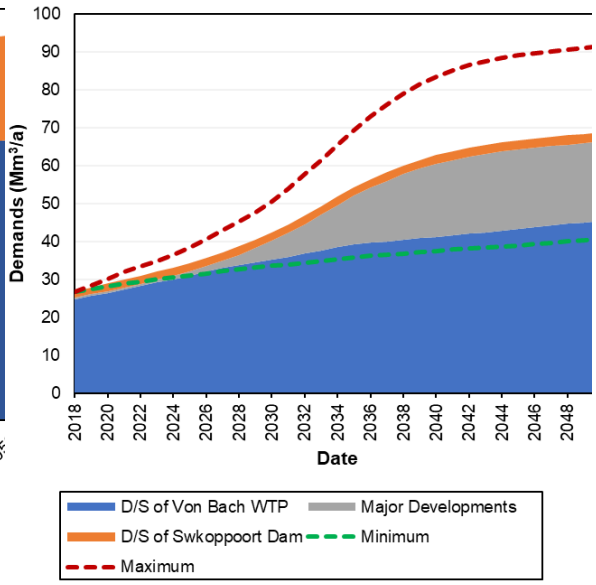


(e) Major Developments Around Windhoek

(f) D/S of Von Bach (Existing Users)



(g) Swakoppoort Dam Node



(h) Total CAN Water Demands

Figure 6.27: Client's Recommended Water Demands for the Various CAN Nodes

6.6.3 Comparison of Water Demand Projections for the Von Bach Node with Previous Assessments

The "Von Bach Node" refers to all demand areas or nodes downstream of the Von Bach Water Treatment Plant as defined above. This node / demand configuration represents the best basis according to which demand projections from different assessments can be compared.

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A comparison of water demand projections for the Von Bach Node from different assessments is provided in **Figure 6.28**. Comparative demands for 2050 are as follows:

- Okavango Feasibility Study or CAN WAS: 80.05 Mm^3/a
- Can Medium Term Options Project of NamWater: (67.66 Mm^3/a)[52]
- Desalination Feasibility Study: 66.32 Mm3/a

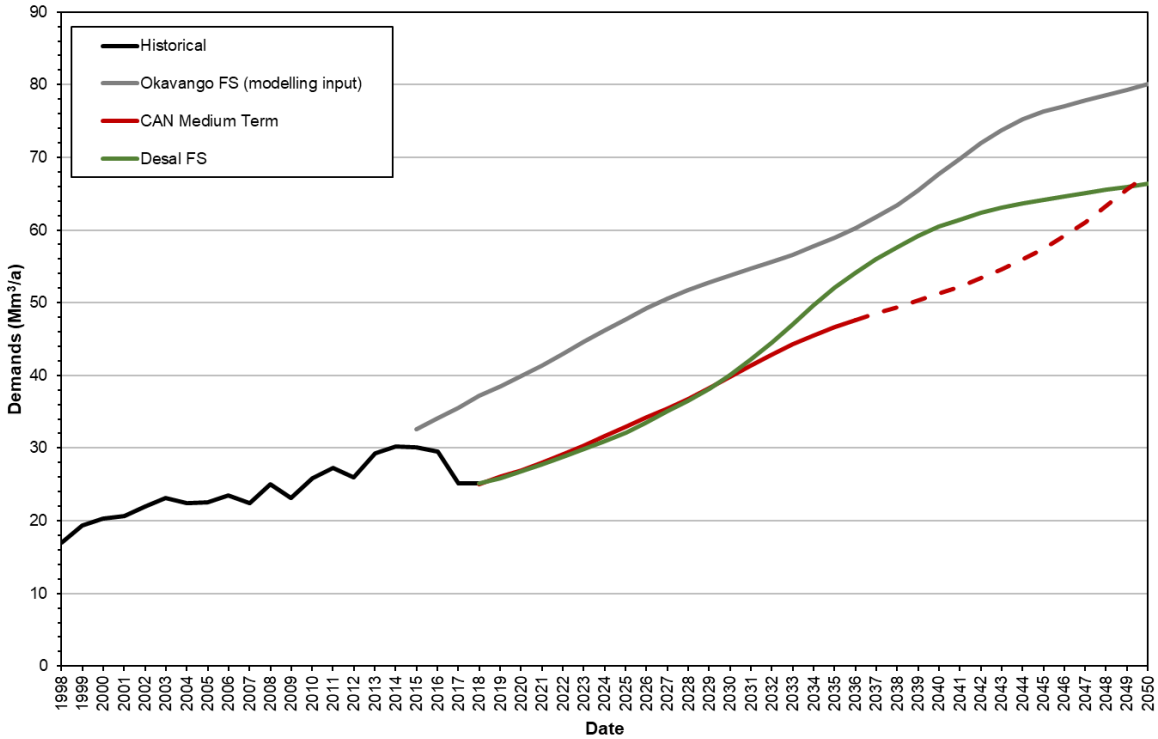

Figure 6.28: Comparison of Water Demand Projections for the Von Bach Node

Notes:
1. Historical = Historical sales, per NamWater data.
2. Okavango FS = "*The Augmentation of Water Supply to the Central Area of Namibia and the Cuvelai: Part I: The Central Area of Namibia: Draft Final Report*", Contract Ref. EoI1/18/2 – 02/2011, also referred to as the CAN WAS (LCE-SCE JV, 2017).
3. CAN Medium Term = "*Medium-Term Water Supply Alternatives for the Central Area of Namibia: Updated Draft Interim Report for Project Phase 1: Assessment and Shortlisting of Identified Options*", Procurement Ref. No. SC/RP/NW-011/2018, also referred to as the CAN Medium Term Options Study (LCE-SCE JV, 2019). Under this study, water demand projections were prepared up to 2035 and not to 2050. The projections were extrapolated from 2035 to 2050 for the purposes of this comparison

[52] Water demand projections were prepared up to 2035 for NamWater's CAN Medium Term Options Study and not to 2050. The projections were extrapolated from 2035 to 2050 for the purposes of this comparison.

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6.7 Water Deficit Projections

6.7.1 Approach to the Derivation of Water Deficit Options and Projections

In following a "deficit approach" (refer to **Section 4.4.5**), the augmentation of deficit volumes represent the difference between the projected water demands (including losses) and the capacity of the existing and local sources, and thus the volumes of desalinated seawater required, either from the existing EDP and / or another seawater desalination plant.

The approach to the estimation of the water demands, the utilisation of existing and local sources and the derivation of deficits requested by NamWater has been that of providing options for each component. From twelve overall water demand options (three options for the water demands of existing consumers, combined with four options for the "Major Developments" around Windhoek; refer above), and different options for the utilisation of the existing sources, 96 overall deficit options are derived.

6.7.2 Utilisation of Existing and Local Water Resources

As indicated in **Section 6.3**, various configurations of the existing water supply sources were discussed and incorporated into supply scenarios, combining these different individual sources into overall supply scenarios. There are presented in **Appendix 2**.

The Client's recommendation for the utilisation of the existing sources in the CAN is based on the use of surface water sources at a higher yield but lower reliability, with the back-up of groundwater sources, as follows:

- Surface water utilisation at 20 Mm^3/a from the CAN dams, which is believed to be at 95% assurance (NamWater), per the 2004 CAN WAS (CAJVC, 2004c)[53];
- Long-term "normal" utilisation of the Windhoek Aquifer at the rate of natural recharge of 1.73 Mm^3/a (Zhang et al., 2002) since surface water is used at a higher yield but lower reliability, and there is therefore unlikely to be sufficient water available for regular artificial recharge of the Windhoek Aquifer. Emergency abstraction of the aquifer will be used to bridge periods when surface water is in short supply, given the lower reliability of utilisation;
- Total reuse of reuse of 45% of the potable supply to Windhoek as a more realistic target than 50%, with additional RO treatment.

[53] This scenario and value was specifically requested by NamWater and is in this form not supported by the Consultant.

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NamWater's proposal for the utilisation of surface water sources can be understood in the context of desalinated seawater providing an hydrologically independent water source, which in combination with the emergency use of groundwater sources, should be able to bridge periods when surface water is in short supply.

6.7.3 Water Deficit Projections for the Central Area of Namibia

The different water resource options (**Section 6.3.7**) combined with the twelve water demand options (**Section 6.6.2.6**) are detailed in **Appendix 2**. The water deficit options provide a broad range of water deficits for 2050; between zero (for the lowest demand options and highest source utilisation option) and 68 Mm^3/a. NamWater's recommendation for the utilisation of the existing sources (39 Mm^3/a) combined with the approved / selected demand option of 69 Mm^3/a, results in an expected water deficit of 30 Mm^3/a for the CAN (as defined) in 2050.

Table 6.12: Summary of the Expected Water Deficits for the Central Area of Namibia

Year	CAN Water Deficits (Mm^3/a)		
	Minimum Option Combination[1]	**Maximum Option Combination[2]**	**Client's Recommendation[3]**
2018	0.00	3.28	0.00
2020	0.00	6.59	1.06
2025	0.00	14.83	4.66
2030	0.00	27.11	10.77
2035	0.00	45.86	20.83
2040	0.00	59.95	27.63
2045	0.00	65.56	29.72
2050	0.00	68.02	30.04

Notes:
1. Minimum deficits derive from the lowest combination of water demand projections and the combination with the highest utilisation of existing sources.
2. Maximum deficits derive from the highest combination of water demand projections and the combination with the lowest utilisation of existing sources
3. The Client's Recommendation derives from the water demand projections recommended by the Client (NamWater and the CoW) and NamWater's recommendations for the utilisation of existing sources.

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6.8 Additional Considerations

6.8.1 Stakeholder Feedback

Several local authorities mentioned that cost is a consideration in water supply, in terms of the possible acceptance of / demand for desalinated water which is likely to come at much greater cost than current tariffs and in terms of affordability by their communities.

The Karibib Town Council reported the presence of biofilm (algae / scum / slime) in their pipes and have received complaints about the (poor) taste of the water, which they ascribe to the quality of water received from NamWater.

6.8.2 Decentralisation of Growth and Demand Away from Windhoek

Windhoek is located close to the watershed of three basins: The Omaruru-Swakop Basin originates just to the north of Windhoek, whilst the Kuiseb Basin originates to the west and the Nossob-Auob Basin to the east and south of the Capital. In other words, water flows away from Windhoek in almost all directions. The Capital is furthermore located in the centre of the country, almost equidistant from the perennial rivers on the northern and southern borders of the country (some 685 km from Noordoewer, some 646 km from the Ruacana Falls and some 587 km from Rundu as the crow flies). As with the country as a whole, hydrologically, evaporation exceeds rainfall by a significant margin, such that Windhoek experiences a water deficit of some 2,000 mm per annum.

As the economic, political, administrative, legislative and social and cultural centre of the country, Windhoek's importance to Namibia cannot be overstated. Windhoek is also the largest water demand node, with the City of Windhoek being NamWater's single largest customer, accounting for 24% of NamWater's total operating revenue (prior to the 2015-17 drought).

Although this situation has arisen over a period of time, the current situation is that the country's capital and most important urban centre is the largest single water demand node, which is located in possibly one of the worst locations from a water supply perspective.

Being almost equidistant from the perennial rivers on the northern and southern borders of the country means that supply from these surface water sources is almost equally difficult regardless of the source. Moreover, Windhoek is located at an altitude of some 1,700 m above sea level, which means that pumping desalinated sea water to the Capital from the coast would incur very high energy demands and consequently costs.

With the water demands of the CAN, for which Windhoek is responsible for by far the largest portion, already exceeding the long-term sustainable yield of the available sources, from a water supply perspective, the continued development in and of Windhoek should be re-examined.

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Even with the application of WDM measures and increased reclamation, further development in and around Windhoek will result in increased water demand, thereby increasing the magnitude of the supply deficit of the CAN. Given the difficulties with Windhoek's location from a water supply perspective, as outlined above, water augmentation from outside of the CAN will be very costly.

By prohibiting further development in and around Windhoek, including densification, an attempt can be made to cap the water demand of the Capital, thereby limiting the magnitude and frequency of future supply shortfalls. The decentralisation of development and water demand is included in the Government's Harambee Prosperity Plan, which includes the proposal to "*develop incentives to bring industrial sites closer to water resources*" which is noted as one of seven strategies and actions to be undertaken under "Water Infrastructure", with the aim of increased water security. "Water Infrastructure" is one of four components of "Infrastructure Development", which is in turn one of the five pillars of the Harambee Prosperity Plan (OOTP, n.d.[2]). Under this strategy, the "*idea is to locate water intensive industries away from the central region and closer to the perennial rivers*" (OOTP, n.d.[2]). This marks the first time the Namibian Government has, in terms of formal policy, proposed that water intensive industries should not develop in the CAN. Furthermore, "*Specific incentive proposals*" regarding the strategy to locate water intensive industries close to the perennial rivers are to be developed by July 2017 under the Harambee Prosperity Plan (OOTP, n.d.[2]). Whilst these intentions may be sound, it is not clear whether any specific incentive proposals have been developed as intended.

However, the principle of decentralisation should apply to the whole of the CAN, not only to Windhoek, otherwise, as was with the case with the SABMiller Brewery in Okahandja, developments which are discouraged in Windhoek may establish in Okahandja or elsewhere in the CAN, which areas are supplied from the same water sources, thereby nullifying any prohibition measures implemented in or by Windhoek.

An extension of the principle of prohibiting further development in and around Windhoek would be the relocation of some industries, businesses and developments out of Windhoek. However, this can be expected to have much more serious implications for Windhoek and Namibia as a whole than a prohibition of further development, including costly relocation and surplus development, land and property in the Capital.

Considering and implementing such a policy of decentralisation would require the full commitment of a number of stakeholders and a determined, focussed, over-arching and coordinated effort on the part of Central Government. This is due in part to a number of factors which would currently inhibit the implementation of such a decentralisation policy, including

- The lack of serviced erven in smaller centres such as Rundu and Katima Mulilo;
- The lack of town plans which cater for large-scale increased development in smaller centres;

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- A lack of skilled personnel in smaller centres who would be able to develop such town plans, the designs for and development of additional serviced land. Smaller town councils would need to be provided with assistance in this regard;
- Smaller town councils lack the funds to plan, design and develop additional serviced land; these would need to be provided by Central Government;
- Smaller towns such as Rundu and Katima Mulilo for example are surrounded by communal areas. Being able to secure freehold title to serviced land would be a prerequisite to attracting large-scale development to areas such as these where water is more readily available than in the CAN. The expansion of such towns would therefore require that communal land is purchased, communities compensated and relocated, urban areas be proclaimed or existing proclaimed areas be extended and such new areas be incorporated into town plans, zoned and developed accordingly;
- These measures can only be accomplished under a clear policy framework and with concerted and coordinated implementation by Central Government;
- The infrastructure in smaller towns such as Rundu and Katima Mulilo for example (roads, telecoms, water and electricity supply etc.), as well as services such as schools and hospitals, are likely inadequate to cater for large-scale additional development. These will therefore need to be upgraded and extended. As above, the smaller town councils lack the skilled personnel and funds to do so, and will need to be supported by the Central Government.

There is a clear benefit to restricting or prohibiting further growth and development in the CAN, particularly Windhoek, in order to cap the water demand of the area, thereby limiting the magnitude and frequency of future supply shortfalls and reducing the costs of any augmentation scheme. However, there are a number of factors which would mitigate against a policy of decentralisation, which would require a clear policy directive, clear, coordinated planning, sufficient funding and a determined effort on the part of Central Government to address.

6.8.3 Considerations Regarding the Utilisation of Existing Sources and Augmentation with Desalinated Water

The design of this Study, in terms of the ToR and the approach followed by NamWater and KfW has placed a great deal of emphasis on deriving very “detailed” water demand projections for 30 years into the future, even though this period extends well beyond the horizon of the planning information available and the fact that economic, political, socio-economic and other factors simply cannot be anticipated that far into the future with any accuracy. By contrast however, comparatively little emphasis has been placed on how existing sources are to be utilised and how desalinated seawater is to be incorporated into the existing configuration of supply.

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One of the chief difficulties with water supply in the CAN is the extreme variability of particularly surface water sources, which together with the complexity of the system, is why NamWater uses a numerical model (termed the CA-Model) to analyse supply / demand in the CAN for the purposes of both long-term and short-term planning. In order to account for the extreme variability of surface water supply, which comprises the majority of sustainable supply to the CAN, the CA-Model uses a "bootstrapping" statistical methodology to generate a random set of future inflows to the CAN dams from the historical inflow record, which is then analysed to derive the statistical probability of shortfalls. The ToR do not require the use of NamWater's CA-Model for the analysis of supply / demand dynamics in the CAN together with desalinated seawater and even if it did, the model could not be used for this purpose, as it does not offer the appropriate functionality[54].

Of necessity therefore, the "traditional approach" per Blersch and du Plessis (2017) or the "incremental approach" per Van Niekerk and Du Plessis (2013b), being approaches which do not account for the variability of surface water sources, has been followed in estimating the capacity of the desalination plant and the volumes of desalinated water required for the CAN (refer to **Section 4.4.5**). It must however be recognised that this is not the ideal approach, as according to Blersch and du Plessis (2017), different results are obtained when desalinated supply is sized to meet the shortfall between the existing system capacity and the projected demands (the "traditional approach") and when a water resources planning approach using stochastic sequences is followed[55].

The possible inclusion of desalinated seawater into the Western Cape water supply system which consists of an integrated system of primarily surface water supply (with several inter-basin transfers), which system is also subject to significant variability, was recently investigated using the South African Water Resources Yield Model and Water Resources Planning Model by Blersch and du Plessis (2017). This work is believed to offer valuable insights which could be applied to the Namibian initiative in the event that the appropriate modelling functionality or analysis tools would be available. Some of the key findings of this work include (Blersch and du Plessis, 2017):

1. As the reservoir trigger level at which the desalination plant kicks in is lowered, the increase in historic firm yield decreases substantially;
2. The maximum increase in historic firm yield is achieved when the desalination plant is always operational;

[54] Due to the rigidity of the model architecture, additional sources cannot be added and different supply or demand priorities cannot be assigned to different sources or demand nodes.

[55] The South African Water Resources Yield Model and Water Resources Planning Model software use a stochastic (statistical) methodology to account to account for the variability of surface water sources as opposed to the bootstrapping methodology used by the CA-Model. Whilst these approaches are not the same, the point is that they are methods used to account for the variability of surface water sources, which is not accounted for in following a "traditional approach" or "incremental approach".

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3. Different results are obtained when desalinated supply is sized to meet the shortfall between the existing system capacity and the projected demands (the "traditional approach") and when a water resources planning approach using stochastic sequences is followed;

4. The maximum increase in yield occurs when the seawater desalination plant is operational all the time, as a base supply. The increase in yield decreases with a decrease in the reservoir trigger levels, implying that there is little benefit to using the desalinated supply as an emergency source;

5. The unit costs[56] for the desalinated water decrease as the percentage of the time for which the desalination plant is operational increases. The lowest possible cost per cubic metre of water supplied is obtained when the plant is operational all the time;

6. Depending on the size of the desalination plant and the percentile scenario, unit costs for desalinated water when introduced at the lowest dam trigger level (15%) are in the order to 10 times greater when desalination is supplied as a base load supply, always operational;

7. It appears that the unit costs decrease with an increase in capacity of the desalination plant, implying that a larger capacity plant up-front may be more cost-effective;

8. For a desalination plant operating as a base supply source, undertaking stochastic modelling to calculate unit cost values is less important than when using the desalination plant as an emergency supply source.

To the Consultant's knowledge, there has been no such research conducted in Namibia. On 10 May 2019, the Founding President of Namibia, Dr. Sam Nujoma, commissioned a pilot desalination plant at the Henties Bay campus of the University of Namibia (Lela, 2019). This solar-powered pilot plant is a joint initiative between the University of Namibia and the University of Turku, Finland and was installed by Solar Water Solutions of Finland (Rittman, 2019). However, the plant is to produce 3 m^3/h of drinkable water (Rittman, 2019), which is less than an average borehole, and a fraction of the production of the high-yielding boreholes in the Windhoek Aquifer (where abstraction can exceed 100 m^3/h). The applicability of any of the results of this pilot project to this Project are therefore severely limited, given the very different magnitudes of scale.

[56] The term "Unit Reference Value" is used in the article, which is equivalent to NamWater's Dynamic Prime Cost; see Van Niekerk and Du Plessis, 2013b.

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Unfortunately, the application of the results of the work of Blersch and du Plessis (2017) to water supply in the CAN was not supported by NamWater, KfW or other stakeholders when presented in the first version of the Inception Report. The nature of the reaction of stakeholders to the Consultant's initial proposals indicate that key stakeholders in the Namibian water sector are not yet ready to consider different water supply / use priorities, which is believed to be necessary to at least consider or analyse the optimal conjunctive use of desalinated seawater and variable surface water sources.

Experience in South Africa (Mossel Bay) and Australia has shown that desalination plants implemented as drought response or emergency measures are more expensive than other comparatively sized plants (Australia) and remain un- or underutilised after the drought has broken (Australia and Mossel Bay), at least in part because there was limited planning regarding the integrated planning for/of seawater desalination (Blersch and Du Plessis, 2017). Even in South Africa, there "*has been little research into the conjunctive use of seawater desalination with surface water supply sources, and how to integrate seawater desalination plants into existing water supply systems*" (Blersch and Du Plessis, 2017). As noted, the Consultant is not aware of any similar research having been conducted for the CAN or otherwise in Namibia.

The different desalination plants constructed in South Africa in response to droughts, of which the one in Mossel Bay (15 Mℓ/d) is the largest, were "*not optimally designed or procured*" as a result of the emergency nature of the projects (Bosman, 2019) and consequently the "*water exit prices achieved were invariably high, usually several multitudes of the international benchmark*" (Bosman, 2019).

The examples of Mossel Bay and Australia highlight the danger of not fully assessing the integration of seawater desalination into existing supply systems, resulting in expensive infrastructure which is un- or underutilised. This represents a scenario, similar to that of the Neckartal Dam, which Namibia should seek to avoid at all costs. Unfortunately, due to the limitations of the CA-Model and other factors, the aspects examined by Blersch and Du Plessis (2017) remain unexamined under this Study. It can also be noted that resource modelling the CAN would be more complex than that for the Western Cape water supply system, due to the inclusion of artificial recharge and water reclamation, which are not present in the Western Cape system.

NamWater should therefore not hesitate to pursue the first available opportunity to update or replace their CA-Model with an appropriate yield / planning model which provides sufficient functionality to be able to analyse different options for incorporating desalinated seawater into the CAN supply system, and then to conduct such analyses, should the provision of desalinated water be pursued beyond this Feasibility Study. It is currently envisaged that at least the following aspects would need to be investigated in more detail:

- What combination of supply and demand priorities provides the optimum system yield;

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- Which water sources (surface water, desalinated seawater, reclaimed water) should be prioritised for which combination of supply and artificial recharge, and at what activation levels, taking into account water quality considerations and infrastructure constraints;
- At what dam "trigger level" should desalinated seawater supply kick in to provide the optimum system yield and / or lowest cost.

Of the long-term water supply options under consideration by NamWater, the provision of desalinated sea water has indisputable advantages relative to the other options by being infinitely scalable, climate-independent (Bosman, 2019) and hydrologically invariable (impervious to drought), thus easier to quantify, plan and manage in order to provide a greater security of supply. When water supply to a major city can be made climate-resistant, supply can be made consistent and predictable, which is "*conducive to economic stability and growth*". In such a case, the availability of water is no longer doubtful and tariffs are predictable, which removes uncertainty from investment decisions and stabilises revenue to the water utility (Bosman, 2019). Furthermore, with an assured supply, tariffs no longer need to be used as punitive measures to discourage consumption, which eases ratepayer tension (Bosman, 2019). Therefore, whilst large-scale desalination is often dismissed as "too expensive", "too energy-intensive" or "too complex", relative to conventional sources, the value proposition of large-scale desalination needs to be properly understood in a wider context. Desalination "*has unique attributes which can fundamentally change the relationship we have with water*" (Bosman, 2019).

As such, desalinated seawater is also a source which provides an opportunity to possibly reconfigure the CAN supply system in terms of the allocation and use of water sources. For example, reserving Swakoppoort Dam for the supply of "en-route" users which are reconfigured to include Navachab Mine (raw water), Karibib and Otjimbingwe (potable water), as well as Usakos and Omaruru (potable) as "new" demand nodes could be considered. Under this proposal, new water treatment capability is to be provided at either Karibib or Swakoppoort, preferably the former, suited to the nature / quality of the raw water, and Karibib would become a distribution hub for supply to the "en-route" users (geographically speaking)[57]. As a result, transfers from Swakoppoort Dam to Von Bach Dam will reduce or cease, with the contribution of Swakoppoort Dam to the CAN being substituted with desalinated water. This might provide cheaper water to the less affluent "en-route" users, with the relatively more affluent Windhoek provided with greater volumes of more expensive desalinated water.

[57] This proposal was put forward in the first version of the Inception Report submitted under this Study (16 April 2019) but was not supported by stakeholders.

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7 EN-ROUTE USERS

7.1 Delineation of the En-Route Users

7.1.1 Identification of the En-Route Users

Overall, the identification and delineation of the en-route users should be based on a consideration of the project concept and those water-stressed areas identified by the Erongo Water Forum (EWF) and the Erongo Regional Council (ERC)[58].

The Central Coastal Area (CCA) is considered to extend up to Arandis, based on the existing configuration of supply and infrastructure. In terms of supplying desalinated water to the CAN, this has been investigated in terms of supply to the Von Bach Node, which comprises all users supplied with potable water by the VBWTP. Geographically therefore, the en-route users could be considered to comprise the area between Usakos (being the first demand node to the east of Arandis which is part of the CCA) and Okahandja.

The ERC have identified Uis, Otjimbingwe and Okombahe as settlement areas to be developed where significant water challenges are experienced. Wlotzkasbaken has also been identified by the ERC as settlement area to be developed, but does not experience major water supply problems. Other areas in need of water or which are water-stressed include Omatjete and Omaruru and areas in the Dâures Constituency (where Uis is located). Leaving aside Wlotzkasbaken which does not experience water supply difficulties, and Uis (separate motivation provided below), Okombahe and Omatjete would likely be linked via Omaruru.

As a result, the water stressed areas in the Erongo Region can be seen as being located to the north (Okombahe and Omatjete) and south (Otjimbingwe) of Karibib, which would be located near the mid-point of a possible transfer pipeline between the coast and the VBWTP, at least along a route aligned with the B2 highway. This concept of the en-route users is shown in **Figure 7.1**.

The Consultant, with the first submission of the Inception Report, proposed two options for the supply of these on-line users; the first using surface water from the Swakoppoort Dam, which is to be reserved for this purpose, and the second, using desalinated water via off-takes or connections to the proposed coast to VBWTP transfer pipeline. These options were not accepted by NamWater and it was noted that the same configuration of the CAN as assessed under the CAN WAS should be assessed under this Study, namely that Karibib and Otjimbingwe are included in the CAN as is the case currently and as was assessed previously.

[58] Stakeholder consultations and discussions were held with the Erongo Water Forum on 28 February 2019 and with the Erongo Regional Council on 27 March 2019.

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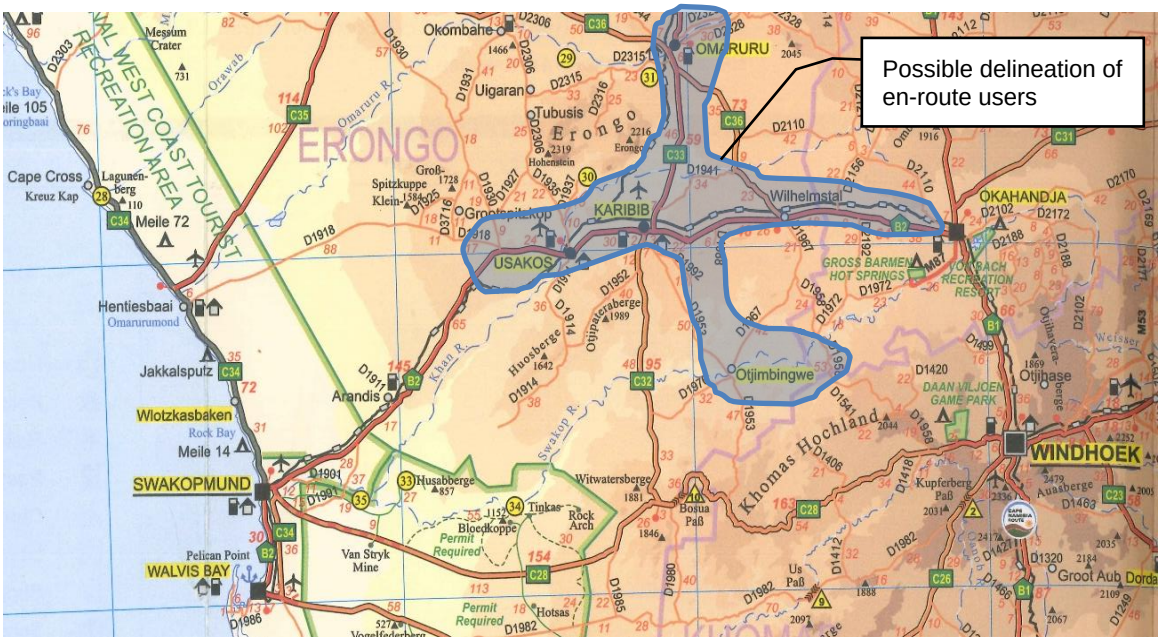

Figure 7.1: Possible Delineation of En-route Users

7.1.2 Possible Water Supply to Uis

7.1.2.1 The Need to Supply Water to Uis

As noted earlier, the ERC have identified Uis as a settlement area to be developed, but one where significant water challenges are experienced. The EWF (which falls under the ambit of the ERC) have identified the potential for irrigation projects in Uis as a means to provide development and employment opportunities (ERC, n.d.).

Water supply to Uis became critical during 2016 as a result of declining water levels in the aquifer under drought conditions in the interior of Namibia, with the residents unable to obtain water for a week in June 2016. Water was thereafter rationed, being made available for three two-hour periods per day (Lela, 2016).

7.1.2.2 Current Water Supply to Uis

Uis is supplied with water from NamWater's Nei-Neis – Uis Scheme, which is a groundwater scheme drawing water from the Nei-Neis alluvial aquifer in the Omaruru River. Whilst the Omaruru River flows more regularly at Omaruru and Okombahe further upstream, the floods become less frequent further downstream of these towns due to infiltration losses (Christellis and Struckmeier, 2001), thus impacting on the recharge of these areas, including the Nei-Neis aquifer. The depth of this aquifer is given as 12 to 28 m, with a total production of 330 m3/a (Christellis and Struckmeier, 2001), whilst the total recommended yield of NamWater's five boreholes in operation is given as 62 m^3/h (SCE, 2011) or 453 000 m^3/a.

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The yield of alluvial aquifers such as Nei-Neis is uncertain, since recharge is dependent on flows in the ephemeral rivers, which are infrequent and variable in both timing quantity (volume of recharge). Securing a more plentiful and reliable water supply to Uis would therefore require augmentation from an outside source.

7.1.2.3 Alternative Sources for Water Supply to Uis

There are no surface water sources in the vicinity of Uis, the closest being Omatako Dam, and the groundwater potential of the surrounding gravel plans of the Erongo Region is limited.

The supply of groundwater from the Omdel Aquifer or the provision of desalinated sea water are both options for supply augmentation to Uis. A dedicated supply pipeline providing desalinated water from the coast to Uis would be very expensive and unlikely in the medium term. It could be possible to pipe desalinated sea water from a connection to the coastal – CAN transfer pipeline in the vicinity of Usakos (some 107 km to Uis along the D1930 road) or via Omaruru, which would be some 123 km in length (from Omaruru if this town is to be supplied).

Alternatively, groundwater from the Omdel Aquifer could be pumped to Uis, over some 122 km alongside the C35 from Henties Bay. This latter option would the cheaper alternative, based on the “source cost” of the water, although due to its relative remoteness, any water augmentation to Uis is likely to be very costly and unaffordable to residents if tariffs are based on cost recovery principles. It is however important to note that groundwater from the Omdel Aquifer constitutes use of the same source currently used to supply Uis (an alluvial aquifer in the Omaruru River), the only benefit being the use of a larger wellfield for water abstraction.

Another potential source to augment supply to Uis could be the Ugab River, although this is also an alluvial aquifer in an ephemeral river, and therefore subject to the same recharge and variability considerations as the Omaruru River. However, at present, water abstraction from the Ugab River is more limited than from the Omaruru River, since only small settlements along the Ugab River are supplied with water directly and not larger towns such as Omaruru. The Ugab River also has a larger catchment area (29 355 km^2 at the mouth) than does the Omaruru River (11 580 km^2 at the mouth; Strohbach, 2008), which may render this alternative source feasible, pending confirmation via a hydrogeological assessment.

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7.1.2.4 Proposal for Water Supply to Uis

For the purposes of this Study, it is proposed that water supply to Uis be investigated separately, being based on a combination of possible supply from a wellfield development in Ugab River, which is under investigation by NamWater, and a reduction in NRW and inefficient use. In the case of the latter, night flows were in 2010 estimated to be 45% of the daily flow rate (SCE, 2011), which is extremely high and inexcusable in a location where the source capacity is limited.

7.1.3 Delineation of the En-Route Users

Based on the above considerations, the en-route users are considered to be Usakos and Omaruru, via which Okombahe and Omatjete could possibly also be supplied.

7.2 Configuration of Supply of the En-Route Users

Both Usakos and Omaruru are supplied with water from local groundwater sources, which are either partly (Usakos) or wholly (Omaruru) owned, operated and maintained by the respective local authorities.

Usakos is currently suppled with groundwater via boreholes and a scheme owned and operated by NamWater and boreholes owned and operated by the Usakos Town Council. The Usakos Town Council indicated that their boreholes supply approximately 90% of the demand of the town and that the NamWater scheme is used for back-up only, supplying only about 10% of their demand. Unfortunately there is insufficient data to ascertain the exact nature of supply to Usakos between the Town Council and NamWater (refer below).

Omaruru is currently suppled with groundwater via boreholes and a scheme owned and operated by the Municipality which draws water from the alluvial aquifer in the Omaruru River.

7.3 Resource Analysis

7.3.1 Kranzberg Aquifer and the Spes Bona Wellfield Supply to Usakos

The Kranzberg Aquifer and the Spes Bona Wellfield are located at least partially in the Khan River, which is an ephemeral river and one of the tributaries of the Swakop River. The Kranzberg Aquifer is located in a paleo-channel of the Kranzberg River which is a tributary of the Khan River.

Under NamWater's CAN Medium Term Options project, it was concluded from the re-evaluation of previous studies, that the Municipal sources tap the same aquifer as the NamWater Kranzberg boreholes, therefore the two borehole groups should be treated as one. The sustainable yield of the Municipal and Kranzberg sources combined is approximately 0.270 Mm^3/a (LCE-SCE JV, 2019).

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The Usakos Town Council have indicated that they do not experience any problems with water supply from their boreholes from a source perspective. There may however be a need to augment the water supply to the town if some or all of the indicated developments are implemented and the water demand increases dramatically in future. There is also considerable uncertainty regarding the actual water supply to and use in Usakos (refer above). For these reasons, is was assumed that the long-term capacity of groundwater supply around Usakos will be lower than current estimates and supply at 50 000 m^3/a was therefore assumed as a conservative estimate.

7.3.2 Omaruru Alluvial Aquifer

Omaruru town is situated along the Omaruru River, approximately 170 km northwest of Windhoek. The town is supplied from 7 production boreholes situated along the ephemeral Omaruru River, which are operated and maintained by the Omaruru Municipality. Both the bulk supply system and the water reticulation in the town are poorly maintained and system leakages are likely to be very high (LCE-SCE JV, 2017).

The Omaruru River Aquifer (ORA) comprises the alluvial beds of the ephemeral Omaruru River. The alluvium deposits form a phreatic aquifer, the dimensions of which are controlled by the configuration of the river channels. In general, it is known that bedrock rises immediately below the road bridge at Omaruru town. From this bedrock high, the ORA stretches upstream for a distance of about 30 km (LCE-SCE JV, 2017).

The Omaruru Municipality abstracts groundwater from compartments A & B only (i.e. the downstream portion or Compartment 1), for which the safe yield is estimated to be in the order of 1 Mm^3/a, although this is dependent on recharge events; i.e. surface flows in the river (LCE-SCE JV, 2017). During drought conditions following insufficient recharge, as in 2017, the aquifer becomes depleted, and water supply to Omaruru becomes insecure / precarious.

In terms of long-term, secure water supply to Omaruru, half of the currently assumed safe yield of Compartment 1 of the Omaruru Aquifer has been assumed in order to derive possible augmentation requirements for 2050, namely 0.5 Mm^3/a.

7.4 Consumption Analyses

7.4.1 Water Demand and Use in Usakos

As the Usakos Town Council has their own water supply and makes use of NamWater supply only to augment their supply, actual consumption in the town could not be determined through NamWater's sales data. Water consumption of Usakos was analysed through local sales data from /AE//Gams Networks (Pty) Ltd (/AE//Gams) for the period July 2009 to June 2018, although data was missing from July 2016 to June 2017 in the data received from /AE//Gams. Billed water sales by the Town Council varied between 0.119 and.166 Mm^3/a for the period analysed.

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However, NamWater indicated their scepticism towards the accuracy of the local town council billing information as received via /AE//Gams, due to poor water meter coverage and readings, leading to a possible underestimation of the water demand and thus suggested that a theoretical demand estimation be carried out. **Table 7.1** summarises the theoretical demand of 0.219 Mm^3/a estimated for Usakos for FY 2018.

Given the large difference between the theoretically estimated and billed consumption values, the theoretically estimate value of 0.219 Mm^3/a was adopted for this Study.

Table 7.1: Theoretical Water Demand Estimation for Usakos

Item	Unit	Value	Comment / Source
IWRM 2010 suggested per capita consumption	ℓ/c/d	120	IWRM (2010)
Population 2011	capita	3 583	2011 Census, NSA (2012)
Estimated 2016 Population	capita	4 563	2016 Interim Census, NSA (2016)
Proposed 2018 population	capita	5 000	Simplified estimate
2018 Theoretical Use			
Daily	ℓ/d	600 000	
Annual	Mm^3/a	0.219	

7.4.2 Water Demand and Use in Omaruru

7.4.2.1 Historical Water Use in Omaruru

Water sales data has proven very difficult to obtain for Omaruru and problematic in terms of accuracy / discrepancies. Under the CAN WAS, no information concerning the annual production from the Omaruru boreholes could be obtained. The only information which could be obtained at that time (received in 2014) was the water sales to end consumers over the preceding 5 years (data up to and including 2012/13). Under the CAN Medium Term Options project of NamWater, municipal sales data was received in September 2018.

In both instances, this data was received from /AE//Gams Networks (Pty) Ltd. (/AE//Gams) who maintains the financial and billing database on behalf of the Municipality of Omaruru, although it is the Municipality of Omaruru who record and enter into the database the water meter readings. Substantial differences in the sales to end users is noted between the data received in 2014 and that received in September 2018.

In 2014, under the CAN WAS, it was found that twelve Government institutions (police facilities, schools, hostels, health and prison facilities, the Ozondje soccer field and the municipal swimming pool), consumed a massive 43.9% of the total water sales in the 2012/13 municipal financial year (LCE-SCE JV, 2017).

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Non-revenue water could not be determined at that time, but based on the condition of infrastructure observed during a visit to Omaruru in November 2013 and the production control systems at the boreholes, it was thought that this may exceed 25% of the abstracted water. A potential WDM saving of 20% (reduction in) of the projected demand figures was thought possible (LCE-SCE JV, 2017).

7.4.2.2 Previous Water Demand Projections

The demand projections for Omaruru prepared under the CAN WAS were based on information from the Municipality regarding their proposals to upgrade the (wet) services to houses in the informal areas, and an estimate of the theoretical water demand for the town, which was some 20% lower than the estimated demand (sales plus 25% non-revenue water allowance) for the 2012/13 municipal financial year (LCE-SCE JV, 2017).

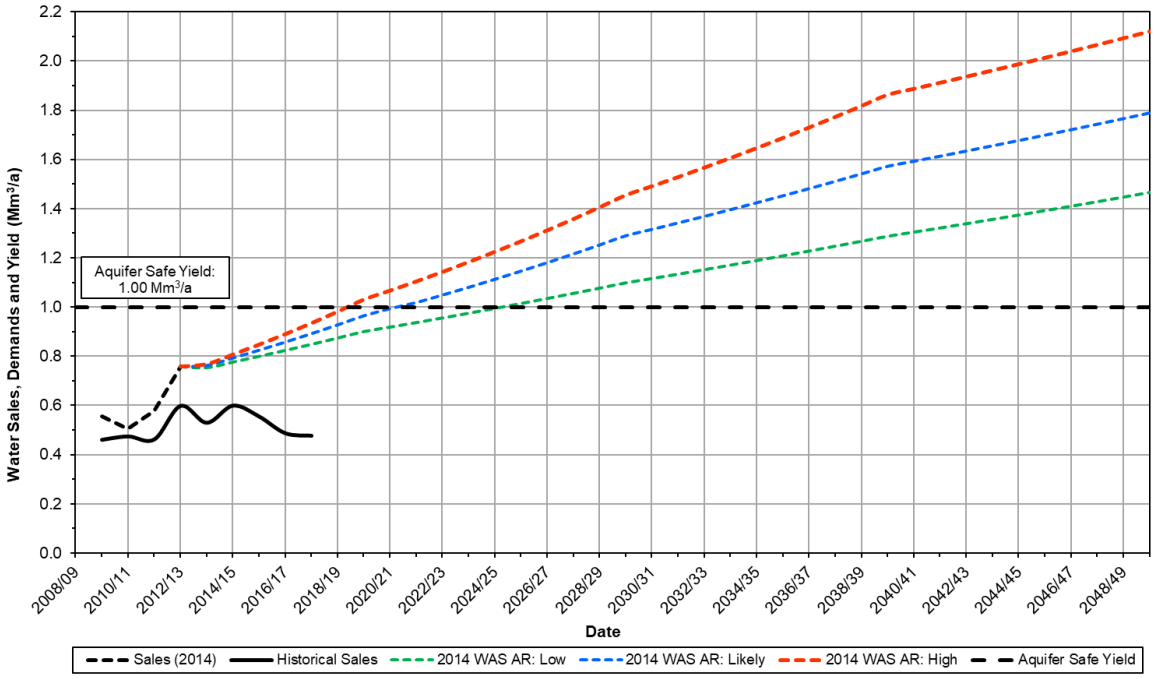

Figure 7.2: Water Sales to End Users in Omaruru and Previous Projections (LCE-SCE JV, 2019)

Notes:
1. Sales (2014) = Sales to end uses as obtained under the CAN WAS (LCE-SCE JV, 2017).
2. Historical Sales = Sales to end users as obtained from /AE//Gams Networks (Pty) Ltd. in September 2018 under the CAN Medium Term Options project (LCE-SCE JV, 2019).
3. 2014 WAS AR = Abstraction requirements prepared in 2014 under the Water Augmentation Study, including losses (LCE-SCE JV, 2017).
4. Aquifer Safe Yield = Total recommended abstraction from Compartment 1 of the Omaruru River Aquifer of 1.0 Mm^3/a.

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7.5 Benchmarking of Water Use Efficiency

Water use efficiency could not be benchmarked for this Study due to the poor quality of the data available. Actual water supply in both towns could not be determined and even the sales / consumption data is also of questionable quality. The 2010 IWRM report indicated poor efficiencies at both Usakos and Omaruru, and recommended savings of 20% and 60% respectively based on a target per capita consumption of 120 ℓ/c/d.

7.6 Water Demand Projections

7.6.1 Development Proposals for Existing Centres

7.6.1.1 Usakos

The Usakos Town Council was able to make available their Town Planning Scheme, dated 2009 (SPC, 2009), which provides town planning data (zoning, densities, boundaries) for Usakos, but not any water demand or other related projections. The Usakos Town Council also indicated a large number of development projects / proposals in and around the town, including:

- A fish canning factory;
- A fish drying factory;
- A truck port;
- A steel manufacturing plant;
- A locomotive remanufacturing plant of TransNamib;
- An oil and gas storage facility.

Usakos is located on the Trans-Kalahari Corridor on both the road and rail links, which stretch to the Democratic Republic of the Congo, Angola and Botswana, among other SADC countries and there is therefore latent development potential based on the town's location. However, it is often the case that prospective developments are not implemented at all, or not as originally envisaged, particularly in terms of time frames, and it is considered unlikely that the town will grow much above historical rates in the short- to medium-term.

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7.6.1.2 Omaruru

The Omaruru Municipality was not able to make available any formal development plan, as they are in process of compiling this, having appointed consultants to do so. The Omaruru Municipality however indicated a number of development projects / proposals in and around Omaruru, including:

- The development of an army base on the north western side of the town, for which the Municipality has made available 3 000 ha;
- A possible gold mine in the vicinity of Omatjete some 20 km to the north / north west of the town;
- Another possible mine some 70 to 80 km from the town.

It is however acknowledged that Omaruru Town and the surrounding areas are water-constrained and development is only likely in the longer-term if water could be made available. It also appears that the mining developments are in the early phases of planning or investigation and would require a secure water source or supply in order to proceed.

7.6.2 Development Proposals for Additional En-Route Demands

7.6.2.1 Direct Pipeline Off-takes

The possible water supply to small farming and agricultural users within a 10 km corridor zone to either side of the pipeline route was considered according to the livestock carrying capacity and rural population density of the areas along the possible pipeline route. These estimations were conducted on a high level for the purposes of this investigation and initial Feasibility Study.

It was assumed that only a 120 km portion of the pipeline route, towards the eastern side, will fall within an area where livestock farming is viable and thus a water demand could be expected. The western portions of the pipeline route are expected to cross State Land and traverse desert areas where livestock farming is not viable. Furthermore, a carrying capacity of 40 ha/LSU was assumed along this area and a livestock unit water demand of 45 ℓ/LSU/d applied, resulting in a total livestock demand of 100 000 m^3/a. Domestic demand was based on a rural population density of 0.56[59] capita/km^2 and an assumed demand of 50 ℓ/c/d, resulting in a domestic demand of 25 000 m^3/a.

This results in a combined demand of 125 000 m^3/a for possible direct pipeline off-takes. It was assumed that this demand would not vary over time as the carrying capacity is unlikely to increase within the timeframe of the Study.

[59] Per the 2016 inter census report of the NSA, there were an estimated 20 790 rural inhabitants in the 36,964 km^2 of the Khomas Region, resulting in a population density of 0.56 c/km^2.

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The demand scenarios adopted for this Study are summarised in **Table 7.2**.

Table 7.2: Water Demand Options for Possible Direct Pipeline Off-Takes

Item	Demand Option		
	PR_1 (0%)	**PR_2: (50%)**	**PR_3: (100%)**
Description	Only human / domestic demand	Full demand	Full demand with 25% increase
2050 Water Demand (Mm^3/a)	**0.025**	**0.125**	**0.156**

7.6.2.2 Development Corridor

Plans for a "development corridor" along the road and rail links between Windhoek and the coast have been put forward in the past, including by Dietlof von Oertzen[60]. The concept of a development corridor envisages linking the Khomas and Erongo Regions, which are the two wealthiest (**Section 2.2.7**) and likely most economically active regions in the country. Areas around Karibib in particular, are flat, land is available, and road and rail infrastructure provide access to the harbour at Walvis Bay and access into SADC via the Trans-Kalahari Corridor. Conceptually, development in this area could link to existing and potential mining developments, but also include intensive, high-value agriculture, manufacturing and processing, to also provide mining-independent development, whilst decentralising development to areas other than Windhoek and the CCA. However, a key aspect needed to enable the development potential of this area is a secure, sufficient, and preferably rainfall-independent water supply.

Enquiries, via NamWater, were made to the National Planning Commission, to establish whether any formal plans exist for such a "development corridor", unfortunately without response.

For the purposes of this Study, it was assumed that the maximum demand that would result from such a development corridor would be 2.5 Mm^3/a (which is more than the current demand of Okahandja, Karibib and Otjimbingwe combined; 1.79 Mm^3/a). The demand scenarios adopted for this Study are summarised in **Table 7.3**. It was assumed that the development corridor would only become active by FY 2027 and that water demands would grow according to a S-curve.

[60] Including during a presentation to the Namibian Scientific Society on 22 June 2016, notes of which inform this paragraph. A formal reference is not available.

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Table 7.3: Water Demand Options for a Possible Development Corridor

Item	Demand Option		
	DC_1 (0%)	**DC_2: (50%)**	**DC_3: (100%)**
Description	No implementation	Half of envisaged maximum 2.5 Mm^3/a	Maximum development
2050 Water Demand (Mm^3/a)	**0.00**	**1.25**	**2.50**

7.6.3 Total Water Demands

Three scenarios for the water demands of Usakos and Omaruru were developed; low likely, likely and high likely scenarios. Furthermore, the extent of a possible development corridor and the development of direct off-takes along the pipeline route were proposed under three scenarios each. A summary of these demand scenarios is provided in in **Appendix 3**.

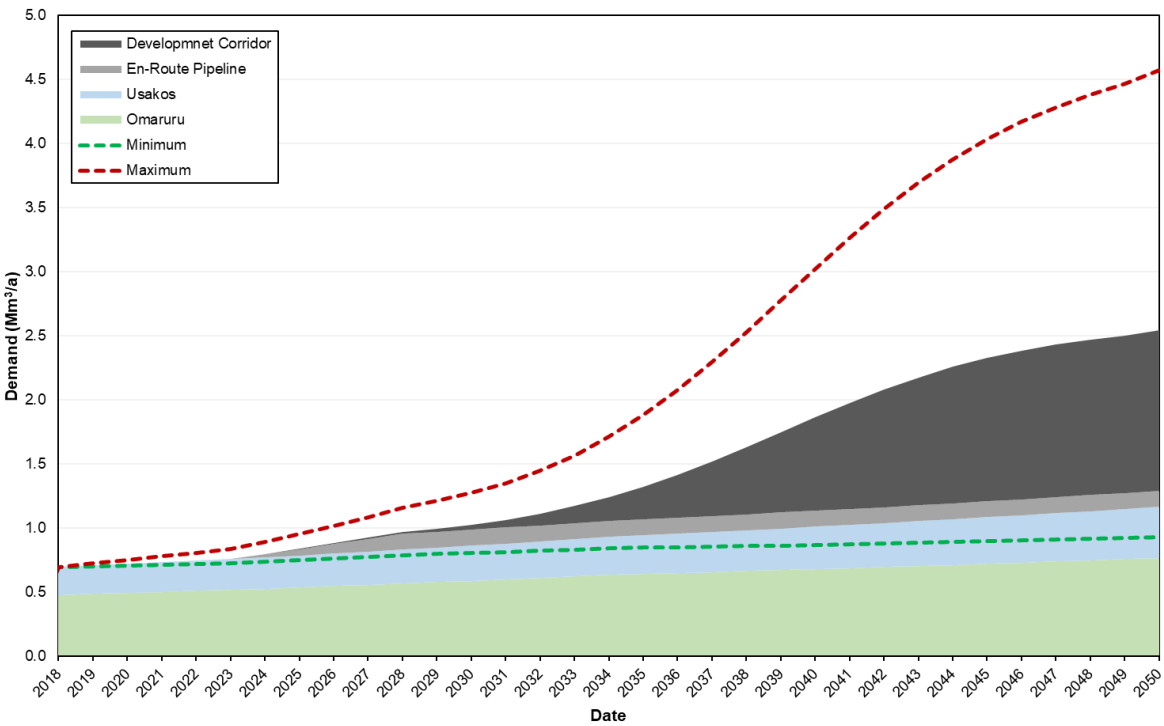

Figure 7.3: En-Route Users Recommended, Minimum and Maximum Water Demand Scenarios

The Client's recommended option entailed the likely demand scenarios for the existing users (Usakos and Omaruru), option 2 for the direct off-takes (PR2) and option 2 for the development corridor (DC1), resulting in a total estimated demand for the en-route users for 2050 of 2.54 Mm^3/a under demand scenario D5. A summary of the details of the recommended demand option is provided in **Table 7.4** and illustrated in **Figure 7.3**, which also includes the minimum and maximum demand scenarios in dashed lines.

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Table 7.4: Client's Recommendation for Water Demands for the En-Route Users

Item			Water Demands (Mm^3/a) and Values Per Node and Total				
			Omaruru	**Usakos**	**Direct Off-Takes**	**Development Corridor**	**Total En-Route Users**
Growth Rate (% p.a.)	Short Term	2018-2023	3.5%	3.5%	Option 2 (PR_2)	Option 2 (DC_1)	Option 5 (D5)
	Medium Term	2023-2035	3.5%	3.0%			
	Long Term	2035-2050	2.5%	2.0%			
Non-revenue water (%)		2018	50%	15%			
		2050	20%	12%			
Water Demands (Mm^3/a)		2018	0.48	0.22	0.00	0.00	0.70
		2020	0.49	0.23	0.00	0.00	0.72
		2025	0.54	0.25	0.05	0.00	0.84
		2030	0.59	0.27	0.13	0.04	1.03
		2035	0.64	0.30	0.13	0.25	1.32
		2040	0.68	0.33	0.13	0.73	1.86
		2045	0.72	0.36	0.13	1.12	2.33
		2050	0.77	0.40	0.13	1.25	2.54

No mining demand was envisaged for the En-Route users, although the possibility of future water use incorporating some form of mining use cannot be entirely eliminated.

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7.7 Water Deficit Projections

7.7.1 Approach to the Derivation of Water Deficit Options and Projections

The same "deficit approach" (refer to **Section 4.4.5**), followed for the CCA and CAN was followed for the En-Route users, where the augmentation of deficit volumes represent the difference between the projected water demands (including losses) and the capacity of the existing and local sources, and thus the volumes of desalinated seawater required, either from the existing EDP and / or another seawater desalination plant.

7.7.2 Utilisation of Existing and Local Water Resources

As discussed in **Section 6.2.1** the long-term sustainable capacity of groundwater supplies to Omaruru and Usakos were assumed to be 0.5 Mm^3/a and 0.05 Mm^3/a respectively. Demands not met by these supply capacities would require augmentation from the proposed desalination supply pipeline passing by these towns. The water demands for the development corridor and en-route direct off-takes would be fully supplied from desalinated water.

7.7.3 Water Deficit Projections for the En-Route Users

The water deficits derived from the water demand scenarios discussed in **Section 7.6** and the utilisation of existing water resources as noted above, are summarised in **Table 7.5** and illustrated in **Figure 7.4**, including maximum and minimum deficits for various scenarios. The 2050 water supply deficit for the en-route users is estimated at 2 Mm^3/a. Further details, including the various demand scenarios analysed, are provided in **Appendix 3**.

Table 7.5: Summary of the Expected Water Deficits for the En-Route Users

Year	Water Deficit (Mm^3/a) for the En-Route Users				
	Omaruru	Usakos	En-Route Pipeline	Development Corridor	Total
2018	0.00	0.17	0.00	0.00	0.17
2020	0.00	0.18	0.00	0.00	0.18
2025	0.04	0.20	0.05	0.00	0.29
2030	0.09	0.22	0.13	0.04	0.48
2035	0.14	0.25	0.13	0.25	0.78
2040	0.18	0.28	0.13	0.73	1.32
2045	0.22	0.31	0.13	1.12	1.78
2050	0.27	0.35	0.13	1.25	2.00

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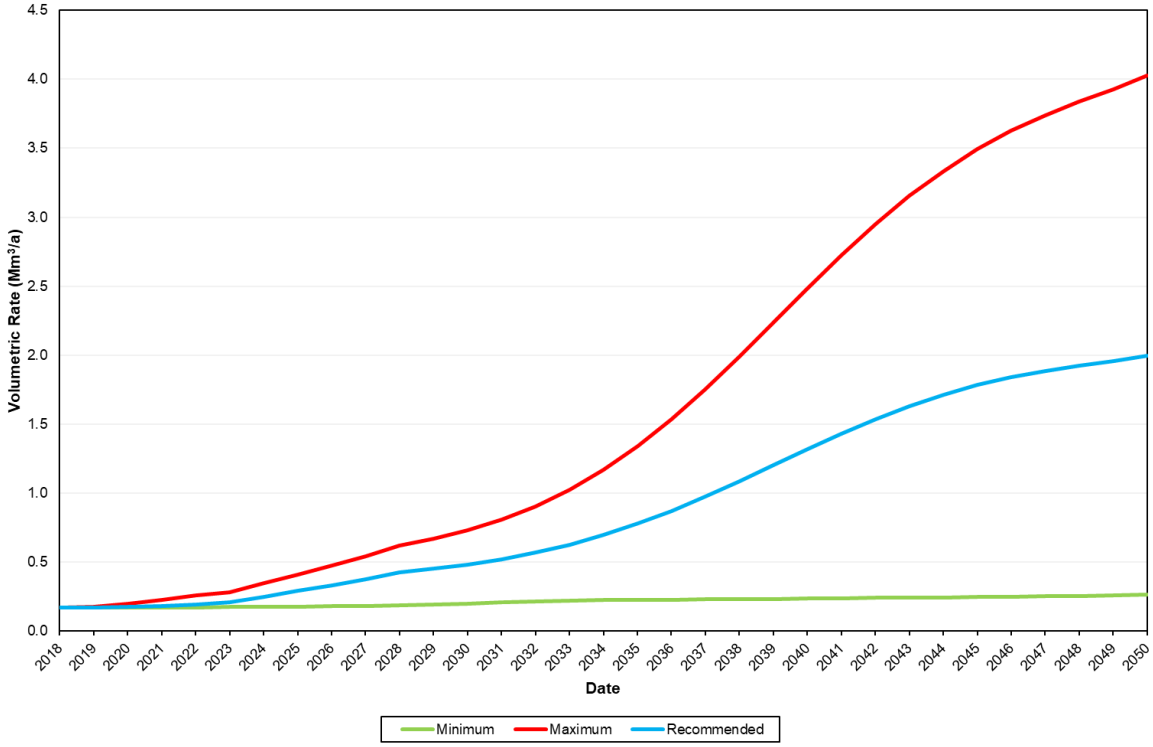

Figure 7.4: En-Route Users: Recommended, Minimum and Maximum Deficit Scenarios

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8 BOTSWANA

The ToR specify that the conceptual design of a transfer system from Windhoek to Gaborone should be sized for a supply capacity of about 20 Mm^3/a.

The south eastern portion of Botswana, centred around the capital city of Gaborone, has in the past few decades experienced rapidly increasing growth, which is expected to continue. Water demands in this area have long ago outstripped the local resources, which have subsequently been augmented from sources in the north east of Botswana. It is expected that water sources supplying this area will become inadequate as soon as 2025 (ORASECOM, 2017).

Plans for the transfer of desalinated seawater from the Atlantic, via Windhoek, to Gaborone, date from an official state visit by President Dr. Hage Geingob of Namibia, to President, Lieutenant-General Seretse Khama Ian Khama of Botswana over 11 and 12 July 2016 (Hattingh, 2016). The ministers of the two countries responsible for water met immediately after the a meeting between the two presidents on 11 July 2016 and agreed to set up a technical committee between the two countries consisting of senior officials and representatives of the appropriate sectors to determine how the cooperation will proceed. The Namibian representatives on this proposed committee were named as Mr. Nehemia (Deputy Permanent Secretary of the MAWLR at the time), Dr. Steytler (Presidential Advisor at the time), Dr. Shivute (CEO of NamWater at the time) and Mr. Kaitungwa (representative of the MME) as well as a representative of the Attorney-General's office (not named) (Hattingh, 2016). The inclusion of the supply of desalinated seawater to Gaborone, via Windhoek, in this Feasibility Study are believed to date from the July 2016 discussions between the heads of state of Namibia and Botswana (the ToR are dated December 2017). In February 2016, during a two-day state visit of President, Lieutenant-General Seretse Khama Ian Khama of Botswana to President Dr. Hage Geingob of Namibia, the initial plans from mid-2016 were reaffirmed (New Era Live, 2018).

However, Botswana has been planning to draw water from the Orange-Senqu system in Lesotho with piped transfer via South Africa since at least 2015 (eNCA, 2015). A "*Lesotho Highlands Botswana Water Transfer Desktop* Study" which assessed the long-term water demand and assessed at "reconnaissance level" the various options for conveyance and water storage, with broad cost estimates, was completed by Bigen Africa (Pty) Ltd. in 2015 (ORASECOM, 2017). This study investigated the Lesotho Highlands Water Project, the Makhaleng River and Senqu/Orange River as possible water sources to supply the area around Gaborone and found the Makhaleng River in Lesotho to be the preferred source (ORASECOM, 2017).

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In 2017 it was reported that the governments of Botswana, South Africa, Lesotho and Namibia had signed an agreement which would allow Botswana to import water from Lesotho using a 600 km long pipeline across South Africa to Botswana's capital Gaborone (Nkala, 2017). The terms of reference of ORASECOM for the feasibility study notes that the governments of Botswana, South Africa, Lesotho decided in December 2016 to study at feasibility level the Lesotho-Botswana Water Transfer Scheme and mandated ORASECOM to manage the preparation stage (ORASECOM, 2017). The feasibility of this project, including a proposed dam in Lesotho, will be determined by a feasibility study costing some US$ 2.3 million which is to be funded by the African Development Bank (Nkala, 2017). It was also reported that the Botswana Government was planning to revive the construction of the north-south carrier water project which would entail the construction of a 360 km long pipeline to transfer water to Gaborone (Nkala, 2017).

More recently, it has been reported that Botswana, Lesotho and South Africa will share the cost of the construction of the 600 km pipeline following the identification of two dam construction sites along the Makhaleng River in Lesotho (CGTN Africa, 2019). However, the ORASECOM-managed feasibility study is not yet complete and thus such indications may be premature.

The terms of reference of ORASECOM for the feasibility study indicates "*that eventually 150 Mm^3/a should be pumped to Botswana with additional supplies for consumers along the route*" (ORASECOM, 2017). The Consultant understands that transfers of between 136 Mm^3/a and 200 Mm^3/a from Lesotho to Botswana are under investigation by the ORASECOM-managed feasibility study,

The local water resources around Gaborone are supplemented with supplies from the Letsibogo Dam to the north east, via Phase 1 of the North-South Carrier, a pipeline transfer scheme over some 360 km, which was completed in 2000. Phase 2 of the project, which is under construction, will duplicate the pipeline of the first phase to transfer some 45 Mm^3/a of water from the Dikgatlhong Dam, which was completed in 2012. Future planning envisages extending the scheme by some 500 km to the Zambezi River near Kasane. The Botswana National Water Master Plan included plans to abstract some 495 Mm^3/a from the Zambezi River for use in agriculture by 2022.

It is clear that there are different options being investigated for the supply of water to the area around Gaborone, of which the option under investigation by this Feasibility Study is only one. Further, water transfers well in excess of 100 Mm^3/a to the area around Gaborone being investigated from Lesotho would dwarf the 20 Mm^3/a of desalinated seawater envisaged under this Feasibility Study, indicating that this proposal, even if viable, is unlikely to be the most important water augmentation option or scheme to Gaborone. Some 1 100 km of pipeline from Windhoek to Gaborone and some 1 400 km of pipeline from the Atlantic Ocean to Gaborone will be much more expensive for the same volume than the envisaged 600 km of transfer from Lesotho or a 500 km extension to the Zambezi River.

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On the basis of the information available, it is unclear what options for water augmentation Botswana may prioritise. In the absence of more detailed information, the 20 Mm^3/a to be transferred to Gaborone specified in the ToR has been applied.

It was assumed that the supply to Botswana would only be online by 2029 (10 years from 2019) and grow per a s-curve to the eventual 20 Mm^3/a by 2050, as indicated in Figure 8.1.

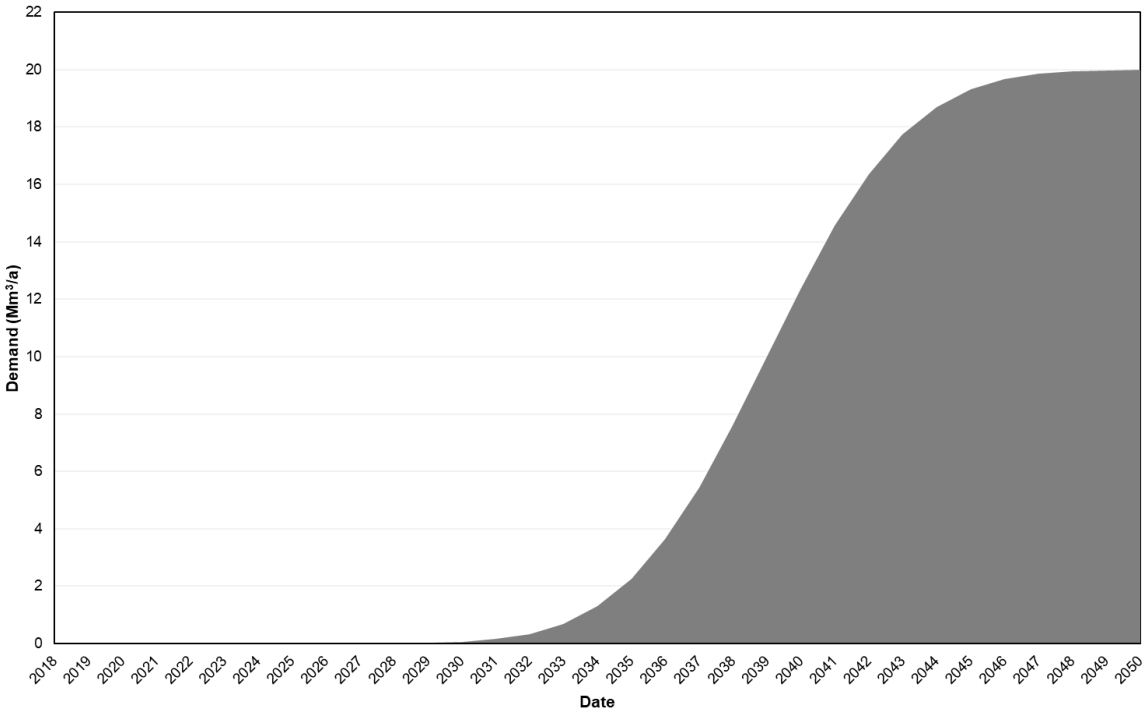

Figure 8.1: Projected Growth for Botswana Supply

It could not be established what categories of water use (mining / non-mining) are included in the 20 Mm^3/a to be transferred to Gaborone.

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9 OVERALL WATER DEMAND AND DEFICIT SCENARIOS

9.1 Overall Water Deficits

A number of options were considered for the water demands, utilisation of existing and local resources and thus water deficits for the three key demand areas within Namibia; the Central Coastal Area (CCA), the Central Area of Namibia (CAN) and the En-Route users (ER). For each of these "individual" demand areas, the Client provided a recommendation for the water deficits. These water deficits or augmentation volumes are now to be combined in accordance with the basic supply options specified in the ToR, and as outlined in **Section 4.4.3**:

1. Supply Scenario 1: Central Coastal Area (SS1 = CCA);
2. Supply Scenario 2: Central Coastal Area, the Central Area of Namibia and the en-route users (SS2 = CCA + CAN + ER);
3. Supply Scenario 3: Central Coastal Area, the Central Area of Namibia and the en-route users as well as Botswana (SS3 = CCA + CAN + ER + Bots).

These project supply scenarios develop cumulatively, and in each instance make use of the option recommended by NamWater and other stakeholders for the "individual" demand areas (e.g. for the CCA, CAN, etc.).

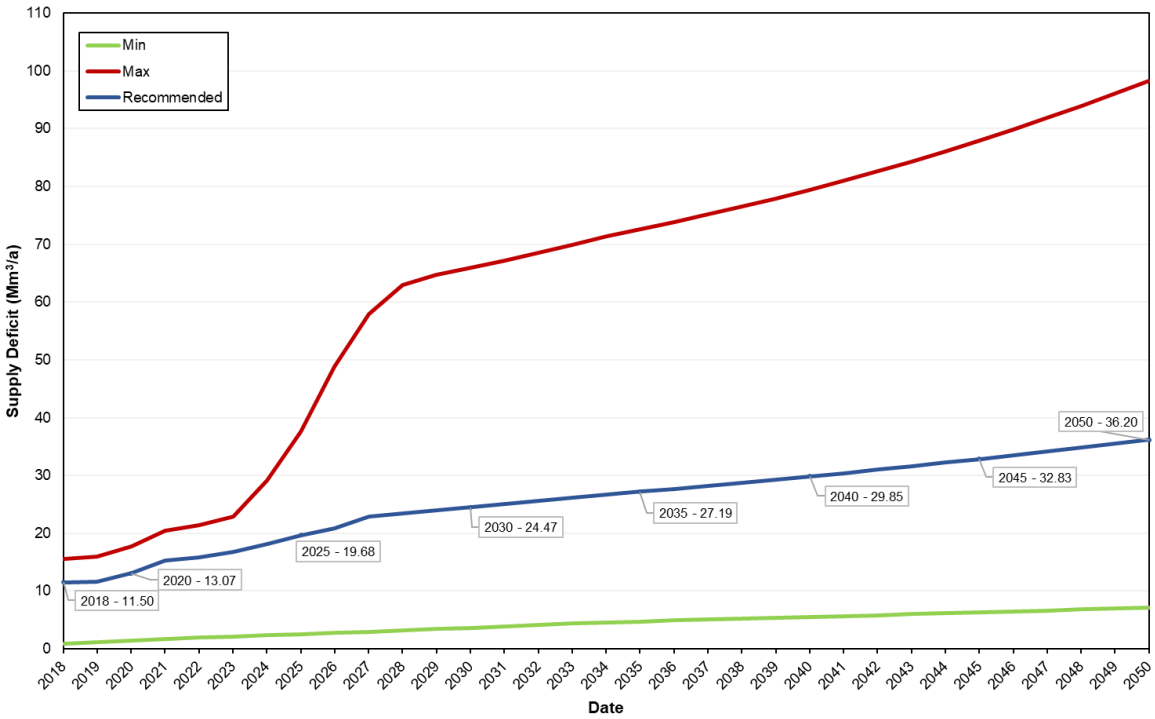

Figure 9.1: Total Water Deficit Projections for Supply Scenario 1: CCA

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Table 9.1: Summary of the Expected Water Deficits for the Project Options

Year	Water Deficits (Mm^3/a) per Scenario								
	Supply Scenario 1: CCA			Supply Scenario 2: CCA + CAN + ER			Supply Scenario 3: CCA + CAN + ER + Bots		
	Minimum Option Combination[1]	Maximum Option Combination[2]	Client's Recommendation[3]	Minimum Option Combination[1]	Maximum Option Combination[2]	Client's Recommendation[3]	Minimum Option Combination[1]	Maximum Option Combination[2]	Client's Recommendation[3]
2018	0.87	15.50	11.50	1.03	18.95	11.67	1.03	18.95	11.67
2020	1.39	17.80	13.07	1.56	24.59	14.30	1.56	24.59	14.30
2025	2.56	37.62	19.68	2.73	52.86	24.63	2.73	52.86	24.63
2030	3.66	65.93	24.47	3.86	93.77	35.72	3.93	93.84	35.78
2035	4.76	72.55	27.19	4.98	119.75	48.80	7.24	122.01	51.06
2040	5.53	79.45	29.85	5.77	141.89	58.79	18.15	154.27	71.17
2045	6.32	87.92	32.83	6.57	156.98	64.33	25.88	176.28	83.64
2050	7.12	98.34	36.20	7.38	170.39	68.24	27.38	190.39	88.24

Notes:
1. Minimum deficits derive from the lowest combination of water demand projections and the combination with the highest utilisation of existing sources.
2. Maximum deficits derive from the highest combination of water demand projections and the combination with the lowest utilisation of existing sources
3. The Client's Recommendation derives from the water demand projections recommended by the Client (NamWater and the CoW) and NamWater's recommendations for the utilisation of existing sources.

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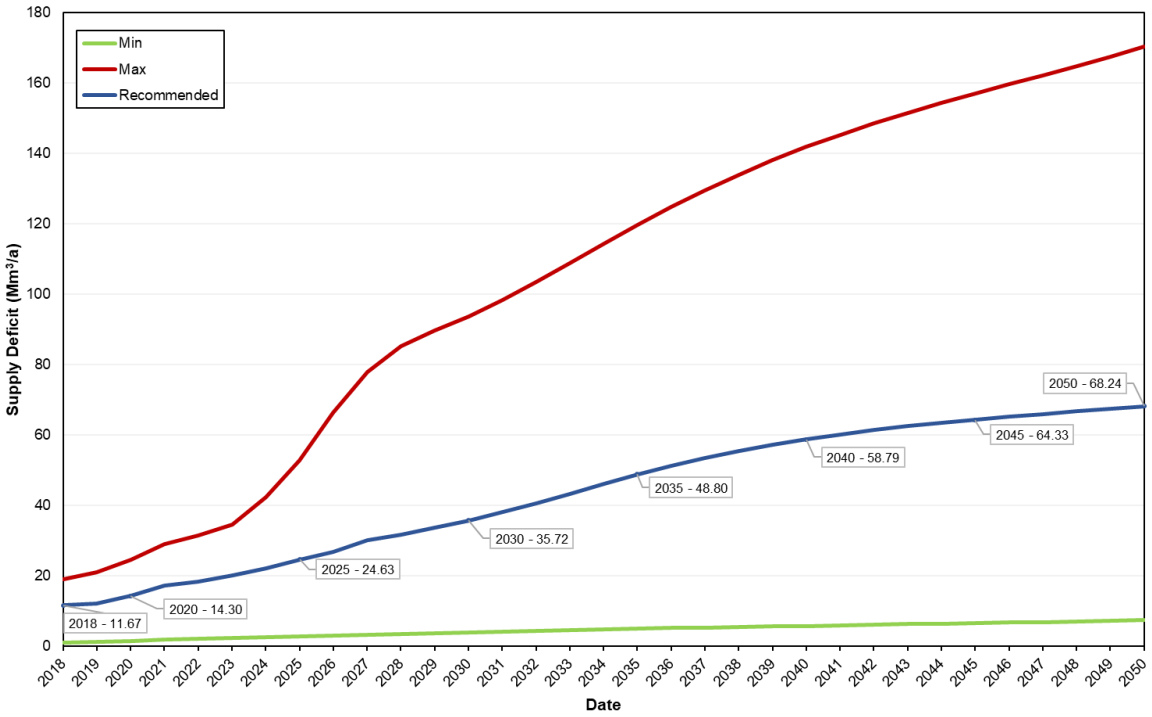

Figure 9.2: Total Water Deficit Projections for Supply Scenario 2: CCA + CAN + ER

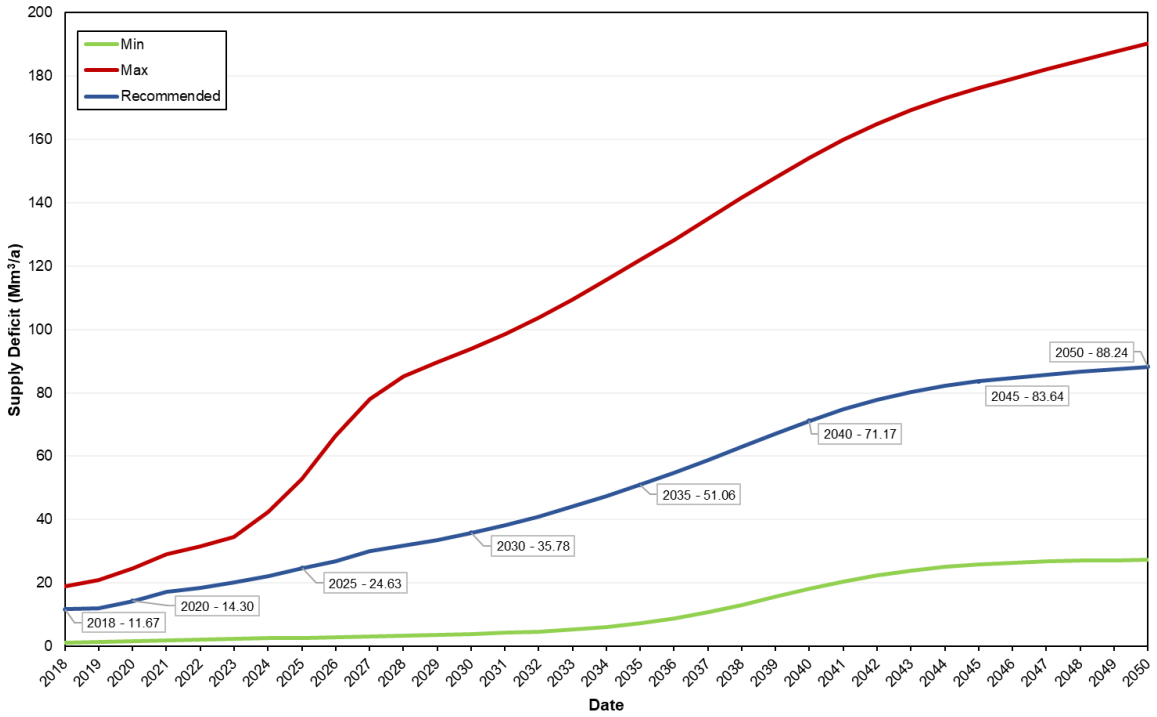

Figure 9.3: Total Water Deficit Projections for Supply Scenario 3: CCA + CAN + ER + Bots

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The recommended water deficits for the project scenarios are provided according to mining and non-mining water use categories.

For the CCA, it was assumed that the non-mining water demands would be supplied with groundwater and the mining demands with desalinated water, as is currently the case. In future, as the non-mining water demands exceed the groundwater supply option, S_2, selected by NamWater, desalinated water will be needed for supply augmentation for this category as well.

Table 9.2: Summary of the Recommended Water Deficits for Supply Scenario 1 (CCA Only)

Date	Water Deficits in the Central Coastal Area for SS1 (Mm^3/a)		
	Mining Deficit	**Non-Mining Deficit**	**SS1 Total Deficit**
2018	10.63	0.87	11.50
2020	11.31	1.75	13.07
2025	15.67	4.01	19.68
2030	18.00	6.47	24.47
2035	18.00	9.19	27.19
2040	18.00	11.84	29.85
2045	18.00	14.83	32.83
2050	18.00	18.19	36.20

Notes:
2. SS1 = Supply Scenario 1.
3. CCA = Central Coastal Area.
4. At present, NamWater supplies the mines with desalinated water and the local authority areas and other non-mining demands are supplied with groundwater at a set rate by NamWater, whereafter additional supply is from desalinated water. In line with this approach of NamWater, the option of groundwater supply selected by NamWater, S_2, at 12.0 Mm^3/a was allocated to the Non-Mining Water demands, as is currently the case, to derive the water deficits. The water demands of the mines equates to a deficit as the current supply from the Erongo Desalination Plant is not included in the supply volume, in order to derive a total deficit of desalinated water.

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Table 9.3: Summary of the Recommended Water Deficits for Supply Scenarios 1 (CCA Only) and 2 (CCA + CAN + ER)

Date	Water Deficit Values in Mm^3/a								
	Water Deficits in the CCA for SS1			Water Deficits for the CAN and En-Route Users			Water Deficits for SS2		
	Mining Deficit	Non-Mining Deficit	SS1 Total Deficit	Mining Deficit	Non-Mining Deficit	Total Deficit: CAN + ER	Mining Deficit	Non-Mining Deficit	SS2 Total Deficit
2018	10.63	0.87	11.50	0.00	0.17	0.17	10.63	1.03	11.67
2020	11.31	1.75	13.07	0.69	0.54	1.23	12.01	2.29	14.30
2025	15.67	4.01	19.68	1.93	3.02	4.95	17.60	7.03	24.63
2030	18.00	6.47	24.47	1.95	9.30	11.25	19.95	15.77	35.72
2035	18.00	9.19	27.19	1.97	19.64	21.61	19.98	28.83	48.80
2040	18.00	11.84	29.85	2.00	26.95	28.95	20.00	38.79	58.79
2045	18.00	14.83	32.83	2.03	29.47	31.50	20.03	44.30	64.33
2050	18.00	18.19	36.20	2.07	29.97	32.04	20.07	48.17	68.24

Notes:
1. SS1 = Supply Scenario 1, ditto SS2 = Supply Scenario 2.
2. CCA = Central Coastal Area.
3. CAN = The portion of the Central Area of Namibia considered for this Project.
4. ER = En-Route (users).
5. The water deficits = The difference between the Client's recommended water demand projections and the Client's recommended supply scenario for each are / supply scenario.
6. Refer to previous tables and notes on the derivations of the water deficits for the mining and non-mining categories for the CCA.
7. The Mining Water Demand in the CAN includes the water demand of the Otjihase Mine and that of the Swakoppoort Raw Water component; Okongava and Navachab Gold Mine (QKR) per the option selected by NamWater.

Table 9.4: Summary of the Recommended Water Deficits for Supply Scenario 3 (CCA + CAN + ER + Bots)

Date	Water Deficit Values in Mm^3/a				
	SS2 Total Deficit	Bots[2]	Water Deficits for SS3		
			Mining Deficit	Non-Mining Deficit	SS3 Total Deficit
2018	11.67	0.00	10.63	1.03	11.67
2020	14.30	0.00	12.01	2.29	14.30
2025	24.63	0.00	17.60	7.03	24.63
2030	35.72	0.06	19.95	15.83	35.78
2035	48.80	2.26	19.98	31.09	51.06
2040	58.79	12.38	20.00	51.17	71.17
2045	64.33	19.31	20.03	63.61	83.64
2050	68.24	20.00	20.07	68.17	88.24

Notes:
1. SS3 = Supply Scenario 3.
2. Bots = Botswana. The Terms of Reference for this Study specify that 20 Mm^3/a is to be transferred from Windhoek towards Gaborone, but does not state the nature of this water use. This water demand is assumed to be for Non-Mining use.

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9.2 Water Transmission System Requirements

The water transmission system requirements entail the supply requirements (via pipeline) from the desalination plant to the various major demand nodes. The transmission requirement may vary based on the pipeline(s) route(s) and the supply scenario pursued. Depending on the supply scenario, the coast will refer to the supply requirements to the CCA while the interior will entail the CAN, En-Route users and Botswana supply. Transmission can be summarised as follows:

1. Coast only - as per Supply Scenario 1
2. Coast and interior - In the case that supply to the interior would be via Swakopmund
3. Interior - Consisting of 2 sub-scenarios:
   a) CAN and En-Route – based on Supply Scenario 2
   b) CAN, En-Route and Botswana – based on Supply Scenario 3

In the case of items 1 and 2 in the list above, the transmission requirements would be equivalent to relevant supply scenario deficits (see **Section 9.1**). Regarding the transmission to the interior (item 3), **Table 9.5** provides a summary of transmission requirements, including the minimum and maximum and maximum, and is also illustrated in **Figure 9.4** and **Figure 9.5**.

Table 9.5: Summary of the Water Transmission System Requirements for Selected Project Options

Year	Water Transmission Requirements (Mm^3/a) per Scenario					
	SS2: CAN and En-Route			SS3: CAN, En-Route and Botswana		
	Minimum Option Combination[1]	Maximum Option Combination[2]	Client's Recommendation[3]	Minimum Option Combination[1]	Maximum Option Combination[2]	Client's Recommendation[3]
2018	0.17	3.45	0.17	0.00	3.45	0.17
2020	0.17	6.79	1.23	0.00	6.79	1.23
2025	0.18	15.24	4.95	0.00	15.24	4.95
2030	0.20	27.85	11.25	0.06	27.85	11.31
2035	0.23	47.20	21.61	2.26	47.31	23.87
2040	0.24	62.44	28.95	12.38	63.06	41.33
2045	0.25	69.05	31.50	19.31	70.02	50.81
2050	0.26	72.05	32.04	20.00	73.05	52.04

Notes:
1. The Client's Recommendation derives from the water demand projections recommended by the Client (NamWater and the CoW) and NamWater's recommendations for the utilisation of existing sources.
2. The transmission requirements represent the volumes of water to be transferred by pipeline(s).

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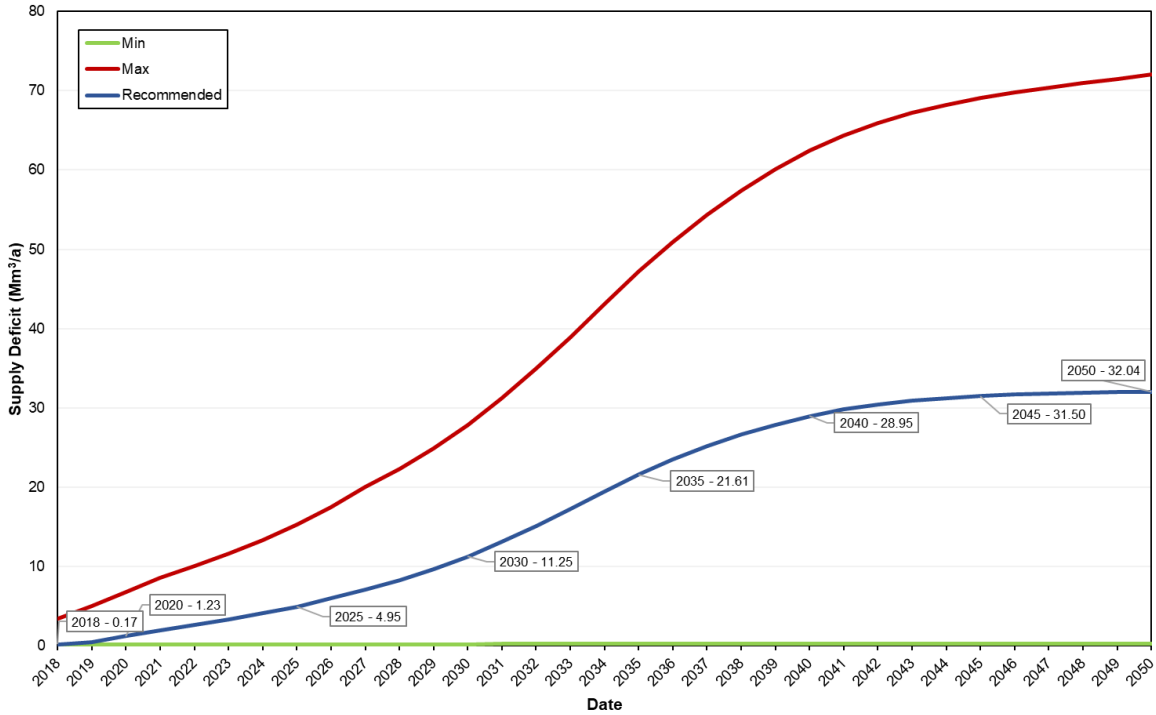

Figure 9.4: Water Transmission Requirements based on Supply Scenario 2: CAN + ER

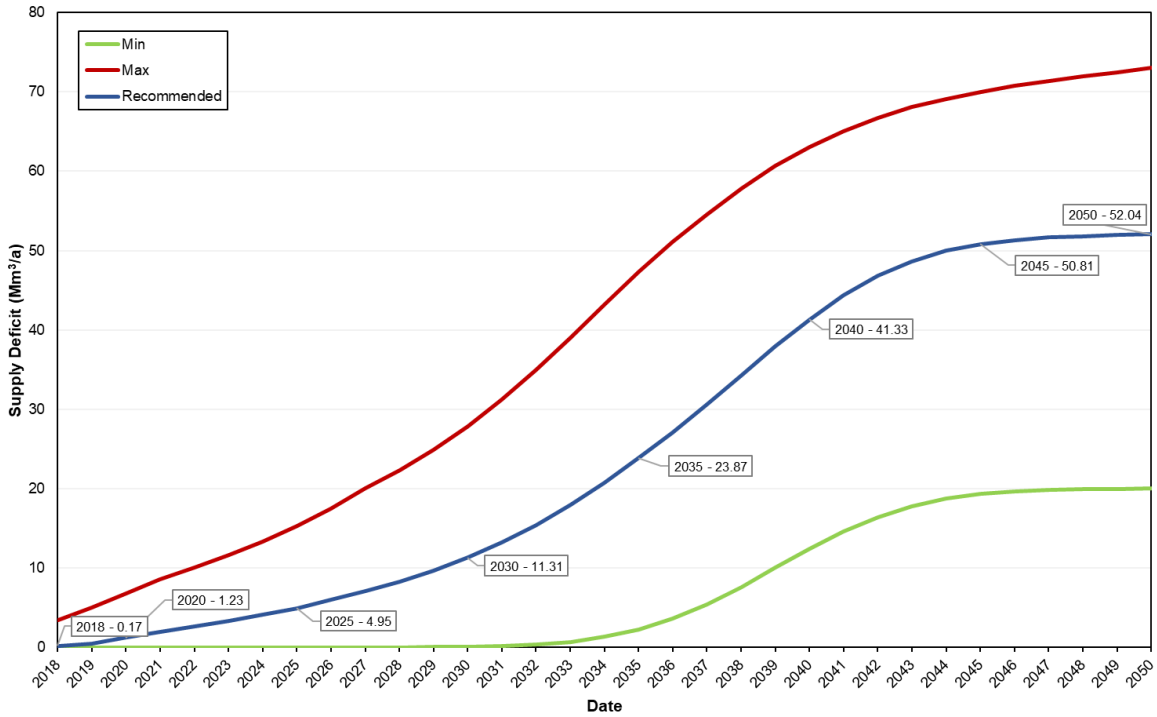

Figure 9.5: Water Transmission Requirements based on Supply Scenario 3: CAN + ER + Bots

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9.3 Project Phases and Implementation Measures

The water deficits represent the volumes of desalinated water which are to augment existing and locally available water resources in the Project Area and which are thus to be supplied by either the existing EDP and / or another seawater desalination plant. Project proposals are to be put forward for the following timeframes, per the ToR:

- Short-term (±5 years);
- Medium-term (approximately 5 to 15 years);
- Long-term (25+ years).

However, these options can only be fully developed once it has been established whether or not the existing EDP will be used for supply to the Project, and if so, whether this will be via purchase by or the Namibian Government or via long-term water supply agreement with Orano, and whether this will be with/out refurbishment. Further options include the expansion of the existing EDP and / or the construction of a new desalination plant. These and other options are detailed under the separate chapter covering the desalination options.

Apart from the source (desalination) options, other measures which can be implemented by the stakeholders associated with this Study include:

- Short-term (±5 years):
    - All local authorities should conduct full non-revenue water and leakage benchmarking exercises to ascertain the level of NRW in their jurisdiction and draw up plans and budgets for addressing these;
    - The MAWLR should by Government Notice in the Government Gazette publish the commencement of the Water Resources Management Act, 11 of 2013;
    - The MAWLR should finalise and publish the necessary regulations which are to accompany the Water Resources Management Act, 11 of 2013;
    - The MAWLR should finalise the establishment of the Water Regulator, which should establish and publish a tariff setting policy for Namibia;
    - NamWater should finalise investigations into the treatment of the Swakoppoort Dam water, the supply of water to Uis, and the supply of water from Abenab Mine / Karst III Aquifer;
    - The CoW should finalise investigations into the water quality requirements for artificial recharge of the Windhoek Aquifer, the further treatment of reclaimed water for artificial recharge and the planning of an additional DPR facility for Windhoek;

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- The CoW, together with the TCE and NamWater also need to decide whether or not, and to what possible extent, further development of the WMARS project will proceed;
- The Walvis Bay Municipality should finalise their planning for the implementation of direct potable reclamation;

- Medium-term (approximately 5 to 15 years):
  - The most appropriate medium-term options for supply are to be implemented (these are still to be confirmed under a separate feasibility study being undertaken by the TCE);
  - Water reclamation facilities are to be constructed and commissioned in Windhoek (additional) and Walvis Bay;
  - Supply from Abenab Mine / Karst III Aquifer: This supply option is currently under investigation by NamWater with the intention that it be implemented, following a development proposal / feasibility investigation by NamWater in 2014 (NamWater, 2014).
  - The outcomes of this Feasibility Study would need to be implemented if desalinated water is to be supplied under any supply scenario.

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10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

Both the CCA and the CAN are important areas in terms of their contribution to the national economy, including employment provision. The CCA, with the Walvis Bay harbour, represents a major gateway, transportation and logistics hub for Namibia and neighbouring countries, whilst the CAN, specifically Windhoek, represents the commercial, economic, political and administrative hub of the country. Windhoek has a good reputation as a regional and international conference venue and a clean and orderly city, with good quality infrastructure, including drinkable tap water. The Hosea Kutako International Airport outside Windhoek is the main point of entry for international and many regional visitors to the country.

In both the CCA and the CAN, water demands have surpassed the capacity of the local conventional water sources and unconventional water sources have been part of the supply mix for some time already. Under this Feasibility Study, it is foreseen that future water deficits, being water demands in excess of the capacity of existing and locally available sources, will be met with desalinated seawater. As a further option, desalinated seawater may also be transferred to Botswana's capital, Gaborone.

Water demands in both the CCA and CAN are currently limited by the capacity of existing and local sources and sustainable, reliable supply augmentation is badly needed to ensure the continued growth and development of these important areas. In most urban centres in these areas, there is also a need to expand and improve the provision of water supply and particularly sanitation services to informal settlements, which represents a significant latent water demand.

The capacity of existing and local sources have been investigated, including the current efficiency of water use (where data allows). Based on these analyses, and including consideration of the various factors which influence water demands, various scenarios for the demand projections for the Planning Horizon were prepared by the Consultant. These demand projections include proposals for improving the efficiency of water use where applicable.

The initial demand projections were "workshopped" with NamWater, following which the amendments requested by NamWater were affected and the revised projections were provided to representatives of the major local authorities in the Project Area for consideration. Following a discussion and review of these projections, approval for their use was obtained from the local authorities in the CCA and Windhoek, which demand projections were thus termed the "Client's Recommendation". Similarly, different scenarios for the utilisation of the existing and local water resources were prepared and submitted to NamWater for consideration. The combination of water demand scenarios and resource utilisation options resulted in a range of water deficit projections for each of the major demand areas in the Project Area; the CCA, CAN and En-route users.

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The water deficits deriving from the water demand projections accepted by NamWater and / or other stakeholders and the option for the utilisation of existing and local resources selected by NamWater, were also termed the "Client's Recommendation". It should not be assumed that the options or scenarios recommended by NamWater and other stakeholders necessarily carry the support of the Consultant (this is also not required under the Project).

Whilst engagement with and the receipt of approval from different stakeholders resulted in significant delays compared with the original project program, it is considered beneficial to the project to have secured the involvement and approval of the key local authority stakeholders.

10.2 Recommended Deficit or Augmentation Volumes

The recommended water deficits for 2050 are expected to be 36.20 Mm^3/a in the CCA, 30.04 Mm^3/a in the CAN and 2.00 Mm^3/a for the En-Route users. The transfer of some 20 Mm^3/a to Gaborone is to be investigated per the ToR. These deficits for 2050 have been combined according the specified project options as follows:

1. Supply Scenario 1: CCA: 36.20 Mm^3/a
2. Supply Scenario 2: CCA + CAN + ER: 68.24 Mm^3/a
3. Supply Scenario 3: CCA + CAN + ER + Bots: 88.24 Mm^3/a

These water deficit or augmentation volumes can be used to design the ultimate capacity of the various project components for sufficiency to 2050. The planning of short- and medium-term interventions and the phasing of any longer-term developments can be based on the water deficit or augmentation volumes, which are provided at five-year intervals in **Table 9.1**.

10.3 Development Phases

The water deficits represent the volumes of desalinated water which are to augment the existing and locally available water resources and which are thus to be supplied by either the existing EDP and / or another seawater desalination plant. However, these options can only be fully developed once it has been established whether or not the existing EDP will be used for supply to the Project, and if so, whether this will be via purchase by the Namibian Government or via long-term water supply agreement with Orano, and whether this will be with/out refurbishment. Further options include the expansion of the existing EDP and / or the construction of a new desalination plant. These and other options are detailed under the separate chapter covering the desalination options.

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10.4 Recommendations Regarding Further Investigations

Should further projects or investigations regarding desalinated seawater emanate from this Feasibility Study, it is strongly recommended that:

- The water demands be re-assessed on the basis of the expected unit costs derived from the outcome of this Study and that the water demand projections provided and the planning and implementation of augmentation schemes be reviewed and updated at least once every 4 to 5 years;
- NamWater should update or replace their CA-Model with an appropriate yield / planning model which provides sufficient functionality to be able to analyse different options for incorporating desalinated seawater into the CAN supply system, and then conduct such analyses.

10.5 Additional Implementation Measures

Apart from the source (desalination) options, other measures which can be implemented by the stakeholders associated with this Study include:

- Short-term (±5 years):
    - All local authorities should conduct full non-revenue water and leakage benchmarking exercises to ascertain the level of NRW in their jurisdiction and draw up plans and budgets for addressing these;
    - The MAWLR should by Government Notice in the Government Gazette publish the commencement of the Water Resources Management Act, 11 of 2013;
    - The MAWLR should finalise and publish the necessary regulations which are to accompany the Water Resources Management Act, 11 of 2013;
    - The MAWLR should finalise the establishment of the Water Regulator, which should establish and publish a tariff setting policy for Namibia;
    - NamWater should finalise investigations into the treatment of the Swakoppoort Dam water, the supply of water to Uis, and the supply of water from Abenab Mine / Karst III Aquifer;
    - The CoW should finalise investigations into the water quality requirements for artificial recharge of the Windhoek Aquifer, the further treatment of reclaimed water for artificial recharge and the planning of an additional DPR facility for Windhoek;
    - The CoW, together with the TCE and NamWater also need to decide whether or not, and to what possible extent, further development of the WMARS project will proceed;

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    - The Walvis Bay Municipality should finalise their planning for the implementation of direct potable reclamation;

- Medium-term (approximately 5 to 15 years):
    - The most appropriate medium-term options for supply are to be implemented (these are still to be confirmed under a separate feasibility study being undertaken by the TCE);
    - Water reclamation facilities are to be constructed and commissioned in Windhoek (additional) and Walvis Bay;
    - Supply from Abenab Mine / Karst III Aquifer: This supply option is currently under investigation by NamWater with the intention that it be implemented, following a development proposal / feasibility investigation by NamWater in 2014 (NamWater, 2014). Greater confidence in the potential of this resource is urgently needed, either on the basis of groundwater modelling, test pumping or utilisation thereof. It is recommended that the outcomes of any of these measures continue to inform and perhaps lead to revisions to the overall supply strategy;
    - The outcomes of this Feasibility Study would need to be implemented if desalinated water is to be supplied under any supply scenario.

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11 APPENDICES

11.1 Appendix 1 – Central Coastal Area

- Demand and Supply Options Summary
- Deficit Summary
- Water Demand Projections

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Domestic Consumption

Large Domestic Users

		Walvis Bay			Swakopmund			Henties Bay			Arandis			Subtotal: Large Domestic		
2017/18 NamWater Sales (Mm^3/a)		6.66			4.44			0.53			0.34			11.98		
Growth & Development Scenarios		Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High
Growth rate per scenario & period (% p.a.)	2018 - 2023	3.0%	4.0%	6.5%	3.0%	4.0%	6.5%	2.5%	3.0%	4.0%	2.0%	2.5%	3.5%			
	2023 - 2035	2.5%	3.5%	5.0%	2.5%	3.5%	6.0%	2.0%	2.5%	3.5%	1.0%	2.0%	3.0%			
	2035 - 2050	2.0%	3.0%	4.5%	2.0%	3.0%	4.0%	1.5%	2.0%	3.0%	1.0%	1.0%	2.5%			
Non-Revenue Water (%)	2018	14.5%	14.5%	14.5%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%			
	2050	5.0%	12.0%	14.5%	10.0%	12.0%	14.5%	10.0%	12.0%	15.0%	10.0%	12.0%	14.5%			
Water Supply Demands (Mm^3/a) for 2050		12.46	18.36	31.13	8.72	12.17	21.41	0.89	1.06	1.50	0.46	0.54	0.83	22.53	32.14	54.86
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	2050	30.0%	20.0%	5.0%	15.0%	10.0%	5.0%	10.0%	5.0%	0.0%	15.0%	10.0%	5.0%			
Water Supply Requirements (Mm^3/a) for 2050		8.72	14.69	29.57	7.41	10.95	20.34	0.80	1.01	1.50	0.39	0.49	0.78	17.32	27.14	52.19
Notes on water demand projections		Growth rates discussed and agreed with NamWater, considering historical growth rates in population and water demands. Growth rates also took congnisance of the Integrated Urban Spatial Development Framework for Walvis Bay (2013), but these values are considered unrealisticly high. Reuse % for likely scenario based on information from the Walvis Bay Municipality.			Growth rates discussed and agreed with NamWater, considering historical growth rates in population and water demands.			Growth rates discussed and agreed with NamWater, considering historical growth rates in population and water demands. Growth rates also took congnisance of the Integrated Urban Spatial Development Framework for Henties Bay (2015), but these values are considered unrealisticly high.			Growth rates discussed and agreed with NamWater, considering historical growth rates in population and water demands.					

Small Domestic Users

		Rooibank / Mile 7 (excl. Walvis Bay)			Swakopmund Terminal Reservoir (excl. Swakopmund)			Swakopmund Rössing (excl. Arandis and Mines)			Omdel - Swakopmund			Swartbank - Schwarzekuppe			Subtotal: Small Domestic		
2017/18 NamWater Sales (Mm^3/a)		0.11			0.01			0.37			0.12			0.28			0.89		
Growth & Development Scenarios		Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High
Growth rate per scenario & period (% p.a.)	2018 - 2023	4.0%	5.5%	6.5%	4.0%	6.5%	7.0%	4.0%	5.0%	6.5%	3.0%	5.0%	6.0%	2.0%	3.0%	4.0%			
	2023 - 2035	3.5%	5.0%	6.0%	3.5%	6.0%	6.5%	3.5%	4.5%	6.0%	2.5%	4.0%	5.5%	2.0%	3.0%	3.5%			
	2035 - 2050	2.0%	4.5%	6.0%	2.0%	3.0%	4.0%	2.0%	4.5%	6.0%	2.0%	2.5%	4.0%	1.5%	2.5%	3.0%			
Non-Revenue Water (%)	2018	16.0%	16.0%	16.0%	16.0%	16.0%	16.0%	10.0%	10.0%	10.0%	16.0%	16.0%	16.0%	20.0%	20.0%	20.0%			
	2050	10.0%	15.0%	16.0%	10.0%	15.0%	16.0%	5.0%	10.0%	10.0%	10.0%	15.0%	16.0%	10.0%	15.0%	16.0%			
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	2050	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Water Supply Requirements		0.25	0.49	0.73	0.03	0.05	0.06	0.86	1.56	2.46	0.23	0.34	0.53	0.43	0.62	0.75	1.79	3.06	4.53
		Minor demand node			Minor demand node			Minor demand node			Minor demand node			Minor demand node					

Total: Domestic

	Large Users			Small Users			Total Domestic		
	Low	Likely	High	Low	Likely	High	Low	Likely	High
2017/18 NamWater Sales (Mm^3/a)	11.98			0.89			12.87		
Water Supply Requirements (Mm^3/a) for 2050	17.32	27.14	52.19	1.79	3.06	4.53	19.12	30.19	56.72

Mining

	Langer Heinrich Uranium Ltd	Rössing Uranium Ltd		Swakop Uranium / Husab	Potential New Mines
2017/18 NamWater Sales (Mm^3/a)	1.79	2.90		5.94	0.00
Water Supply Requirements (Mm^3/a) for 2050	2.80	NamWater expected peak	Possible maximum peak use	10.20	8.61
		5.00	8.00		

	Trekkopje
2017/18 Supply (Mm^3/a)	0.00
Water Supply Requirements (Mm^3/a) for 2050*	20.00

Scenarios for the iclusion of mining water demands

Demand Option	M_1	M_2	M_3	M_4	M_5
Water Supply Requirements (Mm^3/a) for 2050 per scenario	No mining demand included	NamWater expected peak use of Rössing and Husab Mines	100% of demand for existing mines	100% of demand for existing & new mines	100% of demand for existing & new mines and Trekkopje
	0.00	18.00	21.01	29.62	49.62

Notes:

1. Scenario M1 is based on the exclusion of mining water supply per the Water Supply and Sanitation Policy (2008).
2. Peak use of Langer Heinrich, Rössing Uranium and Potential New Mines derived from 2009 CNA BWMP (NamWater). These estimates were made during a very optimistic uranium mining outlook.
3. Scenario M2 considers supply to the existing Rössing, Husab and Langer Heinrich Mines. Peak demand of 10.2 Mm^3/a for Husab Mine per information received from Swakop Uranium. Expected future demand for Rössing Mine of 5 Mm^3/a per NamWater. Peak demand for Langer Heinrich per 2009 CNA BWMP.
4. Scenario M3 considers possible peak use of 8 Mm^3/a for Rössing Mine per the 2009 CNA BWMP (NamWater), the peak demand of Husab Mine and a demand of 2.8 Mm^3/a for Langer Heinrich Mine should this become operational again.
5. Scenario M4 includes demand of prospective new mines identified in the 2009 CNA BWMP (NamWater) in addition to Scenario M3.
6. Scenario M5 includes the possible future operation of Trekkopje Mine at an assumed peak demand of 20 Mm^3/a in accordance with the design capacity of the Erongo Desalination Plant. These estimates for 2050 anticipate a possible increase in the uranium price that will result in prospective mines proceding with operations. When the uranium price increase will occur in the next 30 years is difficult to estimate, hence the conservative approach to forecast it for 2050. This scenario therefore represents a very optimistic outlook on uranium and other mining developments.

Demand Options

Demand Options: Supply Requirements by 2050 (Mm^3/a)

Option			WSR (2050)			Comments
No	Domestic	Mining	Domestic	Mining	Total	
D1	D_{Low}	M_1	19.12	0.00	19.12	
D2	D_{Low}	M_2	19.12	18.00	37.12	
D3	D_{Low}	M_3	19.12	21.01	40.13	
D4	D_{Low}	M_4	19.12	29.62	48.74	
D5	D_{Low}	M_5	19.12	49.62	68.74	
D6	D_{Likely}	M_1	30.19	0.00	30.19	
D7	D_{Likely}	M_2	30.19	18.00	48.20	Client's recommendation
D8	D_{Likely}	M_3	30.19	21.01	51.20	Consultant's recommendation
D9	D_{Likely}	M_4	30.19	29.62	59.81	
D10	D_{Likely}	M_5	30.19	49.62	79.81	
D11	D_{High}	M_1	56.72	0.00	56.72	
D12	D_{High}	M_2	56.72	18.00	74.72	
D13	D_{High}	M_3	56.72	21.01	77.73	
D14	D_{High}	M_4	56.72	29.62	86.34	
D15	D_{High}	M_5	56.72	49.62	106.34	

Water Supply Requirements (2050)

Domestic Demand		
D_{Low}	D_{Likely}	D_{High}
19.12	30.19	56.72

Mining				
M_1	M_2	M_3	M_4	M_5
0.00	18.00	21.01	29.62	49.62

Supply Options

Options for the Utilisation of Groundwater Supply (Omdel & Kuiseb Aquifers) in the Central Coastal Area

Resource	Available Capacity			Source Options 1: Lower utilisation of groundwater sources to allow for uncertainty and the recovery of water levels			Source Option 2: Allow utilisation of groundwater sources in accordance with safe yield and permit values	
				Capacity (Mm^3/a)		Comment		
	Capacity (Mm^3/a)	Description	Reference	Option 1a: Rapid Assessment[2]	Option 1b: Consultant Proposal[3]		Capacity (Mm^3/a)	Comment
Omdel Aquifer	**4.6**	Permit-approved abstraction for 2018. Also, safe yields given for 2015 onwards.	MAWF permit, dated January 2018	**2.7**	**2.3**	Reduced yields (conservative) for higher security of supply (reduced variability) and to allow the recovery of water levels for emergency availability in future, if required.	**4.6**	Allow utilisation of groundwater sources according to the safe yield values determined by NamWater and others, and according to the permit-approved values per MAWF.
Kuiseb Aquifer	**7.0**	Permit-approved abstraction from 2015 onwards	MAWF permits	**5.0**	**5.7**		**7.4 or 9.0**	NamWater has been granted a permit (May 2019) allowing abstraction of 9 Mm3/a with an emergency abstraction of 11.4 Mm3/a. However, NamWater have recommended that the value of 7.4 Mm3/a be applied for the long term use of the aquifer.
	7.4	Safe yield given for 2015 onwards.						
				7.7	**8.0**		**12.0**	Recommended by NamWater (4.6 + 7.4 Mm3/a)
							13.6	

Volumes of Supply from Desalinated Water in the CCA = Future Supply Requirements - Groundwater Supply Volumes

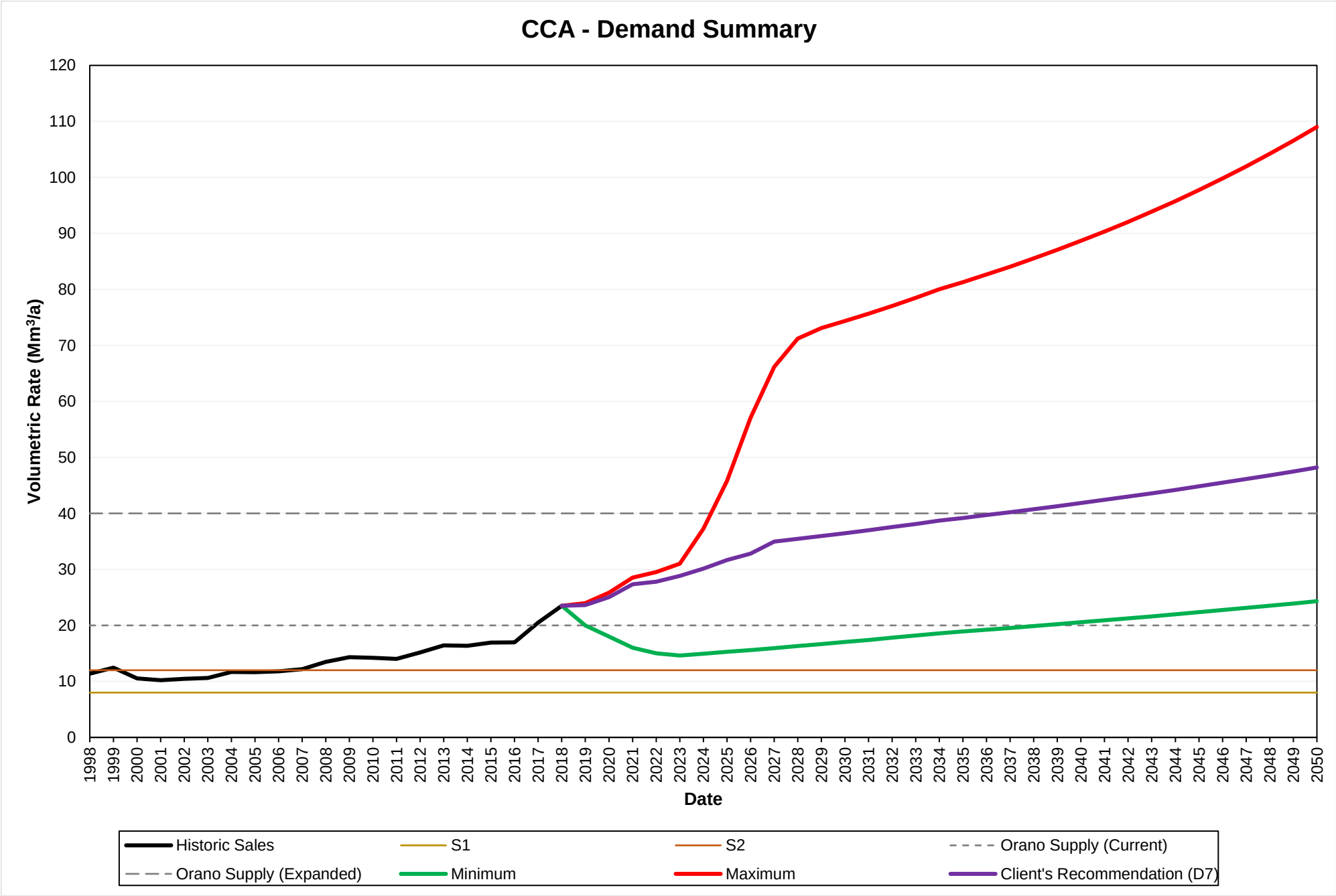
For the Volumes of Desalinated Water Supply:	**Capacity (Mm^3/a)**	
Orano Existing	20	Utilise the existing Orano Plant at capacity, OR new separate plant utilising the same intake & discharge infrastructure
Orano Existing + Expand	40	
All New	TBC	

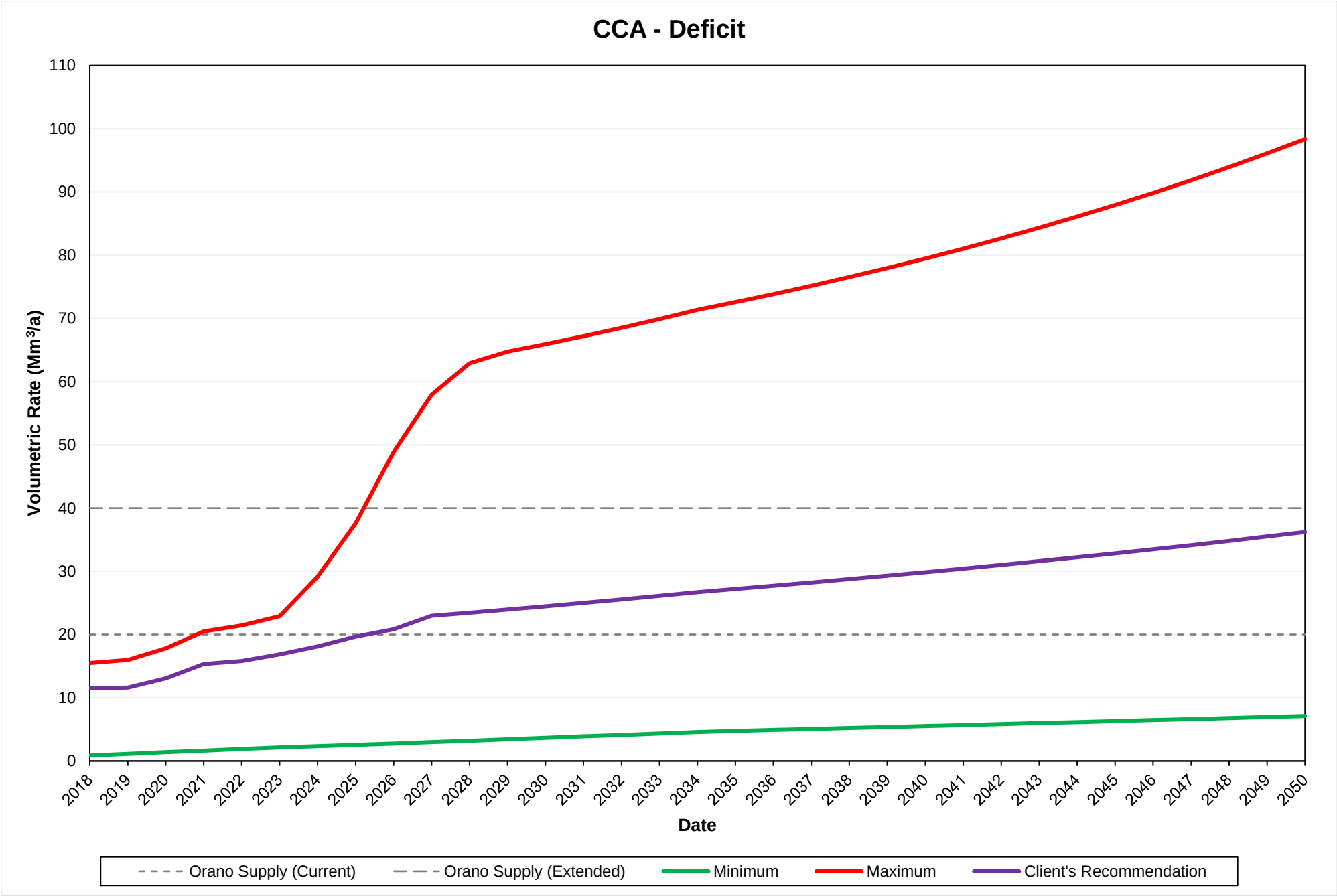
Summary	Capacity
S_1	8.0
S_2	12.0

Overall Options

Overall Options: Values in Mm^3/a

Overall Option	Demand / Suypply Option				Overall Deficit			Comments
	Dem No	Domestic	Mining	Supply	Demand	Supply	Deficit	
O1	D1	D_{Low}	M_1	S_1	19	8	11	
O2	D2	D_{Low}	M_2	S_1	37	8	29	
O3	D3	D_{Low}	M_3	S_1	40	8	32	
O4	D4	D_{Low}	M_4	S_1	49	8	41	
O5	D5	D_{Low}	M_5	S_1	69	8	61	
O6	D6	D_{Likely}	M_1	S_1	30	8	22	
O7	D7	D_{Likely}	M_2	S_1	48	8	40	
O8	D8	D_{Likely}	M_3	S_1	51	8	43	Consultant's reccomendation
O9	D9	D_{Likely}	M_4	S_1	60	8	52	
O10	D10	D_{Likely}	M_5	S_1	80	8	72	
O11	D11	D_{High}	M_1	S_1	57	8	49	
O12	D12	D_{High}	M_2	S_1	75	8	67	
O13	D13	D_{High}	M_3	S_1	78	8	70	
O14	D14	D_{High}	M_4	S_1	86	8	78	
O15	D15	D_{High}	M_5	S_1	106	8	98	Maximum
O16	D1	D_{Low}	M_1	S_2	19	12	7	Minimum
O17	D2	D_{Low}	M_2	S_2	37	12	25	
O18	D3	D_{Low}	M_3	S_2	40	12	28	
O19	D4	D_{Low}	M_4	S_2	49	12	37	
O20	D5	D_{Low}	M_5	S_2	69	12	57	
O21	D6	D_{Likely}	M_1	S_2	30	12	18	
O22	D7	D_{Likely}	M_2	S_2	48	12	36	Client's recommendation
O23	D8	D_{Likely}	M_3	S_2	51	12	39	
O24	D9	D_{Likely}	M_4	S_2	60	12	48	
O25	D10	D_{Likely}	M_5	S_2	80	12	68	
O26	D11	D_{High}	M_1	S_2	57	12	45	
O27	D12	D_{High}	M_2	S_2	75	12	63	
O28	D13	D_{High}	M_3	S_2	78	12	66	
O29	D14	D_{High}	M_4	S_2	86	12	74	
O30	D15	D_{High}	M_5	S_2	106	12	94	


CCA - Demand Summary
Volumetric Rate (Mm³/a)
Date
Historic Sales
S1
S2
Orano Supply (Current)
Orano Supply (Expanded)
Minimum
Maximum
Client's Recommendation (D7)


CCA - Deficit
Volumetric Rate (Mm³/a)
110
100
90
80
70
60
50
40
30
20
10
0
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
Date
Orano Supply (Current)
Orano Supply (Extended)
Minimum
Maximum
Client's Recommendation

CCA Demand and Supply Options Summary

All values in Mm3/a unless otherwise stated

Year (Plot)	NY FY	Date Ref	Historic Sales	Supply				Demand				Deficit			
								Minimum	Maximum	Consultant's Recommndation	Client's Recommndation	Minimum	Maximum	Consulta nt's	Client's Recomm
				S1	S2	Orano	Orano Expand	D1	D15	D8	D7	O16	O15	O8	O22
1997/98	1998	1998	11.38	8.00	12.00	20.00	40.00								
1998/99	1999	1999	12.45	8.00	12.00	20.00	40.00								
1999/00	2000	2000	10.52	8.00	12.00	20.00	40.00								
2000/01	2001	2001	10.21	8.00	12.00	20.00	40.00								
2001/02	2002	2002	10.48	8.00	12.00	20.00	40.00								
2002/03	2003	2003	10.63	8.00	12.00	20.00	40.00								
2003/04	2004	2004	11.70	8.00	12.00	20.00	40.00								
2004/05	2005	2005	11.66	8.00	12.00	20.00	40.00								
2005/06	**2006**	2006	11.80	8.00	12.00	20.00	40.00								
2006/07	2007	2007	12.20	8.00	12.00	20.00	40.00								
2007/08	2008	2008	13.47	8.00	12.00	20.00	40.00								
2008/09	2009	2009	14.32	8.00	12.00	20.00	40.00								
2009/10	2010	2010	14.23	8.00	12.00	20.00	40.00								
2010/11	2011	2011	14.00	8.00	12.00	20.00	40.00								
2011/12	2012	2012	15.17	8.00	12.00	20.00	40.00								
2012/13	2013	2013	16.43	8.00	12.00	20.00	40.00								
2013/14	2014	2014	16.35	8.00	12.00	20.00	40.00								
2014/15	2015	2015	16.94	8.00	12.00	20.00	40.00								
2015/16	2016	2016	16.97	8.00	12.00	20.00	40.00								
2016/17	2017	2017	20.48	8.00	12.00	20.00	40.00								
2017/18	2018	2018	23.50	8.00	12.00	20.00	40.00	23.50	23.50	23.50	23.50	0.87	15.50	15.50	11.50
2018/19	2019	2019		8.00	12.00	20.00	40.00	20.00	23.98	23.83	23.62	1.12	15.96	15.62	11.62
2019/20	2020	2020		8.00	12.00	20.00	40.00	18.00	25.84	25.52	25.07	1.39	17.80	17.07	13.07
2020/21	2021	2021		8.00	12.00	20.00	40.00	16.00	28.55	28.04	27.33	1.65	20.48	19.33	15.33
2021/22	2022	2022		8.00	12.00	20.00	40.00	15.00	29.52	28.80	27.81	1.92	21.42	19.81	15.81
2022/23	2023	2023		8.00	12.00	20.00	40.00	14.62	31.03	30.05	28.85	2.13	22.91	20.85	16.85
2023/24	2024	2024		8.00	12.00	20.00	40.00	14.94	37.28	31.55	30.12	2.34	29.12	22.12	18.12
2024/25	2025	2025		8.00	12.00	20.00	40.00	15.27	45.81	33.35	31.68	2.56	37.62	23.68	19.68
2025/26	2026	2026		8.00	12.00	20.00	40.00	15.61	57.09	34.76	32.83	2.77	48.87	24.83	20.83
2026/27	2027	2027		8.00	12.00	20.00	40.00	15.95	66.18	37.53	34.95	2.99	57.91	27.33	22.95
2027/28	2028	2028		8.00	12.00	20.00	40.00	16.30	71.22	40.23	35.45	3.21	62.91	29.74	23.45
2028/29	2029	2029		8.00	12.00	20.00	40.00	16.66	73.10	41.76	35.95	3.44	64.74	30.95	23.95
2029/30	2030	2030		8.00	12.00	20.00	40.00	17.03	74.35	42.60	36.47	3.66	65.93	31.47	24.47
2030/31	2031	2031		8.00	12.00	20.00	40.00	17.41	75.65	43.49	37.00	3.89	67.18	32.01	25.00
2031/32	2032	2032		8.00	12.00	20.00	40.00	17.79	77.03	44.41	37.55	4.13	68.49	32.56	25.55
2032/33	2033	2033		8.00	12.00	20.00	40.00	18.19	78.48	45.37	38.12	4.36	69.87	33.12	26.12
2033/34	2034	2034		8.00	12.00	20.00	40.00	18.59	80.01	46.37	38.70	4.60	71.33	33.70	26.70
2034/35	2035	2035		8.00	12.00	20.00	40.00	18.90	81.31	47.10	39.19	4.76	72.55	34.20	27.19
2035/36	2036	2036		8.00	12.00	20.00	40.00	19.22	82.65	47.86	39.70	4.91	73.82	34.70	27.70
2036/37	2037	2037		8.00	12.00	20.00	40.00	19.55	84.06	48.64	40.22	5.06	75.14	35.22	28.22
2037/38	2038	2038		8.00	12.00	20.00	40.00	19.88	85.53	49.44	40.75	5.22	76.52	35.75	28.75
2038/39	2039	2039		8.00	12.00	20.00	40.00	20.21	87.06	50.26	41.29	5.38	77.95	36.29	29.29
2039/40	2040	2040		8.00	12.00	20.00	40.00	20.56	88.66	51.11	41.85	5.53	79.45	36.85	29.85
2040/41	2041	2041		8.00	12.00	20.00	40.00	20.90	90.33	51.99	42.41	5.69	81.01	37.42	30.41
2041/42	2042	2042		8.00	12.00	20.00	40.00	21.26	92.06	52.89	43.00	5.85	82.63	38.00	31.00
2042/43	2043	2043		8.00	12.00	20.00	40.00	21.62	93.88	53.82	43.59	6.00	84.32	38.60	31.59
2043/44	2044	2044		8.00	12.00	20.00	40.00	21.98	95.77	54.78	44.21	6.16	86.09	39.21	32.21
2044/45	2045	2045		8.00	12.00	20.00	40.00	22.36	97.75	55.76	44.83	6.32	87.92	39.84	32.83
2045/46	2046	2046		8.00	12.00	20.00	40.00	22.73	99.81	56.77	45.47	6.48	89.84	40.48	33.47
2046/47	2047	2047		8.00	12.00	20.00	40.00	23.12	101.97	57.82	46.13	6.64	91.83	41.14	34.13
2047/48	2048	2048		8.00	12.00	20.00	40.00	23.51	104.21	58.89	46.80	6.80	93.91	41.81	34.80
2048/49	2049	2049		8.00	12.00	20.00	40.00	23.91	106.56	60.00	47.49	6.96	96.08	42.50	35.49
2049/50	2050	2050		8.00	12.00	20.00	40.00	24.32	109.01	61.14	48.20	7.12	98.34	43.20	36.20

11.2 Appendix 2 – Central Area of Namibia

- Demand and Supply Options Summary
- Deficit Summary
- Water Demand Projections

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CAN Demand and Supply Options Summary

Existing Demand Nodes

Downstream of Von Bach

	Okahandja			Resorts			Swakoppoort - Von Bach			Von Bach - Windhoek (online)			Airport Users			Otjihase Mine			Windhoek			Subtotal: D/S Von Bach		
2017/18 NamWater Sales (Mm^3/a)	1.38			0.12			0.09			0.53			0.27			0.02			22.03			24.44		
Growth & Development Scenarios	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High	Low	Likely	High
Growth rate per scenario & period (% p.a.) 2018 - 2023	3.0%	4.0%	5.0%	Not applicable			Not applicable			3.0%	5.0%	6.0%	Not applicable			Not applicable			2.0%	3.0%	4.0%			
Growth rate per scenario & period (% p.a.) 2023 - 2035	2.0%	3.0%	3.5%							2.0%	3.5%	4.5%							1.5%	2.0%	1.8%			
Growth rate per scenario & period (% p.a.) 2035 - 2050	1.3%	2.0%	2.5%							1.0%	1.0%	2.0%							1.0%	1.0%	1.0%			
Non-Revenue Water (%) 2018	14.5%	14.5%	14.5%							0.0%	0.0%	0.0%							15.0%	15.0%	15.0%			
Non-Revenue Water (%) 2050	5.0%	12.0%	14.5%							0.0%	0.0%	0.0%							10.0%	12.0%	14.5%			
Water Demands (Mm^3/a) for 2050	2.84	3.73	4.54	0.14	0.16	0.17	0.14	0.16	0.19	0.88	1.20	1.55	0.82	2.16	2.47	0.00	0.30	0.56	33.26	37.77	41.75	38.08	45.49	51.22
Water Reuse (%) 2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	Reuse for Windhoek addressed in supply scenarios					
Water Reuse (%) 2050	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
Water Supply Requirements (Mm^3/a) for 2050	2.55	3.73	4.54	0.14	0.16	0.17	0.14	0.16	0.19	0.88	1.20	1.55	0.82	2.16	2.47	0.00	0.30	0.56						
Notes on water demand projections	Growth in Okahandja expected to increase as a result of proximity with Windhoek. Population growth at nearly 5% (2001-2011), believed to be largely due to rural-urban migration in the Otjozondjupa Region (negative growth rate in rural population 2001-2016). Water demand growth rate at 3.2% (2013-2018).			Minor demand node. Small growth allowance made for 2050 projections.			Minor demand node. Most growth expected from Greencrisp Farm peaking at 160,000 m^3/a			Immediate growth expected in short term but to drastically reduce in longer term as consumption stabilises. Excludes Osona Village development (refer to major development sheet).			Anticipated completion of the Finkenstein, Herbothsblick, Sungate and new airport developments.			Following assumptions made: • Low: mine would be closed by 2050 • Likely: peak demand of 0.296 Mm^3/a • High: peak historical use of 0.560 Mm^3/a			Anticiapted full development of existing boundaries of the Windhoek basin (excluding north and north-eastern developments) along with urban densification. Growth rate periods defined differently than for other demand nodes. Likely scenario assumes 3% growth rate in water demand in the short-medium term, per NamWater modelling approach.					

Swakoppoort Dam Users

	Swakoppoort Raw Water (Okongava and Navachab)			Karibib WTP (incl. Otjimbingwe)				Subtotal: D/S Swakoppoort		
2017/18 NamWater Sales (Mm^3/a)	1.26			0.43				1.69		
Growth & Development Scenarios	Low	Likely	High	Low	Likely	High		Low	Likely	High
Growth rate per scenario & period (% p.a.) 2018 - 2023	Assume continual operation of the Navachab Mine (life of mine 2061 per Navachab correspondence, 2019) with increased output but at greater efficiency. Minor growth for the Okongava			2.5%	3.0%	4.0%	Karibib Notes: Assumed 3% growth (likely) at Karibib (per NamWater assessment for Karibib Reservoir, 2018) and lower growth at Otjimbingwe for short-medium term.			
Growth rate per scenario & period (% p.a.) 2023 - 2035				1.5%	2.1%	3.0%				
Growth rate per scenario & period (% p.a.) 2035 - 2050				0.5%	0.8%	0.7%				
Non-Revenue Water (%) 2018				10.0%	10.0%	10.0%				
Non-Revenue Water (%) 2050				5.0%	10.0%	10.0%				
Water Demands (Mm^3/a) for 2050				0.55	0.67	0.81		2.08	2.44	3.01
Water Reuse (%) 2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%				
Water Reuse (%) 2050	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%				
Water Supply Requirements (Mm^3/a) for 2050	1.53	1.77	2.20	0.49	0.67	0.81		2.03	2.44	3.01

Total: CAN Users (d/s Von Bach and Swakoppoort)

	D/S Von Bach			D/S Swakoppoort			Total Domestic		
	Low	Likely	High	Low	Likely	High	Low	Likely	High
2017/18 NamWater Sales (Mm^3/a)	24.44			1.69			26.13		
Water Demands (Mm^3/a) for 2050	38.08	45.49	51.22	2.08	2.44	3.01	40.16	47.93	54.22

Major Developments

Scenarios for the extent of implementation of Osona Village

Demand Option	OV_1	OV_2	OV_3	OV_4
Water Demands (Mm^3/a) for 2050 per scenario	0%	20%	40%	75%
	0.00	0.73	1.46	2.74

Scenarios for the extent of implementation of Elisenhiem and Brakwater

Demand Option	$E\&B_1$	$E\&B_2$	$E\&B_3$	$E\&B_4$
Water Demands (Mm^3/a) for 2050 per scenario	0%	20%	40%	75%
	0.50	4.35	8.19	14.92

Scenarios for the extent of implementation of Ongos and Monte Christo developments

Demand Option		$O\&MC_1$	$O\&MC_2$	$O\&MC_3$	$O\&MC_4$
Water Demands (Mm^3/a) for 2050 per scenario		0%	20%	40%	75%
		0.00	6.58	13.17	24.69
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%
	2050	0.0%	5.0%	15.0%	20.0%
Water Supply Requirements (Mm^3/a) for 2050		0.00	6.25	11.19	19.75

Total Major Developments

Demand Option	MD_1	MD_2	MD_3	MD_4
Water Supply Requirements (Mm^3/a) for 2050	0%	20%	40%	75%
	0.51	11.34	20.85	37.41

Area	Demand (Mm^3/a)	
	Current Demands	100% full development
Osona Village	0.00	3.65
Elisenheim	0.15	3.29
Brakwater	0.36	16.44
Ongos	0.00	9.59
Monte Christo	0.00	23.33
Total	**0.51**	**56.30**

Notes:

1. Osona Village fully developed water demand based on design demand of 10,000 m^3/day (correspondence with Knight Piesold and Mutschler Consulting Services, 2019).
2. Elisenheim's full development water demand based on design demand of 9,000 m^3/day (correspondence with Windhoek Consulting Engineers, 2019)
3. Brakwater full development water demand based on design demand of 45,000 m^3/day (CoW Brakwater Bulk Services Master Plan, 2010)
4. Ongos and Monte Christo full development water demand based on design demand on 26,250 and 63,868 m^3/day respectively (CoW NW and SW Windhoek Bulk Water and Sewer Reticulation Master Plan, 2016). The Master Plan also envisages direct potable reuse for the developments with a maximum 35% blending ratio. Suggested reuse % are of the Consultant's estimates.
5. Total Major Developments (*MD*) = *OV+EB+O&MC*
6. Scenario 1 in all instances assumes 0% further development, but includes current demand assumed to continue into the future.

Demand Options

Demand Options: Water Demands by 2050 (Mm^3/a)

Option			Demands (2050)			Commentary
No	Existing	Major Developments	Existing	Future	Total	
D1	D_{Low}	MD_1	40.16	0.51	40.67	
D2	D_{Low}	MD_2	40.16	11.34	51.50	
D3	D_{Low}	MD_3	40.16	20.85	61.01	
D4	D_{Low}	MD_4	40.16	37.41	77.58	
D5	D_{Likely}	MD_1	47.93	0.51	48.43	
D6	D_{Likely}	MD_2	47.93	11.34	59.26	
D7	D_{Likely}	MD_3	47.93	20.85	68.78	Client's Recommendation
D8	D_{Likely}	MD_4	47.93	37.41	85.34	
D9	D_{High}	MD_1	54.22	0.51	54.73	
D10	D_{High}	MD_2	54.22	11.34	65.56	
D11	D_{High}	MD_3	54.22	20.85	75.07	
D12	D_{High}	MD_4	54.22	37.41	91.64	

Water Demands (2050)

Existing Demand Nodes		
D_{Low}	D_{Likely}	D_{High}
40.16	47.93	54.22

Major Developments			
MD_1	MD_2	MD_3	MD_4
0.51	11.34	20.85	37.41

Demand options presented here are serve the combinations of existing supply nodes and future major developments

Supply Options

All values in Mm3/a unless otherwise stated

General supply options to the CAN and utilisation layout

Resource	Options	Scenario Name	Note	Yield / Net-Benefit Mm3/a	Commentary
WMARS	Natural recharge	WMARS1		1.73	Zhang et al., 2002
	Alternative benefit	WMARS2		5	Best estimate of overall benefit of WMARS
Surface Water	95% yield	SW1		20	Yield values per 2004 CAN WAS.
	Reduced yield	SW2		10	Consultants recommended yield for surface water sources. Please refer to Annexure.
Reclamation at Windhoek	Fixed capacity: current to med term	Reuse1		11.8	Reclamation capacity assumed for the Okavango FS (CAN WAS, 2017)
	Reuse: Low Scenario	Reuse2	50%	17	Linked to % reclamation of Winhoek
	Reuse: Likely Scenario	Reuse3	45%	17	Linked to % reclamation of Winhoek
	Reuse: High Scenario	Reuse4	35%	15	Linked to % reclamation of Winhoek

Notes on WMARS:

1. Best estimate was derived from an analysis of the output files of the CA-Model from the modelling analyses conducted for the Okavango FS (CAN WAS 2017).
2. Overall benefit of WMARS is difficult to quantify, particularly in the long term without adequate volumes available for artifcial recharge.

Notes on reuse percentages:

1. 11.8 Mm^3/a represents maximum current capacity (7.6 Mm^3/a) + additional reuse (4.2 Mm^3/a) per Okavango FS (CAN WAS 2017).
2. 50% potable reuse is maximum implemented internationally (Wichita Falls).
3. 45% potable reuse is based on a realistic maximum rate, even though 50% may nominally be targeted.
4. 35% potable reuse is based on the current blending ratio restrictions.

Supply scenarios per supply combinations

Supply Options	WMARS	Surface Water	Reclamation at Windhoek	WMARS	Surface Water	Reclamation at Windhoek	Total	Commentary
S1	WMARS1	SW1	Reuse1	1.73	20.00	11.80	34	
S2	WMARS1	SW1	Reuse2	1.73	20.00	16.63	38	
S3	WMARS1	SW1	Reuse3	1.73	20.00	17.00	39	Client's Recommendation
S4	WMARS1	SW1	Reuse4	1.73	20.00	14.61	36	
S5	WMARS1	SW2	Reuse1	1.73	10.00	11.80	24	
S6	WMARS1	SW2	Reuse2	1.73	10.00	16.63	28	
S7	WMARS1	SW2	Reuse3	1.73	10.00	17.00	29	
S8	WMARS1	SW2	Reuse4	1.73	10.00	14.61	26	
S9	WMARS2	SW1	Reuse1	5.00	20.00	11.80	37	
S10	WMARS2	SW1	Reuse2	5.00	20.00	16.63	42	
S11	WMARS2	SW1	Reuse3	5.00	20.00	17.00	42	
S12	WMARS2	SW1	Reuse4	5.00	20.00	14.61	40	
S13	WMARS2	SW2	Reuse1	5.00	10.00	11.80	27	
S14	WMARS2	SW2	Reuse2	5.00	10.00	16.63	32	Consultant's Recommendation
S15	WMARS2	SW2	Reuse3	5.00	10.00	17.00	32	
S16	WMARS2	SW2	Reuse4	5.00	10.00	14.61	30	

Overall Options

All values in Mm3/a unless otherwise stated. Figures represent 2050 projection estimates

Overall Options per supply and demand combinations

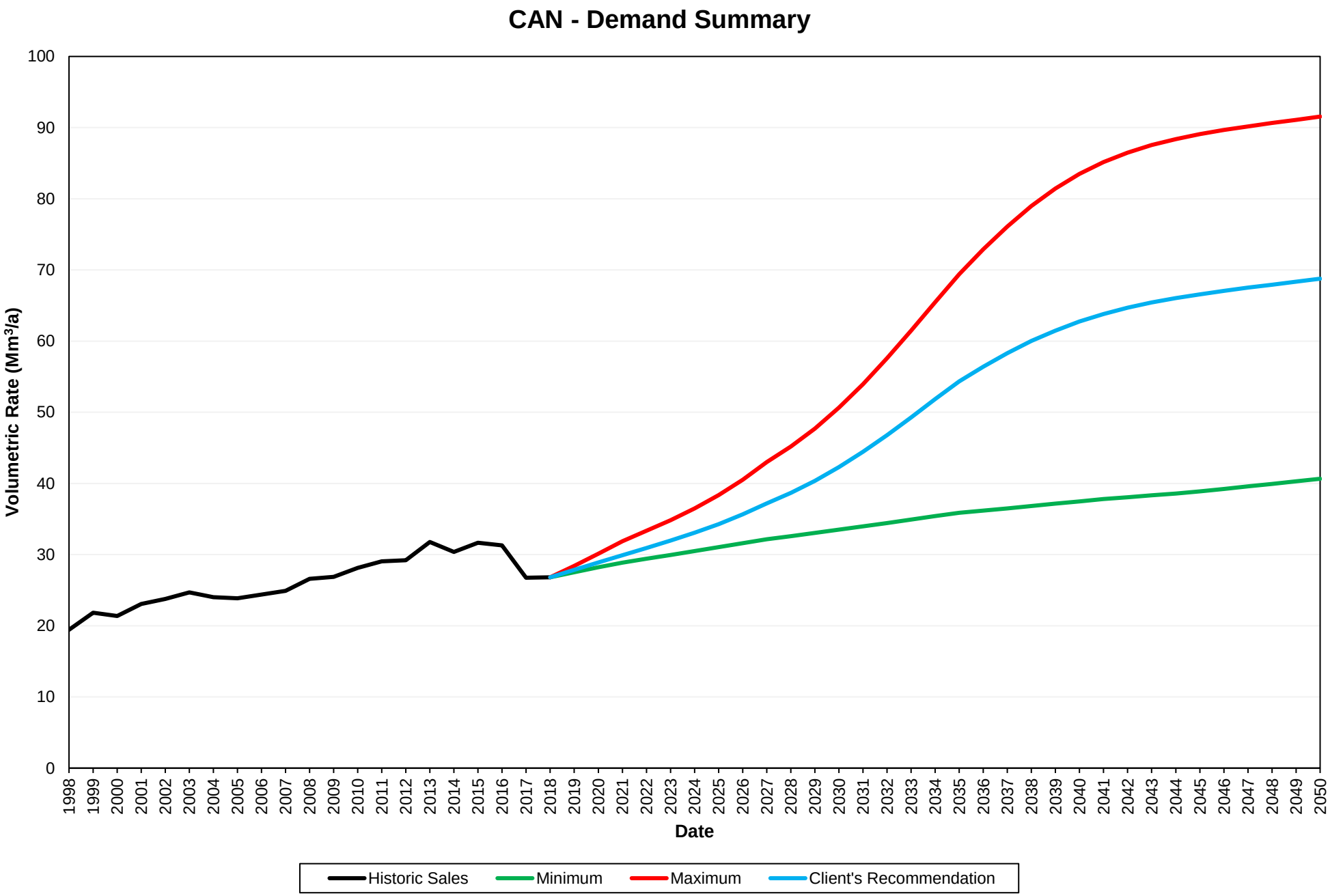
No	Overall Option	Demand / Suypply Option				Overall Deficit			Comments
		Dem No	Domestic	Developments	Supply	Demand	Supply	Deficit	
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	O1	D1	D_{Low}	MD_1	S1	41	34	7	
2	O2	D2	D_{Low}	MD_2	S1	51	34	18	
3	O3	D3	D_{Low}	MD_3	S1	61	34	27	
4	O4	D4	D_{Low}	MD_4	S1	78	34	44	
5	O5	D5	D_{Likely}	MD_1	S1	48	34	15	
6	O6	D6	D_{Likely}	MD_2	S1	59	34	26	
7	O7	D7	D_{Likely}	MD_3	S1	69	34	35	
8	O8	D8	D_{Likely}	MD_4	S1	85	34	52	
9	O9	D9	D_{High}	MD_1	S1	55	34	21	
10	O10	D10	D_{High}	MD_2	S1	66	34	32	
11	O11	D11	D_{High}	MD_3	S1	75	34	42	
12	O12	D12	D_{High}	MD_4	S1	92	34	58	
13	O13	D1	D_{Low}	MD_1	S2	41	38	2	
14	O14	D2	D_{Low}	MD_2	S2	51	38	13	
15	O15	D3	D_{Low}	MD_3	S2	61	38	23	
16	O16	D4	D_{Low}	MD_4	S2	78	38	39	
17	O17	D5	D_{Likely}	MD_1	S3	48	39	10	
18	O18	D6	D_{Likely}	MD_2	S3	59	39	21	
19	O19	D7	D_{Likely}	MD_3	S3	69	39	30	Client's Recommendation
20	O20	D8	D_{Likely}	MD_4	S3	85	39	47	
21	O21	D9	D_{High}	MD_1	S4	55	36	18	
22	O22	D10	D_{High}	MD_2	S4	66	36	29	
23	O23	D11	D_{High}	MD_3	S4	75	36	39	
24	O24	D12	D_{High}	MD_4	S4	92	36	55	
25	O25	D1	D_{Low}	MD_1	S5	41	24	17	
26	O26	D2	D_{Low}	MD_2	S5	51	24	28	
27	O27	D3	D_{Low}	MD_3	S5	61	24	37	
28	O28	D4	D_{Low}	MD_4	S5	78	24	54	
29	O29	D5	D_{Likely}	MD_1	S5	48	24	25	
30	O30	D6	D_{Likely}	MD_2	S5	59	24	36	
31	O31	D7	D_{Likely}	MD_3	S5	69	24	45	
32	O32	D8	D_{Likely}	MD_4	S5	85	24	62	
33	O33	D9	D_{High}	MD_1	S5	55	24	31	
34	O34	D10	D_{High}	MD_2	S5	66	24	42	
35	O35	D11	D_{High}	MD_3	S5	75	24	52	
36	O36	D12	D_{High}	MD_4	S5	92	24	68	Maximum
37	O37	D1	D_{Low}	MD_1	S6	41	28	12	
38	O38	D2	D_{Low}	MD_2	S6	51	28	23	
39	O39	D3	D_{Low}	MD_3	S6	61	28	33	
40	O40	D4	D_{Low}	MD_4	S6	78	28	49	
41	O41	D5	D_{Likely}	MD_1	S7	48	29	20	
42	O42	D6	D_{Likely}	MD_2	S7	59	29	31	
43	O43	D7	D_{Likely}	MD_3	S7	69	29	40	
44	O44	D8	D_{Likely}	MD_4	S7	85	29	57	
45	O45	D9	D_{High}	MD_1	S8	55	26	28	
46	O46	D10	D_{High}	MD_2	S8	66	26	39	
47	O47	D11	D_{High}	MD_3	S8	75	26	49	
48	O48	D12	D_{High}	MD_4	S8	92	26	65	
49	O49	D1	D_{Low}	MD_1	S9	41	37	4	
50	O50	D2	D_{Low}	MD_2	S9	51	37	15	
51	O51	D3	D_{Low}	MD_3	S9	61	37	24	
52	O52	D4	D_{Low}	MD_4	S9	78	37	41	
53	O53	D5	D_{Likely}	MD_1	S9	48	37	12	
54	O54	D6	D_{Likely}	MD_2	S9	59	37	22	
55	O55	D7	D_{Likely}	MD_3	S9	69	37	32	
56	O56	D8	D_{Likely}	MD_4	S9	85	37	49	

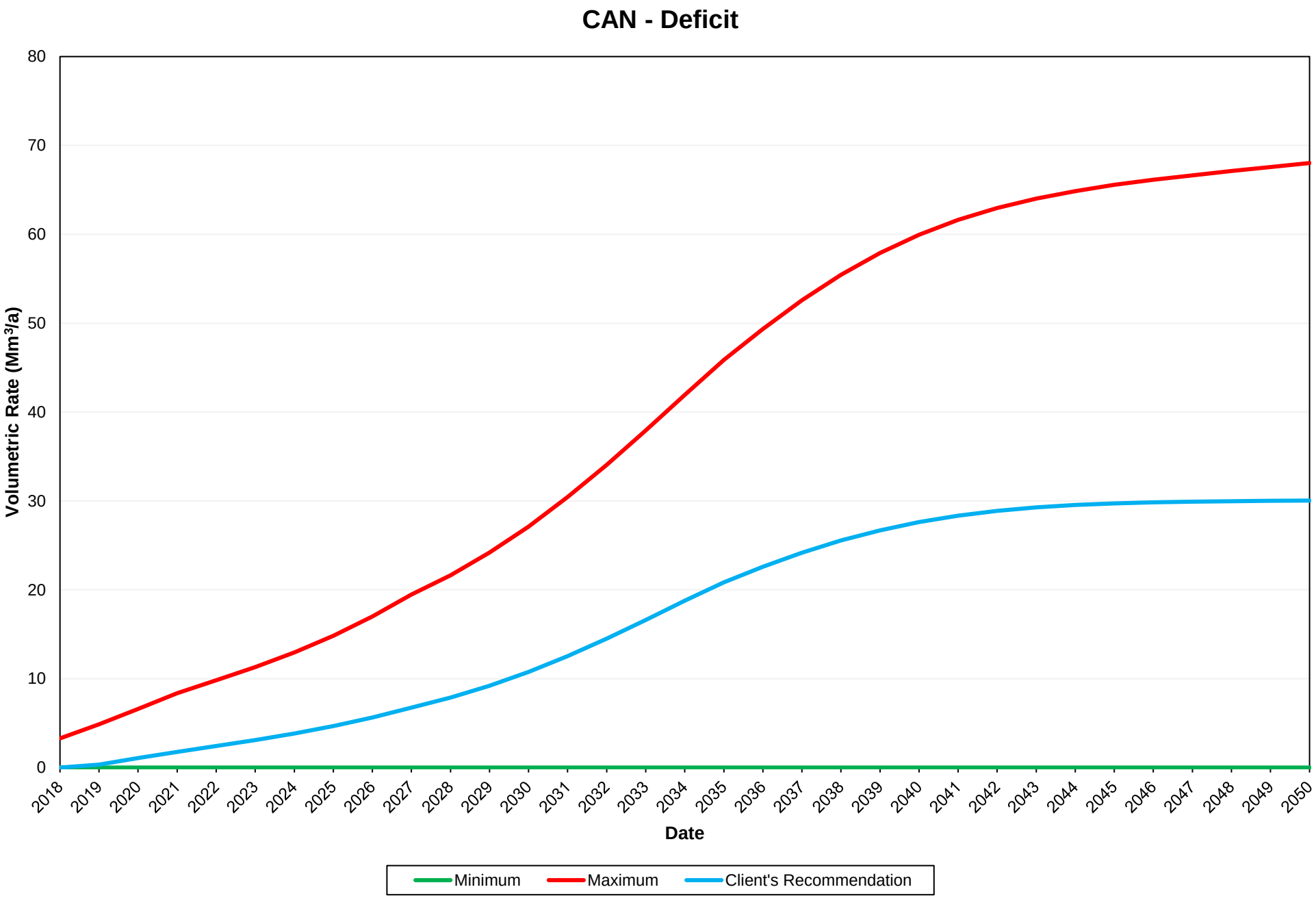
Overall Options

All values in Mm3/a unless otherwise stated. Figures represent 2050 projection estimates

Overall Options per supply and demand combinations

No	Overall Option	Demand / Suypply Option				Overall Deficit			Comments
		Dem No	Domestic	Developments	Supply	Demand	Supply	Deficit	
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
57	O57	D9	D_{High}	MD_1	S9	55	37	18	
58	O58	D10	D_{High}	MD_2	S9	66	37	29	
59	O59	D11	D_{High}	MD_3	S9	75	37	38	
60	O60	D12	D_{High}	MD_4	S9	92	37	55	
61	O61	D1	D_{Low}	MD_1	S10	41	42	0	Minimum
62	O62	D2	D_{Low}	MD_2	S10	51	42	10	
63	O63	D3	D_{Low}	MD_3	S10	61	42	19	
64	O64	D4	D_{Low}	MD_4	S10	78	42	36	
65	O65	D5	D_{Likely}	MD_1	S11	48	42	6	
66	O66	D6	D_{Likely}	MD_2	S11	59	42	17	
67	O67	D7	D_{Likely}	MD_3	S11	69	42	27	
68	O68	D8	D_{Likely}	MD_4	S11	85	42	43	
69	O69	D9	D_{High}	MD_1	S12	55	40	15	
70	O70	D10	D_{High}	MD_2	S12	66	40	26	
71	O71	D11	D_{High}	MD_3	S12	75	40	35	
72	O72	D12	D_{High}	MD_4	S12	92	40	52	
73	O73	D1	D_{Low}	MD_1	S13	41	27	14	
74	O74	D2	D_{Low}	MD_2	S13	51	27	25	
75	O75	D3	D_{Low}	MD_3	S13	61	27	34	
76	O76	D4	D_{Low}	MD_4	S13	78	27	51	
77	O77	D5	D_{Likely}	MD_1	S13	48	27	22	
78	O78	D6	D_{Likely}	MD_2	S13	59	27	32	
79	O79	D7	D_{Likely}	MD_3	S13	69	27	42	
80	O80	D8	D_{Likely}	MD_4	S13	85	27	59	
81	O81	D9	D_{High}	MD_1	S13	55	27	28	
82	O82	D10	D_{High}	MD_2	S13	66	27	39	
83	O83	D11	D_{High}	MD_3	S13	75	27	48	
84	O84	D12	D_{High}	MD_4	S13	92	27	65	
85	O85	D1	D_{Low}	MD_1	S14	41	32	9	
86	O86	D2	D_{Low}	MD_2	S14	51	32	20	
87	O87	D3	D_{Low}	MD_3	S14	61	32	29	
88	O88	D4	D_{Low}	MD_4	S14	78	32	46	
89	O89	D5	D_{Likely}	MD_1	S15	48	32	16	
90	O90	D6	D_{Likely}	MD_2	S15	59	32	27	
91	O91	D7	D_{Likely}	MD_3	S15	69	32	37	Consultant's Recommendation
92	O92	D8	D_{Likely}	MD_4	S15	85	32	53	
93	O93	D9	D_{High}	MD_1	S16	55	30	25	
94	O94	D10	D_{High}	MD_2	S16	66	30	36	
95	O95	D11	D_{High}	MD_3	S16	75	30	45	
96	O96	D12	D_{High}	MD_4	S16	92	30	62	


CAN - Demand Summary
Volumetric Rate (Mm³/a)
Date
Historic Sales
Minimum
Maximum
Client's Recommendation


CAN - Deficit
Volumetric Rate (Mm³/a)
80
70
60
50
40
30
20
10
0
2018
2019
2020
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2022
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2043
2044
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2046
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2048
2049
2050
Date
Minimum
Maximum
Client's Recommendation

Annexure: Surface Water Yields

A constant draft (demand) was assumed only on the Windhoek Node (no other demands were modelled)

Draft 20 Mm3/a

Type	Mean	Median	99%	98%	95%	90%
2017/18	21.7	21.7	21.7	21.7	21.7	21.7
2018/19	21.5	21.7	18.5	18.9	19.9	21.7
2019/20	19.8	21.7	4.1	5.4	7.2	12.6
2020/21	20.2	21.7	2.3	5.5	9.0	14.6
2021/22	20.4	21.7	5.3	6.2	9.7	16.4
2022/23	20.3	21.7	4.8	5.7	9.8	15.7
2023/24	20.5	21.7	5.9	6.9	10.8	17.7
2024/25	20.8	21.7	5.9	7.1	13.0	20.0
2025/26	20.5	21.7	5.6	7.2	11.1	18.1
2026/27	20.3	21.7	2.9	4.4	7.2	16.0
2027/28	20.4	21.7	5.4	6.3	8.0	17.3
2028/29	20.8	21.7	3.9	6.3	14.2	20.6
2029/30	20.8	21.7	6.1	7.4	12.1	21.7
2030/31	20.8	21.7	4.8	7.5	14.0	21.7
2031/32	20.9	21.7	7.1	7.9	13.8	20.2
2032/33	20.8	21.7	5.6	7.2	13.9	20.9
2033/34	20.7	21.7	4.2	5.7	11.9	21.5
2034/35	20.7	21.7	6.6	7.2	10.9	19.8
2035/36	20.8	21.7	5.3	8.0	11.7	21.7
2036/37	20.8	21.7	4.8	7.8	14.3	21.7
2037/38	20.6	21.7	4.2	5.3	11.1	21.7
2038/39	20.6	21.7	5.2	7.2	11.1	19.7
2039/40	20.7	21.7	6.7	7.2	11.3	21.1
2040/41	20.9	21.7	7.5	8.8	14.4	20.9
2041/42	20.4	21.7	4.0	5.3	11.1	16.4
2042/43	20.5	21.7	5.3	6.6	8.7	19.0
2043/44	20.6	21.7	5.3	8.7	11.0	18.3
2044/45	20.7	21.7	5.1	8.0	12.2	19.2
2045/46	20.7	21.7	5.1	6.9	10.7	21.0
2046/47	20.8	21.7	5.7	7.2	14.5	21.1
2047/48	20.7	21.7	5.6	7.2	11.3	20.7
2048/49	21.0	21.7	6.8	8.6	16.1	21.7
2049/50	20.9	21.7	7.1	8.7	14.3	20.5
Average	20.7	21.7	6.2	7.8	12.2	19.5

Draft 15 Mm3/a

Type	Mean	Median	99%	98%	95%	90%
2017/18	16.3	16.3	16.3	16.3	16.3	16.3
2018/19	16.3	16.3	16.3	16.3	16.3	16.3
2019/20	15.9	16.3	6.9	9.5	14.4	16.3
2020/21	15.8	16.3	5.4	6.9	12.6	16.3
2021/22	15.9	16.3	6.7	7.5	14.8	16.3
2022/23	15.9	16.3	6.3	8.2	15.2	16.3
2023/24	15.9	16.3	6.9	8.4	14.3	16.3
2024/25	16.0	16.3	6.7	9.2	16.3	16.3
2025/26	15.9	16.3	5.4	7.2	16.3	16.3
2026/27	15.9	16.3	4.1	7.2	16.3	16.3
2027/28	16.1	16.3	6.8	9.6	16.3	16.3
2028/29	16.1	16.3	8.3	15.2	16.3	16.3
2029/30	16.1	16.3	8.1	12.0	16.3	16.3
2030/31	16.1	16.3	7.8	12.0	16.3	16.3
2031/32	16.0	16.3	6.6	11.8	16.3	16.3
2032/33	15.9	16.3	4.3	7.2	15.6	16.3
2033/34	15.9	16.3	6.3	7.0	15.7	16.3
2034/35	16.0	16.3	6.5	8.1	16.3	16.3
2035/36	16.1	16.3	6.9	11.4	16.3	16.3
2036/37	16.1	16.3	8.1	12.2	16.3	16.3
2037/38	16.0	16.3	5.5	9.1	16.3	16.3
2038/39	16.0	16.3	7.3	9.2	16.3	16.3
2039/40	16.0	16.3	5.5	9.4	16.3	16.3
2040/41	16.0	16.3	9.6	11.0	16.3	16.3
2041/42	16.0	16.3	6.4	11.0	16.3	16.3
2042/43	16.0	16.3	6.9	10.8	16.3	16.3
2043/44	16.0	16.3	7.3	10.6	16.3	16.3
2044/45	15.9	16.3	5.8	7.8	15.9	16.3
2045/46	15.9	16.3	5.6	6.6	16.3	16.3
2046/47	16.0	16.3	7.1	10.2	16.3	16.3
2047/48	16.0	16.3	5.4	9.8	16.3	16.3
2048/49	15.9	16.3	5.6	7.2	15.5	16.3
2049/50	15.9	16.3	4.7	8.1	15.5	16.3
Average	16.0	16.3	7.1	9.8	15.9	16.3

Draft 10 Mm3/a

Type	Mean	Median	99%	98%	95%	90%
2017/18	10.9	10.9	10.9	10.9	10.9	10.9
2018/19	10.9	10.9	10.9	10.9	10.9	10.9
2019/20	10.9	10.9	10.9	10.9	10.9	10.9
2020/21	10.8	10.9	9.6	10.9	10.9	10.9
2021/22	10.8	10.9	8.6	10.9	10.9	10.9
2022/23	10.8	10.9	10.9	10.9	10.9	10.9
2023/24	10.8	10.9	10.9	10.9	10.9	10.9
2024/25	10.8	10.9	10.8	10.9	10.9	10.9
2025/26	10.8	10.9	10.9	10.9	10.9	10.9
2026/27	10.8	10.9	10.9	10.9	10.9	10.9
2027/28	10.8	10.9	10.9	10.9	10.9	10.9
2028/29	10.8	10.9	10.8	10.9	10.9	10.9
2029/30	10.8	10.9	10.9	10.9	10.9	10.9
2030/31	10.9	10.9	10.9	10.9	10.9	10.9
2031/32	10.9	10.9	10.9	10.9	10.9	10.9
2032/33	10.9	10.9	10.9	10.9	10.9	10.9
2033/34	10.8	10.9	10.9	10.9	10.9	10.9
2034/35	10.8	10.9	10.9	10.9	10.9	10.9
2035/36	10.8	10.9	10.3	10.9	10.9	10.9
2036/37	10.8	10.9	10.9	10.9	10.9	10.9
2037/38	10.8	10.9	10.9	10.9	10.9	10.9
2038/39	10.8	10.9	10.8	10.9	10.9	10.9
2039/40	10.8	10.9	10.8	10.9	10.9	10.9
2040/41	10.8	10.9	10.8	10.9	10.9	10.9
2041/42	10.8	10.9	10.8	10.9	10.9	10.9
2042/43	10.8	10.9	10.8	10.9	10.9	10.9
2043/44	10.8	10.9	10.9	10.9	10.9	10.9
2044/45	10.8	10.9	10.9	10.9	10.9	10.9
2045/46	10.8	10.9	10.9	10.9	10.9	10.9
2046/47	10.8	10.9	10.9	10.9	10.9	10.9
2047/48	10.8	10.9	9.0	10.9	10.9	10.9
2048/49	10.8	10.9	10.8	10.9	10.9	10.9
2049/50	10.8	10.9	10.8	10.9	10.9	10.9
Average	10.8	10.9	10.7	10.9	10.9	10.9

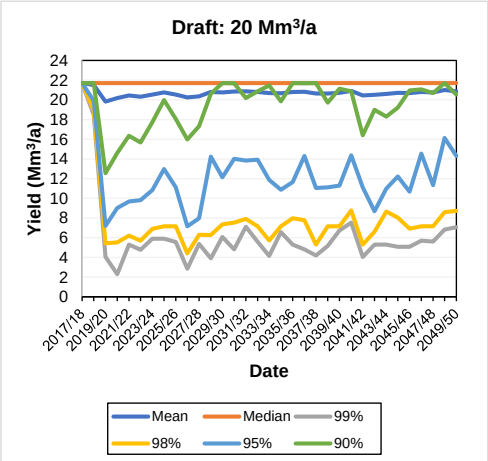
A simplified yield analysis was done to estimate the yields from the 3-dam system using the CA-Model.

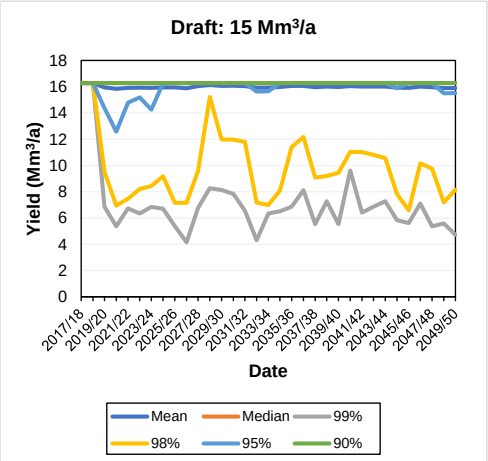
Only one demand node was activated, namely Windhoek, and at a constant draft / demand for a 33 year period (equivalent to 2018 to 2050). All other demand nodes were set to zero and all other supply sources were set to zero.

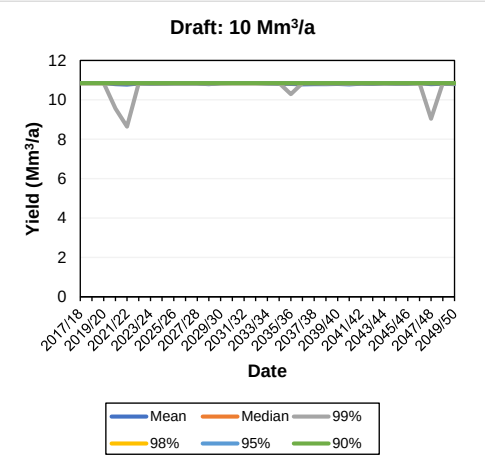
Three draft values were tested, 20, 15, and 10 Mm^3/a. From the Von Bach to Windhoek transfer files, the percentile values equivalent to 99%, 98%, 95% and 90% were abstracted per year. The mean and median values are also included for reference.

It is clear that for a 99% and 95%, the 3 Dam system cannot yield $20Mm^3/a$. On a 99%, the 3 Dam system cannot yield $15Mm^3/a$, but can do so at 95%. Lastly, at a draft of $10Mm^3/a$, even the highest percentiles (99%) can be yielded.

Therefore, the most representative 99% yield for the 3 Dam system can confidently be put at $10Mm^3/a$. The consultant strongly advises a revision of the 95% yield of $20Mm^3/a$, which is the current assumed 3 Dam yield used by NamWater. The Consultant would recommend a preliminary 95% yield of $15Mm^3/a$ and a 99% yield of $10Mm^3/a$ prior to more detailed yield determination for the 3 Dam system.







All values in Mm3/a unless otherwise state

Year (Plot)	NY FY	Date Ref	Historic Sales	Demand Minimum	Demand Maximum	Demand Client's Recommendation	Deficit Minimum	Deficit Maximum	Deficit Client's Recommendation	Deficit Consultant's Recommendation
				D1	D12	D7	O61	O36	O19	O91
1997/98	1998	1998	19.44							
1998/99	1999	1999	21.84							
1999/00	2000	2000	21.36							
2000/01	2001	2001	23.05							
2001/02	2002	2002	23.77							
2002/03	2003	2003	24.69							
2003/04	2004	2004	24.00							
2004/05	2005	2005	23.87							
2005/06	**2006**	2006	24.40							
2006/07	2007	2007	24.91							
2007/08	2008	2008	26.60							
2008/09	2009	2009	26.87							
2009/10	2010	2010	28.14							
2010/11	2011	2011	29.05							
2011/12	2012	2012	29.19							
2012/13	2013	2013	31.77							
2013/14	2014	2014	30.39							
2014/15	2015	2015	31.68							
2015/16	2016	2016	31.30							
2016/17	2017	2017	26.74							
2017/18	2018	2018	26.81	26.81	26.81	26.81	0.00	3.28	0.00	6.30
2018/19	2019	2019		27.53	28.39	27.86	0.00	4.86	0.32	7.05
2019/20	2020	2020		28.22	30.12	28.91	0.00	6.59	1.06	7.79
2020/21	2021	2021		28.86	31.89	29.93	0.00	8.36	1.75	8.48
2021/22	2022	2022		29.44	33.35	30.94	0.00	9.82	2.42	9.15
2022/23	2023	2023		29.96	34.84	31.96	0.00	11.31	3.09	9.82
2023/24	2024	2024		30.49	36.49	33.07	0.00	12.96	3.82	10.55
2024/25	2025	2025		31.04	38.36	34.29	0.00	14.83	4.66	11.39
2025/26	2026	2026		31.59	40.52	35.65	0.00	16.99	5.62	12.35
2026/27	2027	2027		32.16	43.00	37.19	0.00	19.47	6.74	13.47
2027/28	2028	2028		32.60	45.17	38.66	0.00	21.64	7.87	14.60
2028/29	2029	2029		33.05	47.72	40.36	0.00	24.19	9.21	15.94
2029/30	2030	2030		33.51	50.64	42.28	0.00	27.11	10.77	17.50
2030/31	2031	2031		33.97	53.95	44.44	0.00	30.42	12.54	19.27
2031/32	2032	2032		34.44	57.59	46.78	0.00	34.06	14.50	21.23
2032/33	2033	2033		34.92	61.47	49.28	0.00	37.94	16.60	23.33
2033/34	2034	2034		35.41	65.46	51.85	0.00	41.93	18.76	25.49
2034/35	2035	2035		35.86	69.39	54.34	0.00	45.86	20.83	27.56
2035/36	2036	2036		36.18	72.89	56.41	0.00	49.36	22.58	29.31
2036/37	2037	2037		36.50	76.11	58.31	0.00	52.58	24.17	30.90
2037/38	2038	2038		36.83	78.97	60.01	0.00	55.44	25.55	32.28
2038/39	2039	2039		37.15	81.43	61.48	0.00	57.90	26.69	33.42
2039/40	2040	2040		37.48	83.48	62.75	0.00	59.95	27.63	34.36
2040/41	2041	2041		37.82	85.15	63.81	0.00	61.62	28.35	35.08
2041/42	2042	2042		38.05	86.49	64.69	0.00	62.96	28.89	35.62
2042/43	2043	2043		38.34	87.54	65.42	0.00	64.01	29.27	36.00
2043/44	2044	2044		38.59	88.39	66.04	0.00	64.86	29.54	36.27
2044/45	2045	2045		38.88	89.09	66.58	0.00	65.56	29.72	36.45
2045/46	2046	2046		39.23	89.66	67.06	0.00	66.13	29.84	36.57
2046/47	2047	2047		39.58	90.17	67.50	0.00	66.64	29.91	36.64
2047/48	2048	2048		39.94	90.64	67.93	0.00	67.11	29.97	36.70
2048/49	2049	2049		40.29	91.09	68.35	0.00	67.56	30.00	36.73
2049/50	2050	2050		40.65	91.55	68.77	0.00	68.02	30.04	36.77

11.3 Appendix 3 – En-Route Users

- Demand and Supply Options Summary
- Deficit Summary
- Water Demand Projections

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Domestic Consumption

En-Route: Existing Demands

		Omaruru			Usakos			Total		
2017/18 Sales / Estimated Use (Mm^3/a)		0.48			0.22			**0.70**		
Growth & Development Scenarios		Low	Likely	High	Low	Likely	High	Low	Likely	High
Growth rate per scenario & period (% p.a.)	2018 - 2023	3.0%	3.5%	5.0%	3.0%	3.5%	6.5%			
	2023 - 2035	3.0%	3.5%	4.0%	2.0%	3.0%	6.0%			
	2035 - 2050	2.0%	2.5%	3.5%	1.0%	2.0%	4.0%			
Non-Revenue Water (%)	2018	50.0%	50.0%	50.0%	15.0%	15.0%	15.0%			
	2050	15.0%	20.0%	30.0%	10.0%	12.0%	14.5%			
Water Demands (Mm^3/a) for 2050		0.62	0.77	1.15	0.28	0.40	0.76	0.90	1.17	1.91
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	2050	10.0%	0.0%	0.0%	10.0%	0.0%	0.0%			
Water Supply Requirements (Mm^3/a) for 2050		0.56	0.77	1.15	0.26	0.40	0.76	0.81	1.17	1.91

Notes on water demand projections

Only AeGamms sales data available for Omaruru as it is not supplied by NamWater.

Moderate growth projected for the likely scenario (2001-2011 growth rate at 2.8%). The 2010 IWRM indicated high water losses and large reductions in inefficiencies were incorporated into the scenarios.

Consumption was estimated based on recommended per capita consumption per IWRM 2010 for Usakos as AeGamms data is considered inaccurate by NamWater.

Moderate growth projected for the likely scenario (2001-2011 growth rate at 2.0%) allowing for immediate development prospects that decreases over time.

En-Route and Development Corridor

All values in Mm3/a unless otherwise stated

Development Corridor

Assumed full development **2.50** **Mm3/a**

Demand Option	DC_1	DC_2	DC_3
	0%	50%	100%
Water Supply Requirements (Mm^3/a) for 2050	0.00	1.25	2.50

Pipeline Route Demands

Demand Option	PR_1	PR_2	PR_3
Water Supply Requirements	0.03	0.13	0.16

Development Corridor
Industrial and business development was accommodated as a "development corridor" that would follow the desalinated supply pipeline route. Such a proposal has been discussed on a conceptual level, though very little published information was available to the Consultant. A total demand of 2.5 Mm^3/a was estimated as a preliminiary upper limit. The options presented reprsent no such development (DC1), 50% of the total demand (DC2) and full development (DC3).

Pipeline Route Demands
Pipeline route demands were estimated based on supply for a 10km buffer area around the pipline around the area where livestock farming demands could be accommodated. A 120 km length was selected for a carrying capacity of 40 ha/LSU and a 50 litre/cap/day human demand for a Khomas rural population density (0.56 cap/km^2). The low scenario represents no such implementation, the likely the stated demand and high 1.25 times the likely demand.

Demand Options

Demand Options: Water Demands by 2050 (Mm^3/a)

Option				Demands (2050)				Commentary
No	Existing	Development Corridor	Pipeline Route	Domestic	Development Corridor	Pipeline Route	Total	
D1	D_{Low}	DC_1	PR_1	0.81	0.00	0.03	0.84	
D2	D_{Low}	DC_2	PR_1	0.81	1.25	0.03	2.09	
D3	D_{Low}	DC_3	PR_1	0.81	2.50	0.03	3.34	
D4	D_{Likely}	DC_1	PR_2	1.17	0.00	0.13	1.29	
D5	D_{Likely}	DC_2	PR_2	1.17	1.25	0.13	2.54	Consultant's recommended option
D6	D_{Likely}	DC_3	PR_2	1.17	2.50	0.13	3.79	
D7	D_{High}	DC_1	PR_3	1.91	0.00	0.16	2.07	
D8	D_{High}	DC_2	PR_3	1.91	1.25	0.16	3.32	
D9	D_{High}	DC_3	PR_3	1.91	2.50	0.16	4.57	

Water Supply Requirements (2050)

Domestic Demand		
D_{Low}	D_{Likely}	D_{High}
0.81	1.17	1.91

Development Corridor		
DC_1	DC_2	DC_3
0.00	1.25	2.50

Pipeline Route		
PR_1	PR_2	PR_3
0.13	0.13	0.16

Supply Options

All values in Mm3/a unless otherwise stated

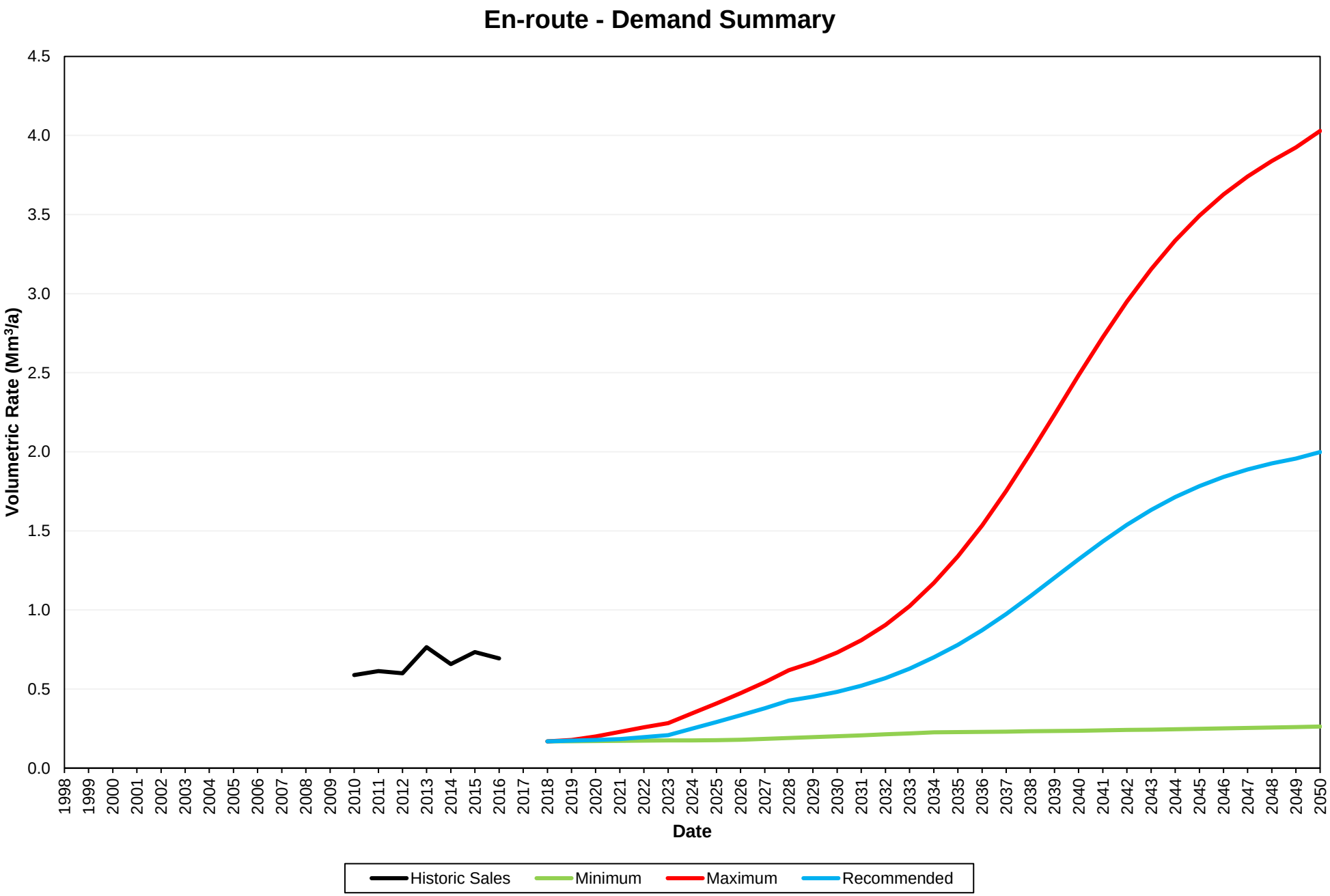
Resource	Estimated / Recommended	Comments
Omaruru Aquifer	0.5	Information regarding the Omaruru aquifer is extremely limited. It ws conservatively estimated that long term safe yield would be half of 1Mm^3/a, hence 0.5 Mm^3/a
Usakos Boreholes	0.05	Information regarding the Omaruru aquifer is extremely limited. It ws conservatively estimated that the supply from Usakos' own boreholes is 0.05 Mm^3/a
Total (S1)	**0.55**	

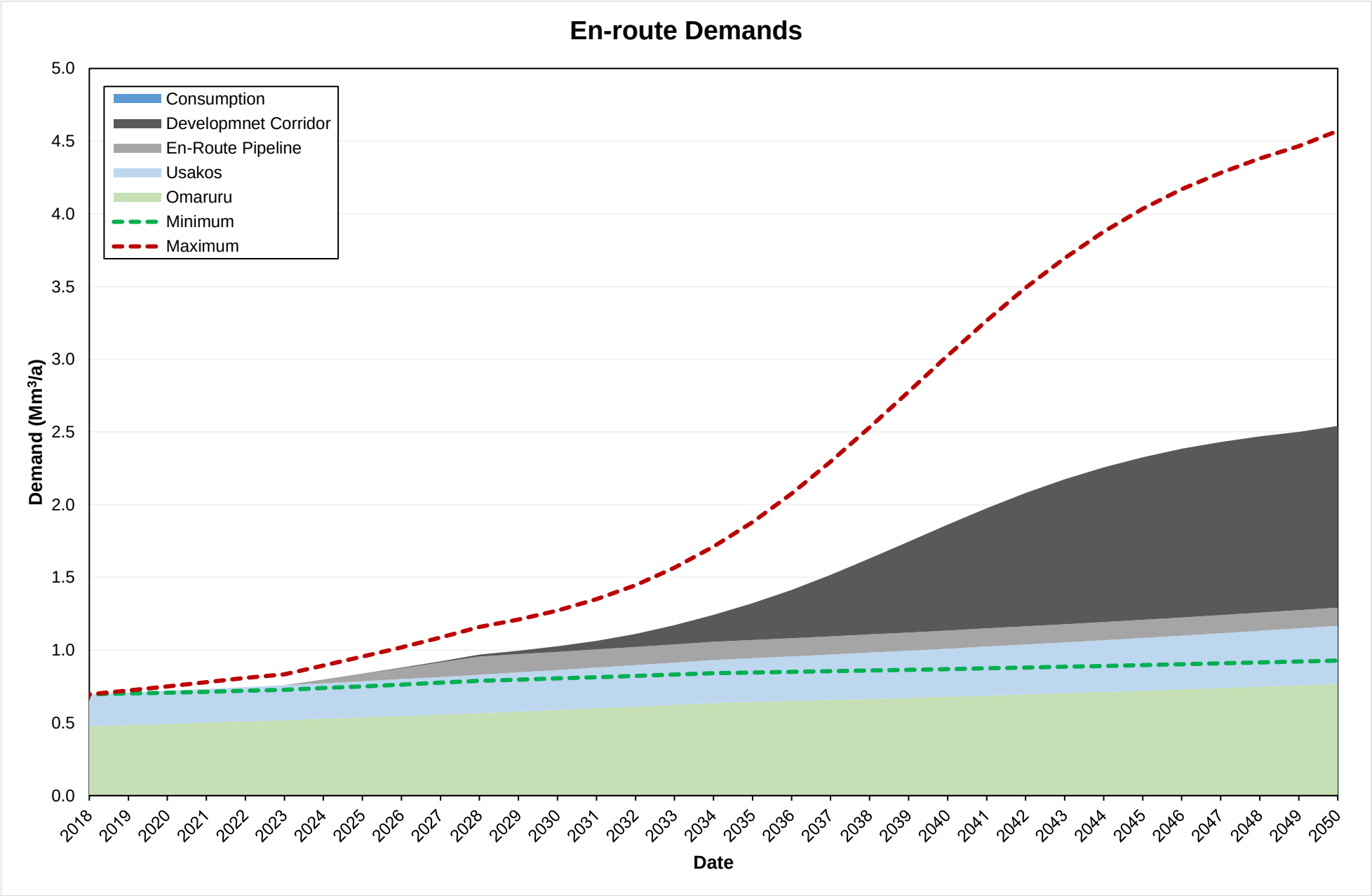
Overall Options

All values in Mm3/a unless otherwise stated. Figures represent 2050 projection estimates

Overall Options per supply and demand combinations

No	Overall Option No	Demand / Suypply Option					Overall Deficit			Comments
		Dem No	Domestic	Development Corridor	Pipeline Route	Supply	Demand	Supply	Deficit	
C1	C2	C3	C4	C5	C52	C6	C7	C8	C9	C10
1	O1	D1	D_{Low}	DC_1	PR_1	S1	0.84	0.55	0.29	Minimum
2	O2	D2	D_{Low}	DC_2	PR_1	S1	2.09	0.55	1.54	
3	O3	D3	D_{Low}	DC_3	PR_1	S1	3.34	0.55	2.79	
4	O4	D4	D_{Likely}	DC_1	PR_2	S1	1.29	0.55	0.74	
5	O5	D5	D_{Likely}	DC_2	PR_2	S1	2.54	0.55	1.99	Consultant's recommendation
6	O6	D6	D_{Likely}	DC_3	PR_2	S1	3.79	0.55	3.24	
7	O7	D7	D_{High}	DC_1	PR_3	S1	2.07	0.55	1.52	
8	O8	D8	D_{High}	DC_2	PR_3	S1	3.32	0.55	2.77	
9	O9	D9	D_{High}	DC_3	PR_3	S1	4.57	0.55	4.02	Maximum


En-route - Demand Summary
Volumetric Rate (Mm³/a)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Date
Historic Sales
Minimum
Maximum
Recommended


En-route Demands
Consumption
Developmnet Corridor
En-Route Pipeline
Usakos
Omaruru
Minimum
Maximum
Demand (Mm³/a)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2018
2019
2020
2021
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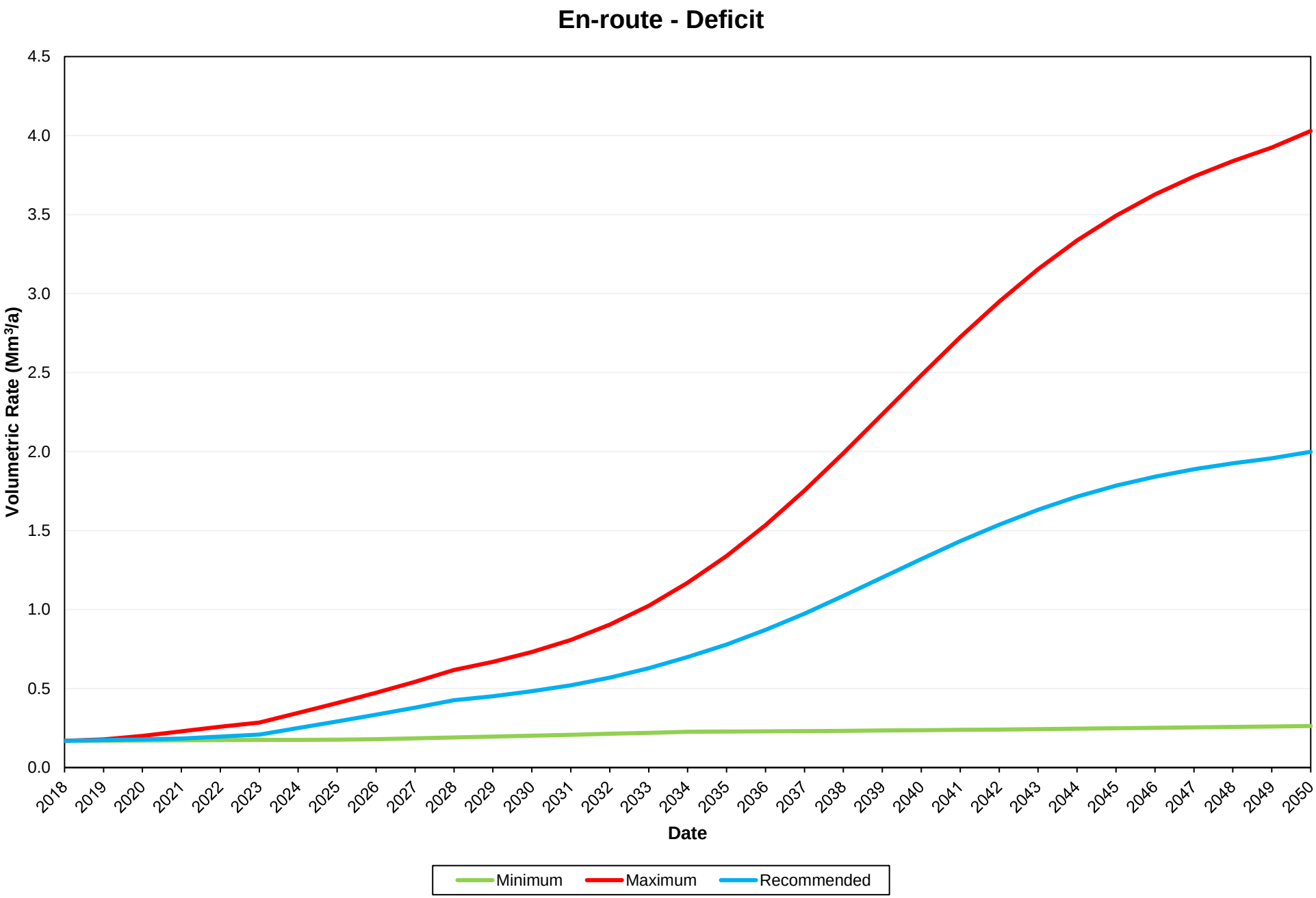
2049
2050
Date


En-route - Deficit
Volumetric Rate (Mm³/a)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2018
2019
2020
2021
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2034
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2036
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2042
2043
2044
2045
2046
2047
2048
2049
2050
Date
Minimum
Maximum
Recommended

All values in Mm3/a unless otherwise state

Year (Plot)	NY FY	Date Ref	Historic Sales	Demand			Deficit		
				Minimum	Maximum	Consultant's Recommendatio	Minimum	Maximum	Consultant's Recommendatio
				D1	D9	D5	O1	O9	O5
1997/98	1998	1998							
1998/99	1999	1999							
1999/00	2000	2000							
2000/01	2001	2001							
2001/02	2002	2002							
2002/03	2003	2003							
2003/04	2004	2004							
2004/05	2005	2005							
2005/06	**2006**	2006							
2006/07	2007	2007							
2007/08	2008	2008							
2008/09	2009	2009							
2009/10	2010	2010	0.59						
2010/11	2011	2011	0.61						
2011/12	2012	2012	0.60						
2012/13	2013	2013	0.76						
2013/14	2014	2014	0.66						
2014/15	2015	2015	0.73						
2015/16	2016	2016	0.69						
2016/17	2017	2017							
2017/18	2018	2018	0.60	0.17	0.17	0.17	0.17	0.17	0.17
2018/19	2019	2019		0.17	0.18	0.17	0.17	0.18	0.17
2019/20	2020	2020		0.17	0.20	0.18	0.17	0.20	0.18
2020/21	2021	2021		0.17	0.23	0.18	0.17	0.23	0.18
2021/22	2022	2022		0.17	0.26	0.20	0.17	0.26	0.20
2022/23	2023	2023		0.17	0.28	0.21	0.17	0.28	0.21
2023/24	2024	2024		0.18	0.35	0.25	0.18	0.35	0.25
2024/25	2025	2025		0.18	0.41	0.29	0.18	0.41	0.29
2025/26	2026	2026		0.18	0.47	0.33	0.18	0.47	0.33
2026/27	2027	2027		0.18	0.54	0.38	0.18	0.54	0.38
2027/28	2028	2028		0.19	0.62	0.43	0.19	0.62	0.43
2028/29	2029	2029		0.20	0.67	0.45	0.20	0.67	0.45
2029/30	2030	2030		0.20	0.73	0.48	0.20	0.73	0.48
2030/31	2031	2031		0.21	0.81	0.52	0.21	0.81	0.52
2031/32	2032	2032		0.21	0.90	0.57	0.21	0.90	0.57
2032/33	2033	2033		0.22	1.02	0.63	0.22	1.02	0.63
2033/34	2034	2034		0.23	1.17	0.70	0.23	1.17	0.70
2034/35	2035	2035		0.23	1.34	0.78	0.23	1.34	0.78
2035/36	2036	2036		0.23	1.53	0.87	0.23	1.53	0.87
2036/37	2037	2037		0.23	1.75	0.97	0.23	1.75	0.97
2037/38	2038	2038		0.23	1.99	1.09	0.23	1.99	1.09
2038/39	2039	2039		0.23	2.24	1.20	0.23	2.24	1.20
2039/40	2040	2040		0.24	2.48	1.32	0.24	2.48	1.32
2040/41	2041	2041		0.24	2.72	1.43	0.24	2.72	1.43
2041/42	2042	2042		0.24	2.95	1.54	0.24	2.95	1.54
2042/43	2043	2043		0.24	3.15	1.63	0.24	3.15	1.63
2043/44	2044	2044		0.25	3.34	1.71	0.25	3.34	1.71
2044/45	2045	2045		0.25	3.49	1.78	0.25	3.49	1.78
2045/46	2046	2046		0.25	3.63	1.84	0.25	3.63	1.84
2046/47	2047	2047		0.25	3.74	1.89	0.25	3.74	1.89
2047/48	2048	2048		0.26	3.84	1.93	0.26	3.84	1.93
2048/49	2049	2049		0.26	3.92	1.96	0.26	3.92	1.96
2049/50	2050	2050		0.26	4.03	2.00	0.26	4.03	2.00

11.4 Appendix 4 – Water Demands Assessment and Projections Approvals

- Attachment 4a

  Letter of Approval of Water Demands from the City of Windhoek

- Attachment 4b

  Minutes of Meeting Approving the Water Demand Projections of the Local Authorities in the Central Coastal Area (attached)

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OFFICE OF THE CHIEF EXECUTIVE

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Fax: (+264) 61 290 2615 Tel. (+264) 61 290 2344

ENQ: S Husselmann **PHONE:** 290-2345
DATE: 09 August 2019 **Ref: Feasibility Study**

Mr Abraham Nehemia
The Chief Executive Officer
Namibia Water Corporation
Private Bag 13389
Windhoek

Dear Mr Nehemia,

RE: BID REF: SC/OIB/NW-01/2018: FEASIBILITY STUDY (FS) FOR DESALINATION PLANT AND WATER CARRIAGE SYSTEM TO SECURE WATER SUPPLY TO CENTRAL COAST, WINDHOEK AND EN-ROUTE USERS – **REQUEST FOR WATER DEMANDS ASSESSMENT AND PROJECTIONS APPROVAL**

Your memorandum referenced *Desal /Water Demand Projections Approval 2019/07/04 25* and dated 09 July 2019 has reference.

In trying to seek clarifications and respond to the requested water demand projections of the City of Windhoek (CoW) our technical departments, through correspondences and two meetings, fruitfully engaged with the NamWater project team as well as the ILF Consulting Engineers and Lund Consulting Engineers who are carrying out the feasibility study project.

From these discussions the likely projected water demands for the CoW by 2050 is estimated at 60 Mm^3/annum, a figure which corresponds to approximately 3.3% water demand growth rate and it also correlates to the predicted population growth for Windhoek and neighboring developments.

It was difficult to ascertain this figure since one can never be sure given the 30-year horizon however, the following factors were taken into consideration:

1. Anticipated growth in population, rural to urban migration, expanded of the city boundaries, the slowdown of economy in the short term;
2. Historical water demand and related long-term growth of the city, anticipated water cost and associated tariffs, as well as the affordability of future water supplies;
3. The future planned growth of erven in the development areas (city growth points) such as Ongos, Monte Christo, BrakWater, Elisenheim etc.
4. Planned individualization of water and sanitation services to the informal settlements where such services are still communally shared.
5. Water demand projection figures presented by the Consultants and NamWater (refer to attached **Annexures 1 and 2,** the figures highlighted in yellow).

The Consultants and NamWater project team are free to work-out the projected water demands (low and high) from the likely figure of 60 Mm^3/a for the City of Windhoek over the given horizon of 30 years.

Should there be more questions, or a need for clarification of the projected water demand for Windhoek, kindly refer such to **Mr Ludwig Narib, Strategic Executive: Infrastructure, Water and Technical Services** and his team.

Yours sincerely

RN Kahimise
CHIEF EXECUTIVE OFFICER

Chief Accounting Officer in line with 27 (1) Local Authority Act 23 of 1992
13 AUG 2019
Box 59
Windhoek
Tel: 061 - 290 2615

MINUTES – CCA WATER DEMAND PROJECTIONS MEETING WITH THE COASTAL MUNICIPALITIES
24TH July 2019 at 09h30

Feasibility Study for "Desalination Plant and Water Carriage Plant and Water Carriage System to secure Water Supply to Central Coast, Windhoek and en-route Users"

Venue: **NamWater Swakopmund Board Room**

1. Attendance

Messrs	C Koegelenberg	NamWater
	E Shiluama	NamWater
	G Pazvakawambwa	NamWater (Chairperson)
	L Muhimba	NamWater
	G Hörlesberger	Consultant (ILF),
	C Mc Clune	Swakopmund Municipality (GM: Eng. Services)
	H Shikongo	Walvis Bay Municipality (Engineer)
	D Kambatuamasa	Henties Bay Municipality (Strategic Executive)
	S Norris	Arandis Town Council (CEO)

2. Apologies

John Esterhuizen

3. Welcome & Introductions

The Chief BU Namib, Mr C Koegelenberg welcomed those in attendance and requested the attendees to introduce themselves.

4. Discussion

The floor was then handed over to Dr Pazvakawambwa who give the background of the study and the project progress update, a word of appreciation was given to the Local Authorities that have assisted with providing requested Feasibility data by the Consultant.

Dr Pazvakawambwa indicated that the purpose of the meeting was to have the coastal Local authorities confirm the water demand projections for the coastal towns as provided in the **Feasibility Study for "Desalination Plant and Water Carriage System to Secure Water Supply to Central Coast, Windhoek and en-route Users"**. He presented the projected water demand as in **Annexure 1**.

In summary the discussions were noted as follows;

4.1. Larger Domestic Consumption

4.1.1. The tables summarising the current and projected Central Coastal domestic as well as mines water demands were discussed.

4.1.2. The assumed Non-Revenue water (losses) of 14% perceived to be lower than the reality on the ground.

Swakopmund – Indicated that they are currently in the process of determining their non-revenue water which are believed to be higher that 14%, therefore they can`t confirm the figure to be correct.

Henties Bay – indicated that their current non-revenue water (losses) is about 45 – 50% due aging infrastructures. It was also indicated that since the town is more of a holiday town the non-revenue figures were bound to fluctuate.

Walvis Bay – indicated that they are happy with the proposed figure of 14% for non-revenue water.

Arandis – indicated that their non-revenue figure is around 16%, however they are in the process of appointing a consultant to determine the actual figures.

4.1.3. In the absence of tangible facts, the figure of 14% for non-revenue water (losses) *would be acceptable* although each local authority would be required to work towards this bench mark figure. The gains that would accrue through the envisaged water demand measures would thus cushion any underestimated future water demands given the potential growth of these central coastal municipalities. However, FS report should indicate that the actual non-revenue water (%) for respective towns may have been under stated and in case of seeking funds to replace the dilapidated water networks this FS should not give the contrary.

4.1.4. Although the technology and use of water reclamation was still lagging with most of the local municipalities save for Walvis Bay and Swakopmund, the presented proposed water reuse figures were agreed. Water reuse would be the way forward in the future because it's cheaper than desalinated water.

- Swakopmund and Walvis Bay Municipalities indicated that they are already reusing water for irrigation purpose.
- Arandis Town Council indicated that they do not have infrastructure for water reuse.

4.1.5. It was questioned why Henties Bay water reuse (%) was lower than the other towns even lower than Arandis Town Council?

It was indicated that since Henties Bay Municipality water demand are usually fluctuating with higher peaks during holidays and lower during non-holiday periods, this results in lower continuous flow averages.

4.1.6. The impact of water reuse on the size of the desalination plant was questioned?

It was indicated that the impact may be significant and if not implemented in full, this could be attenuated by the envisaged improvements of the water demand management measures. The impact of water reuse supported by the figures provided; where with reclamation the total central coastal domestic water requirement will be 27.14Mm^3/a while without the reclamation it will be 32.14Mm^3/a, difference of 5Mm^3/a.

4.2. Small Domestic Users

4.2.1. It was noted that currently Rooibank and Mile 7 water supply areas customers are supplied direct from NamWater and not from Walvis Bay but with the future plans to develop plot 55 they would be handed over the Walvis Bay Municipality.

4.2.2. The water demand projections for future development for the high likely growing peri-urban domestic users for both Walvis Bay and Swakopmund are reflected in the jump from the current total water demand of 0.89Mm^3/a to 3.06Mm^3/a.

4.3. Mining

4.3.1. **Langer Heinrich:** The NamWater Chief BU Coastal indicated that there are signs that this mine could be resuscitated in 2021 from its present care and maintenance state. It was indicated that the pipeline infrastructure design capacity is 1.79Mm^3/a, however to meet a requested water demand of 2.8Mm^3/a in the past this not only required additional pump stations but the operational costs were deemed uneconomical. Thus, the potential of the existing pipeline infrastructure would have a threshold of 2.8Mm^3/a although high unlikely to be operated at this capacity. However, this figure was adopted to be used for the feasibility study.

4.3.2. **Rossing Uranium;** The NamWater Chief BU Coastal indicated that the system was designed with a capacity flow of 12Mm^3/a and thus Rossing has been operating this scheme with a reserve capacity for ±8Mm^3/a. In the absence of firmed figures from Rossing whose mine is currently on sale, Mr C Koegelenberg further indicated that the proposed threshold future water requirement of 5Mm^3/a was satisfactory to him used in the FS.

4.3.3. **Swakop Uranium / Husab:** The figure of 10.2Mm^3/a provided by the mine (see Consultants minutes with this mine personnel) was adopted.

4.3.4. **Potential New Mines;** The figure of 8.61Mm^3/a as calculated and presented by the Consultants was also agreed upon.

4.3.5. **Trekkopje;** In the event that the mine is resuscitated the future water requirement of 20Mm^3/a was agreed on

4.4. Different Mines Demand Options and Scenarios

4.4.1. The different demand scenarios were highlighted as provided for in the Consultants draft Water Demand and Supply report e.g. M_1, M_2...M_5, , However, the total projected water demand of existing mines (100%) of 21.01Mm^3/a was revised as this was incorrect. The corrected figure was i.e. 2.8 +10.20 + 5 =18 Mm^3/a and this figure is what was adopted.

4.5. Supply Options

4.5.1. The abstraction permits for the Kuiseb and Omdel Aquifer was explained as provided in the report.

4.6. Graphs

4.6.1. The different graphs were explained

5. AOB

5.1. The Orano Plant sulphur problem was highlighted to be a concern.

5.2. Appointment of Transactional Advisor on the purchase / long term agreement of the Orano Plant desalinated water is in progress.

5.3. It was requested that the proposed pipeline routes be communicated to the local authorities and vis a-vis the current developmental town plans be shared with the Consultants of the FS to allow provisional servitude in these town planning. Mr G Hörlesberger indicated that access to information on the Swakopmund Town master plans being developed by SPC town planners (in particular Mr. G Stubenrauch) was difficult. Mr C Mc Clune promised to help in this regard.

6. Closing Remarks

6.1. The local authorities expressed the need to be assisted in curbing the water loses in their areas.

6.2. It was proposed to have similar meeting regularly (every second month) with the local authority's technical teams.

6.3. The two tier approach on the approval of deliverables was recommended. First tier being the project team and the second level of approval being the wider key stakeholders of the FS.

7. Closure

The chairman concluded and adjourned the meeting at 11h15.

14. ACCEPTANCE OF MEETING RECORDS

Minutes signed as being correct;

G Pazvakawambwa
Project Manager (NamWater being the Employer)

01/08/2019

Date

G Hörlesberger
Project Manager (ILF Consulting Engineers)

01.08.2019

Date

Domestic Consumption

Large Domestic Users

		Walvis Bay			Swakopmund			Henties Bay			Arandis			Subtotal: Large Domestic		
2017/18 NamWater Sales (Mm^3/a)		6.66			4.44			0.53			0.34			11.98		
Growth & Development Scenarios		Low	Likely		Low	Likely		Low	Likely		Low	Likely		Low	Likely	
Growth rate per scenario & period (% p.a.)	2018 - 2023	4.0%	5.0%	6.5%	4.0%	6.0%	6.5%	2.5%	3.0%	4.0%	2.0%	3.0%	3.5%			
	2023 - 2035	3.5%	4.5%	5.0%	3.5%	4.0%	6.0%	2.0%	2.5%	3.5%	1.5%	2.5%	3.0%			
	2035 - 2050	2.0%	3.0%	4.5%	2.0%	3.0%	4.0%	1.5%	2.0%	3.0%	1.0%	2.0%	2.5%			
Non-Revenue Water (%)	2018	14.5%	14.5%	14.5%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%			
	2050	5.0%	12.0%	14.5%	10.0%	12.0%	14.5%	10.0%	12.0%	15.0%	10.0%	12.0%	14.5%			
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	2050	30.0%	20.0%	5.0%	15.0%	10.0%	5.0%				15.0%	10.0%	5.0%			
Water Supply Requirements (Mm^3/a) for 2050		14.55	21.41	31.13	10.18	13.91	21.41	0.89	1.06	1.50	0.49	0.69	0.83	26.11	37.07	54.86

Small Domestic Users

		Rooibank / Mile 7 (excl. Walvis Bay)			Swakopmund Terminal Reservoir (excl. Swakopmund)			Swakopmund Rössing (excl. Arandis and Mines)			Omdel - Swakopmund			Swartbank - Schwarzekuppe			Subtotal: Small Domestic		
2017/18 NamWater Sales (Mm^3/a)		0.11			0.01			0.37			0.12			0.28			0.89		
Growth & Development Scenarios		Low	Likely		Low	Likely		Low	Likely		Low	Likely		Low	Likely		Low	Likely	
Growth rate per scenario & period (% p.a.)	2018 - 2023	4.0%	5.5%	6.5%	4.0%	6.5%	7.0%	4.0%	5.0%	6.5%	3.0%	5.0%	6.0%	2.0%	3.0%	4.0%			
	2023 - 2035	3.5%	5.0%	6.0%	3.5%	6.0%	6.5%	3.5%	4.5%	6.0%	2.5%	4.0%	5.5%	2.0%	3.0%	3.5%			
	2035 - 2050	2.0%	4.5%	6.0%	2.0%	3.0%	4.0%	2.0%	4.5%	6.0%	2.0%	2.5%	4.0%	1.5%	2.5%	3.0%			
Non-Revenue Water (%)	2018	16.0%	16.0%	16.0%	16.0%	16.0%	16.0%	10.0%	10.0%	10.0%	16.0%	16.0%	16.0%	20.0%	20.0%	20.0%			
	2050	10.0%	15.0%	16.0%	10.0%	15.0%	16.0%	5.0%	10.0%	10.0%	10.0%	15.0%	16.0%	10.0%	15.0%	16.0%			
Water Reuse (%)	2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	2050	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Water Supply Requirements		0.25	0.49	0.73	0.03	0.05	0.06	0.86	1.56	2.46	0.23	0.34	0.53	0.43	0.62	0.75	1.79	3.06	4.53

Total: Domestic

	Large Users			Small Users			Total Domestic		
	Low	Likely		Low	Likely		Low	Likely	
2017/18 NamWater Sales (Mm^3/a)	11.98			0.89			12.87		
Water Supply Requirements (Mm^3/a) for 2050	26.11	37.07	54.86	1.79	3.06	4.53	27.90	40.13	59.39

Mining

	Langer Heinrich Uranium Ltd	Rössing Uranium Ltd	Swakop Uranium / Husab	Potential New Mines	Total
2017/18 NamWater Sales (Mm^3/a)	1.79	2.90	5.94	0.00	10.63
Water Supply Requirements (Mm^3/a) for 2050	2.80	8.00	10.20	8.61	29.62

	Trekkopje
2017/18 Supply (Mm^3/a)	0.00
Water Supply Requirements (Mm^3/a) for 2050*	20.00

*Full expected demand as per original design of Orano desal plant

Scenarios for the iclusion of mining water demands

Demand Option	M_1	M_2	M_3	M_4	M_5
Water Supply Requirements (Mm^3/a) for 2050 per scenario	No mining demand included	75% of demand for existing mines	100% of demand for existing mines	100% of demand for existing & new mines	100% of demand for existing & new mines and Trekkopje
	0.00	15.76	21.01	29.62	49.62

Demand Options

Demand Options: Supply Requirements by 2050 (Mm^3/a)

Option			WSR (2050)		
No	Domestic	Mining	Domestic	Mining	Total
D1	D_{Low}	M_1	27.90	0.00	27.90
D2	D_{Low}	M_2	27.90	15.76	43.66
D3	D_{Low}	M_3	27.90	21.01	48.91
D4	D_{Low}	M_4	27.90	29.62	57.52
D5	D_{Low}	M_5	27.90	49.62	77.52
D6	D_{Likely}	M_1	40.13	0.00	40.13
D7	D_{Likely}	M_2	40.13	15.76	55.89
D8	D_{Likely}	M_3	40.13	21.01	61.14
D9	D_{Likely}	M_4	40.13	29.62	69.75
D10	D_{Likely}	M_5	40.13	49.62	89.75
D11	D_{High}	M_1	59.39	0.00	59.39
D12	D_{High}	M_2	59.39	15.76	75.14
D13	D_{High}	M_3	59.39	21.01	80.40
D14	D_{High}	M_4	59.39	29.62	89.01
D15	D_{High}	M_5	59.39	49.62	109.01

Water Supply Requirements (2050)

Domestic Demand		
D_{Low}	D_{Likely}	D_{High}
27.90	40.13	59.39

Mining				
M_1	M_2	M_3	M_4	M_5
0.00	15.76	21.01	29.62	49.62

Supply Options

Options for the Utilisation of Groundwater Supply (Omdel & Kuiseb Aquifers) in the Central Coastal Area

Resource	Available Capacity			Source Options 1: Lower utilisation of groundwater sources to allow for uncertainty and the recovery of water levels			Source Option 2: Allow utilisation of groundwater sources in accordance with safe yield and permit values	
				Capacity (Mm^3/a)		Comment		
	Capacity (Mm^3/a)	Description	Reference	Option 1a: Rapid Assessment[2]	Option 1b: Consultant Proposal[3]		Capacity (Mm^3/a)	Comment
Omdel Aquifer	**4.6**	Permit-approved abstraction for 2018. Also, safe yields given for 2015 onwards.	MAWF permit, dated January 2018	**2.7**	**2.3**	Reduced yields (conservative) for higher security of supply (reduced variability) and to allow the recovery of water levels for emergency availability in future, if required.	**4.6**	Allow utilisation of groundwater sources according to the safe yield values determined by NamWater and others, and according to the permit-approved values per MAWF. NamWater have applied for increased abstraction from the Kuiseb Aquifer, from 7.4 Mm^3/a to 11.4 Mm^3/a. Confirmation / permit approval is pending
Kuiseb Aquifer	**7.0**	Permit-approved abstraction from 2015 onwards	MAWF permits	**5.0**	**5.7**		**7.4 or 11.4**	
	7.4	Safe yield given for 2015 onwards.						
				7.7	**8.0**		**12.0**	
							16.0	

Volumes of Supply from Desalinated Water in the CCA = Future Supply Requirements - Groundwater Supply Volumes

For the Volumes of Desalinated Water Supply:	**Capacity (Mm^3/a)**	
Orano Existing	20	Utilise the existing Orano Plant at capacity, OR new separate plant utilising the same intake & discharge infrastructure
Orano Existing + Expand	40	
All New	TBC	

Summary	Capacity
S_1	8.0
S_2	16.0

Overall Options

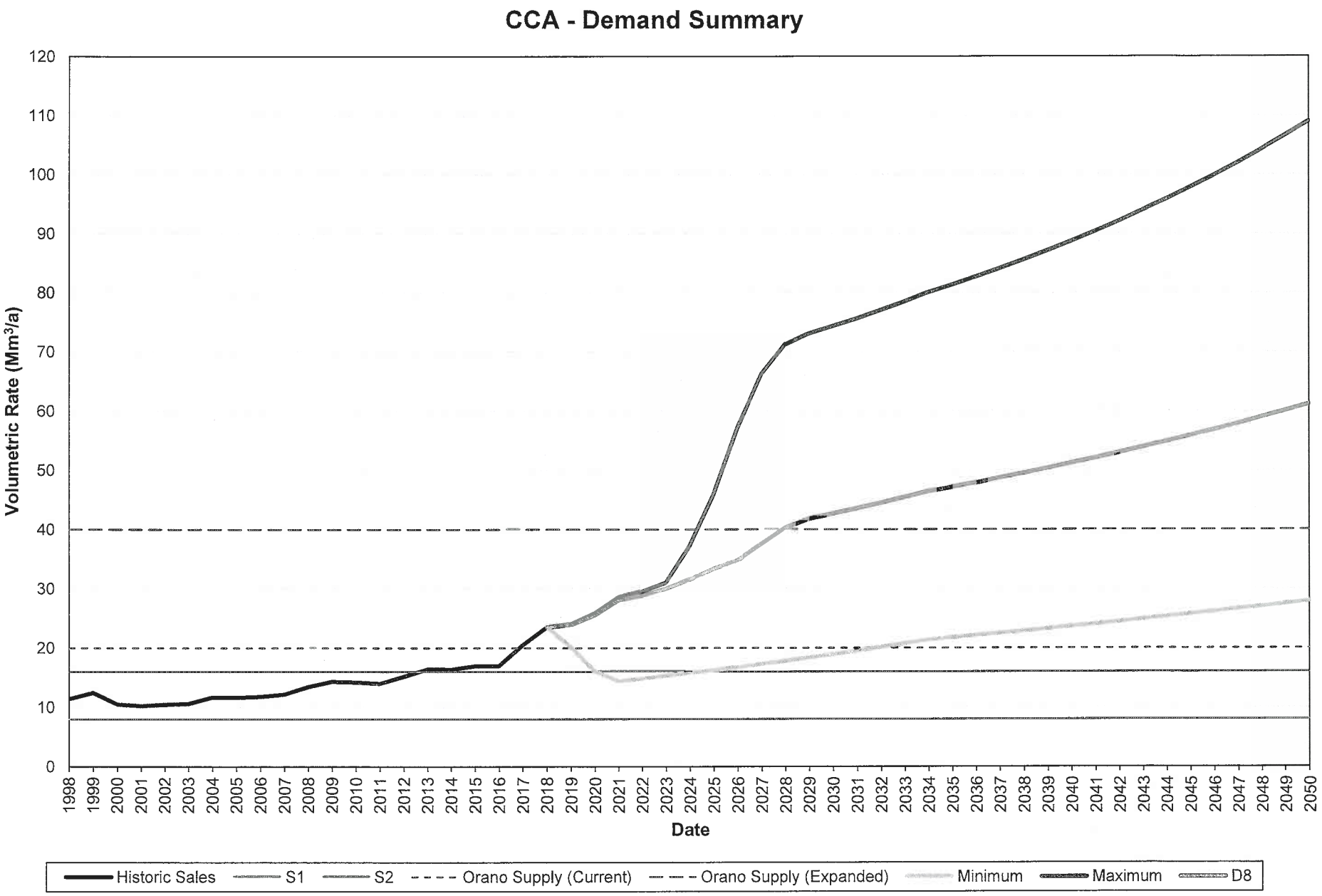
Overall Options: Values in Mm^3/a

Overall Option	Demand / Suypply Option				Overall Deficit		
	Dem No	Domestic	Mining	Supply	Demand	Supply	Deficit
O1	D1	D_{Low}	M_1	S_1	28	8	20
O2	D2	D_{Low}	M_2	S_1	44	8	36
O3	D3	D_{Low}	M_3	S_1	49	8	41
O4	D4	D_{Low}	M_4	S_1	58	8	50
O5	D5	D_{Low}	M_5	S_1	78	8	70
O6	D6	D_{Likely}	M_1	S_1	40	8	32
O7	D7	D_{Likely}	M_2	S_1	56	8	48
O8	D8	D_{Likely}	M_3	S_1	61	8	53
O9	D9	D_{Likely}	M_4	S_1	70	8	62
O10	D10	D_{Likely}	M_5	S_1	90	8	82
O11	D11	D_{High}	M_1	S_1	59	8	51
O12	D12	D_{High}	M_2	S_1	75	8	67
O13	D13	D_{High}	M_3	S_1	80	8	72
O14	D14	D_{High}	M_4	S_1	89	8	81
O15	D15	D_{High}	M_5	S_1	109	8	101
O16	D1	D_{Low}	M_1	S_2	28	16	12
O17	D2	D_{Low}	M_2	S_2	44	16	28
O18	D3	D_{Low}	M_3	S_2	49	16	33
O19	D4	D_{Low}	M_4	S_2	58	16	42
O20	D5	D_{Low}	M_5	S_2	78	16	62
O21	D6	D_{Likely}	M_1	S_2	40	16	24
O22	D7	D_{Likely}	M_2	S_2	56	16	40
O23	D8	D_{Likely}	M_3	S_2	61	16	45
O24	D9	D_{Likely}	M_4	S_2	70	16	54
O25	D10	D_{Likely}	M_5	S_2	90	16	74
O26	D11	D_{High}	M_1	S_2	59	16	43
O27	D12	D_{High}	M_2	S_2	75	16	59
O28	D13	D_{High}	M_3	S_2	80	16	64
O29	D14	D_{High}	M_4	S_2	89	16	73
O30	D15	D_{High}	M_5	S_2	109	16	93

CCA Demand and Supply Options Summary

All values in Mm3/a unless otherwise stated

Year (Plot)	NY FY	Date Ref	Historic Sales	Supply				Demand			Deficit			
								Minimum	Maximum	Selected Option	Minimum	Maximum	Selected Options	
				S1	S2	Orano	Orano Expand	D1	D15	D8	O16	O15	O8	O23
1997/98	1998	1998	11.38	8.00	16.00	20.00	40.00							
1998/99	1999	1999	12.45	8.00	16.00	20.00	40.00							
1999/00	2000	2000	10.52	8.00	16.00	20.00	40.00							
2000/01	2001	2001	10.21	8.00	16.00	20.00	40.00							
2001/02	2002	2002	10.48	8.00	16.00	20.00	40.00							
2002/03	2003	2003	10.63	8.00	16.00	20.00	40.00							
2003/04	2004	2004	11.70	8.00	16.00	20.00	40.00							
2004/05	2005	2005	11.66	8.00	16.00	20.00	40.00							
2005/06	**2006**	2006	11.80	8.00	16.00	20.00	40.00							
2006/07	2007	2007	12.20	8.00	16.00	20.00	40.00							
2007/08	2008	2008	13.47	8.00	16.00	20.00	40.00							
2008/09	2009	2009	14.32	8.00	16.00	20.00	40.00							
2009/10	2010	2010	14.23	8.00	16.00	20.00	40.00							
2010/11	2011	2011	14.00	8.00	16.00	20.00	40.00							
2011/12	2012	2012	15.17	8.00	16.00	20.00	40.00							
2012/13	2013	2013	16.43	8.00	16.00	20.00	40.00							
2013/14	2014	2014	16.35	8.00	16.00	20.00	40.00							
2014/15	2015	2015	16.94	8.00	16.00	20.00	40.00							
2015/16	2016	2016	16.97	8.00	16.00	20.00	40.00							
2016/17	2017	2017	20.48	8.00	16.00	20.00	40.00							
2017/18	2018	2018	23.50	8.00	16.00	20.00	40.00	23.50	23.50	23.50		16.40	8.40	16.40
2018/19	2019	2019		8.00	16.00	20.00	40.00	20.00	23.98	23.83		16.88	8.68	16.68
2019/20	2020	2020		8.00	16.00	20.00	40.00	16.00	25.84	25.52		18.79	10.36	18.36
2020/21	2021	2021		8.00	16.00	20.00	40.00	14.29	28.55	28.04		21.58	12.91	20.91
2021/22	2022	2022		8.00	16.00	20.00	40.00	14.80	29.52	28.80		22.55	13.61	21.61
2022/23	2023	2023		8.00	16.00	20.00	40.00	15.25	31.03	30.05		24.10	14.82	22.82
2023/24	2024	2024		8.00	16.00	20.00	40.00	15.72	37.28	31.55	0.14	30.47	16.28	24.28
2024/25	2025	2025		8.00	16.00	20.00	40.00	16.20	45.81	33.35	0.53	39.18	18.05	26.05
2025/26	2026	2026		8.00	16.00	20.00	40.00	16.70	57.09	34.76	0.92	50.59	19.40	27.40
2026/27	2027	2027		8.00	16.00	20.00	40.00	17.22	66.18	37.53	1.35	59.75	22.16	30.16
2027/28	2028	2028		8.00	16.00	20.00	40.00	17.75	71.22	40.23	1.77	64.86	24.85	32.85
2028/29	2029	2029		8.00	16.00	20.00	40.00	18.30	73.10	41.76	2.19	66.76	26.29	34.29
2029/30	2030	2030		8.00	16.00	20.00	40.00	18.87	74.35	42.60	2.60	68.00	27.02	35.02
2030/31	2031	2031		8.00	16.00	20.00	40.00	19.45	75.65	43.49	3.02	69.29	27.78	35.78
2031/32	2032	2032		8.00	16.00	20.00	40.00	20.05	77.03	44.41	3.45	70.66	28.57	36.57
2032/33	2033	2033		8.00	16.00	20.00	40.00	20.67	78.48	45.37	3.89	72.09	29.39	37.39
2033/34	2034	2034		8.00	16.00	20.00	40.00	21.32	80.01	46.37	4.33	73.60	30.23	38.23
2034/35	2035	2035		8.00	16.00	20.00	40.00	21.68	81.31	47.10	4.51	74.87	30.82	38.82
2035/36	2036	2036		8.00	16.00	20.00	40.00	22.04	82.65	47.86	4.70	76.19	31.42	39.42
2036/37	2037	2037		8.00	16.00	20.00	40.00	22.41	84.06	48.64	4.88	77.56	32.03	40.03
2037/38	2038	2038		8.00	16.00	20.00	40.00	22.79	85.53	49.44	5.06	78.99	32.66	40.66
2038/39	2039	2039		8.00	16.00	20.00	40.00	23.18	87.06	50.26	5.24	80.48	33.30	41.30
2039/40	2040	2040		8.00	16.00	20.00	40.00	23.57	88.66	51.11	5.43	82.03	33.96	41.96
2040/41	2041	2041		8.00	16.00	20.00	40.00	23.97	90.33	51.99	5.61	83.65	34.63	42.63
2041/42	2042	2042		8.00	16.00	20.00	40.00	24.38	92.06	52.89	5.80	85.34	35.32	43.32
2042/43	2043	2043		8.00	16.00	20.00	40.00	24.79	93.88	53.82	5.98	87.10	36.03	44.03
2043/44	2044	2044		8.00	16.00	20.00	40.00	25.21	95.77	54.78	6.17	88.93	36.75	44.75
2044/45	2045	2045		8.00	16.00	20.00	40.00	25.64	97.75	55.76	6.35	90.83	37.49	45.49
2045/46	2046	2046		8.00	16.00	20.00	40.00	26.08	99.81	56.77	6.54	92.82	38.25	46.25
2046/47	2047	2047		8.00	16.00	20.00	40.00	26.52	101.97	57.82	6.73	94.89	39.03	47.03
2047/48	2048	2048		8.00	16.00	20.00	40.00	26.97	104.21	58.89	6.91	97.05	39.82	47.82
2048/49	2049	2049		8.00	16.00	20.00	40.00	27.43	106.56	60.00	7.10	99.30	40.63	48.63
2049/50	2050	2050		8.00	16.00	20.00	40.00	27.90	109.01	61.14	7.29	101.65	41.47	49.47


CCA - Demand Summary
Volumetric Rate (Mm³/a)
0
10
20
30
40
50
60
70
80
90
100
110
120
1998
1999
2000
2001
2002
2003
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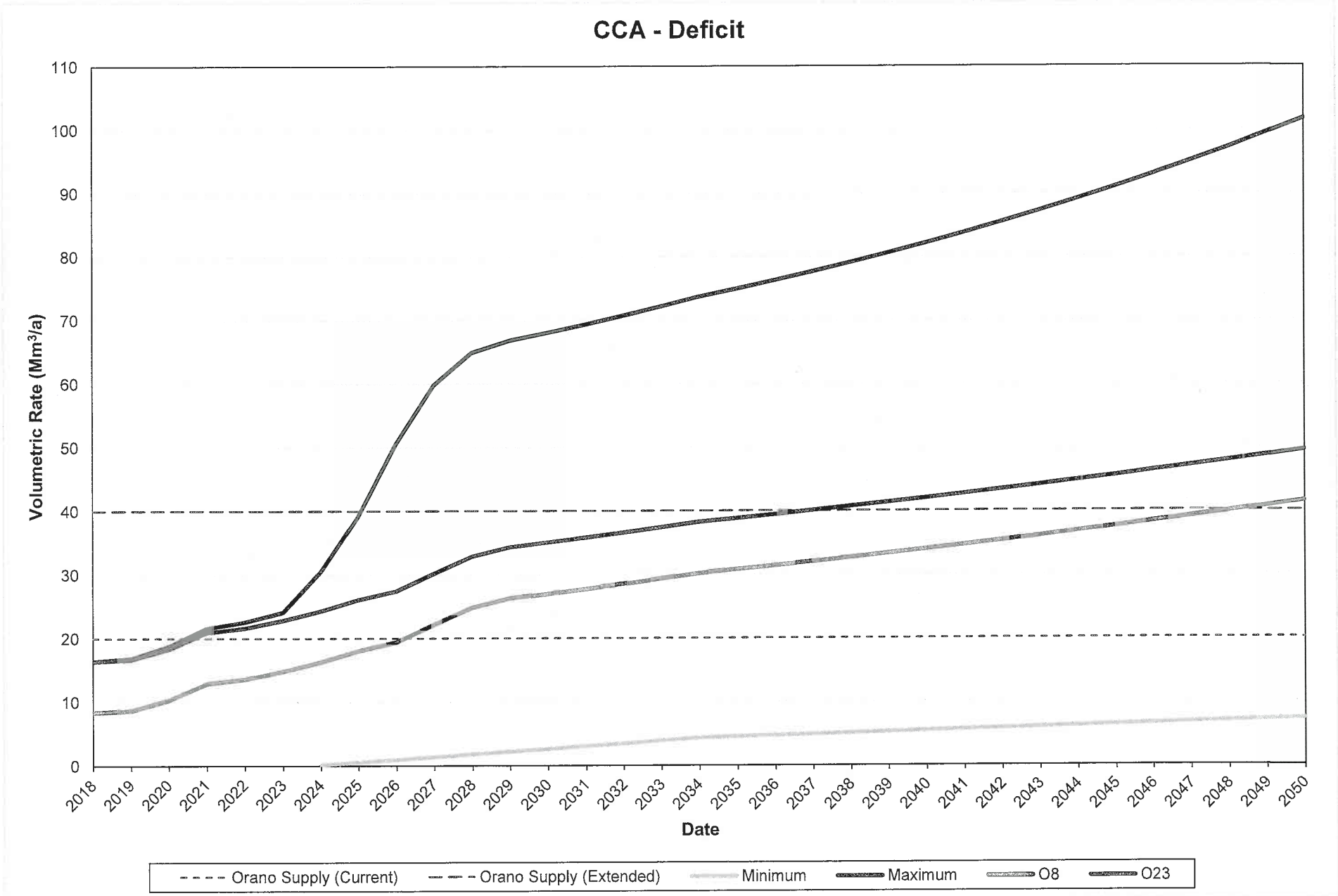
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
Date
Historic Sales
S1
S2
Orano Supply (Current)
Orano Supply (Expanded)
Minimum
Maximum
D8


CCA - Deficit
Volumetric Rate (Mm³/a)
110
100
90
80
70
60
50
40
30
20
10
0
2018
2019
2020
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2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
Date
Orano Supply (Current)
Orano Supply (Extended)
Minimum
Maximum
O8
O23

11.5 Appendix 5 – Comment Resolution Sheets

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Comment Resolution Sheet

Project :	Feasibility Study for Desalination Plant and Water Carriage System to secure Water Supply to Central Coast, Windhoek and en-route Users
Project No. :	SC/OIB/NW-01/2018 (NamWater) O992 (Consultant)
Project Client :	NamWater
Consultant :	ILF Consulting Engineers

Document Ref.	Rev No.	Rev Date	Document Subject
O992-ILF-OD-0012/REV. 4	4	19/03/2021	FS Chapter - Water Resources and Water Demand Projections: Rev. 4.
O992-ILF-OD-0012/REV. 3	3	23/11/2020	FS Chapter - Water Resources and Water Demand Projections: Rev. 3: Concept Workshop Comments included.
O992-ILF-OD-0012/REV. 2	2	08/11/2019	FS Chapter - Water Resources and Water Demand Projections: Rev. 2: Incl. Additional NamWater comments
O992-ILF-OD-0012/REV. 1	1	24/10/2019	FS Chapter - Water Resources and Water Demand Projections: Rev. 1: Incl. NamWater comments
O992-ILF-OD-0012/REV. 0	0	30/08/2019	FS Chapter - Water Resources and Water Demand Projections: First Submission

Comment Sheet Ref: O992_CS_FS_Chapter_WaterDemand_Rev0.xlsx

No.	NamWater / KfW Comments	Comment Incorporated	Consultant Clarification	Remarks
1	Recent water supply schemes and investments;	Yes; Rev. 1	Section 1.3.3 was added on recent water supply schemes and investments.	by HB
2	Informal settlements and affordability	Yes; Rev. 1	Section 2.2.5 was added on informal settlements and affordability.	by HB
3	Gini coefficients / inequality aspects.	Yes; Rev. 1	Section 2.2.11 was added on the Gini coefficients / inequality aspects.	by HB

4	Various spelling and formatting errors	Yes; Rev. 1	Those requested by NamWater and a few more detected were corrected.	by HB
5	Section 4.2: Affordability of Water, Perceptions of Cost and Other Considerations especially Paragrapgh 4.2.2, Affordability Estimates and concluding - this Section should be conclusively qualified when there is due consideration of the Gini Coefficient that speaks not only to the disparity in incomes but almost a considerable number of people in the informal settlements of the study area not having any meaningful income.	Yes; Rev. 1	Section 4.2.2 was updated in line with the addition of the section on the Gini coefficent and affordability considerations; specifically a paragraph below Table 4.3 on page 133 as added.	by HB
6		Yes; Rev. 1	Some additional clarifications and edits made by the Consultant.	by HB
7	Include CoW Approval of Water Demands Assessment letter.	Yes; Rev. 2	Appendix 4: CoW (letter) and CCA (Minutes) Approval of Water Demands Assessment added.	by SR
8	Include the Comment Resolution Sheet in an appendix.	Yes; Rev. 2	Appendix 5: Comment Resolution Sheet added.	by SR

Comments Received from KfW via NamWater on 04 February 2020

No.	NamWater / KfW Comments	Comment Incorporated	Consultant Clarification	Remarks
21a	Detailed analysis of the performance of the local authorities regarding tariff structures, billing / collection / revenues, operation cost structures, organisational set-up and operation efficiency (refer to 4.15). Furthermore, recommendations for optimising operation processes and minimising losses with the ultimate goal of reducing costs for the operation of the existing water supply distribution systems in the project towns.		This information / data was requested from the various local authorities several times but unfortunately not received. Kindly also refer to Item 29 of the Clarification Note No. 1 of 23 February 2018, which states that this information will be provided to the Consultant by NamWater / EWF. The Consultant has used the time budgeted for this component of the study. This matter cannot be left "open" indefinitely, as the Consultant's proposal was based on submitting this chapter / report within 3 months of project commencement. Further liaison with the local authorities to obtain the data requested already several times and the inclusion of the analyses on any data received can be undertaken against additional time and costs.	

21b	Analysis of the bulk water transfer systems operated by NamWater regarding operation, energy, repair and maintenance costs, revenues, management and organisational set-up, etc. and a gap analysis of the current effectiveness of operation with the available human and financial resources, as well as the physical condition and supply capacities of the existing systems (refer to 4.17)		In terms of the physical condition and supply capacities of the existing systems (refer to 4.17 of the ToR); kindly refer to Item 36 of the Clarification Note No. 1 of 23 February 2018, which states that this information will be provided by NamWater. This information was unfortunately not received. The Consultant included the infrastructure capacities for the CCA in Figure 5.2 and for the CAN in Figure 6.2. The Consultant has used the time budgeted for this component of the study. This matter cannot be left "open" indefinately, as the Consultant's proposal was based on submitting this chapter / report within 3 months of project commencement. Further liaison with NamWater to obtain the data requested and the inclusion of the analyses on any data received can be undertaken against additional time and costs.	
22	Abbreviations – Kindly replace “Kreditanstalt für Wiederaufbau” by “KfW Development Bank”	Yes; Rev. 3	Done.	by HB
23	Item 1.1 to 1.2.1 etc - These chapters appear in several chapters and reports. Please avoid duplication and only list in one adequate chapter.		Introductory chapters are considered for each Chapter.	
24	page 81/82, figure 2.14/2.15 – Kindly provide the amounts/thresholds of household income (N$) for “poor” and “severely poor”	Yes; Rev. 3	Table 2.7 added with the requested values.	by HB
25	page 86, 2.12.1 - It is not sufficient to say that other aspects, like household expenditure, gender aspects are not available from formal statistics. Please ask the Consultant to search for other sources of information.		Kindly refer to Item 34 of the Clarification Note No. 1 of 23 February 2018, which states that the Consultant shall extract data from the Census 2011 documents, per Annex 1 of the ToR. The Consultant has gone very far beyond this requirement and these documents; sourcing data from a much larger number of reports and other sources. The requested data is not readily available, as stated. The Consultant can search for other sources of information against additional time and costs.	
26	page 94, 3 - Have the mentioned ministries been contacted and listed as key stakeholders?	Yes.	The Ministries of Agriculture, Water and Forestry, Environment and Tourism and Finance have been contacted and all attended the Concept Workshop of 29 & 30 January 2020. The MAWF have been involved from the outset and also attended the first workshop of 07 May 2019.	

27	page 99, 3.2.2.1 – What is the position of NamWater and/or MAWF regarding the Water Resource Management Act 11 of 2013?		The MAWF has been working on the Regulation of the Water Resource Management Act 11 of 2013 together with the Ministry of Justice Legal drafters, required for the Act to commence. The process is at an advanced stage and the Regulations are with MoJ. They need to finalise and return to MAWF so the Minister can take the process forward.	
28	page 100, 3.2.2.3 – It remains unclear whether the water regulator determines already today the tariffs, targets etc. Kindly ask the Consultant to explain the current situation (see also 3.3.2).		Kindly refer to Section 4.1.2 which explains the current situation.	
29	page 101, 3.2.2.5 – Kindly ask the Consultant to compare the Namibia Water Quality Standards/Guidelines (NWQS/NWQG) with international standards.		Kindly refer to the Design Criteria Report where this is analysed in detail.	
30	page 115, 3.10 – Have the basin management committees (Omaruru, Upper Swakop) been contacted and listed as key stakeholders?		The Upper Swakop Basin Management Committee has been contacted and their chairman attended the Concept Workshop of 29 & 30 January 2020. NamWater initially indicated that stakeholder engagement with the Omaruru Basin Management Committee was not required. They will however be contacted and provided with information via the BID.	
31	page 128, 4.1.3 – Kindly inform about the tariffs which reflect the cost to NamWater for desalinated water (mines etc) and the (respective/total) quantities of desalinated water supplied to the different customers.		Kindly note that NamWater did not fromally make available the costs to them of desalinated water. The Consultant was requested to only refer to NamWater's costs for desalinated water in general terms in respect of the analysis of irrigation water and not to state in any report the costs to NamWater charged by Orano. Kindly refer to Section 5.4.3 for the volumes of desalinated water supplied from the EDP.	
32	page 133, 4.2.2 – Kindly provide the amounts/thresholds of household income (N$) for “poor” and “severely poor” (see above) and calculate the respective percentages of cost of water.	Yes; Rev. 3	Table 4.4 included with these values.	by HB

33	page 133, 4.2.2 – The Consultant repeats countless times in all chapters and reports that the affordability of desalinated water is a concern, although the average portions are quite low. Unfortunately it does not show ideas and/or minimum requirements for (block) tariff setting in any report. Please ask the Consultant to work this out in detail.		Kindly note that the matter of affordability is a key concern raised by NamWater (numerous times) as well as by the stakeholders consulted by the Consultant. The Consultant was instructed by NamWater to adequately address these aspects / concerns. The assessments provided by the Consultant - Table 4.3 (Section 4.2.2) and Section 4.2.3 are an attempt to provide some perspective on the matter; in short that water is regarded as "expensive", whilst this is objectively not supported by average household expenditures, comparison with other commodities or the fact that tariffs do not account for the full, sustainable cost of water. Aspects of public (mis)perceptions are referred to... (think of irrigation with desalinated water for example). Further kindly note that block tariffs etc. relate to municipal tariff setting, whilst the aim of this project is "bulk" water on the part of NamWater, as currently. The matter of tariff setting and structures at municipal levels is therefore beyond the scope of this study. However, a note to the extent that affordability concerns can be addressed in this manner has been included in Section 4.2.3.	
34	page 134, 4.2.3 – What about the collection efficiency? This topic does not seem to be addressed anywhere. Please ask the Consultant to work this out in detail.		Kindly note that Section 4.2.3 deals with an historical perspective on water costs and tariffs. Unfortunately the Consultant does not have data/information to assess collection efficiency; kindly refer to previous comments/replies.	
35	page 136, 4.2.3 – It would be interesting to learn which percentage of subsidies is required finally in resulting in affordable (block) tariffs. Please ask the Consultant to provide these information and calculations in the Financing Chapter.		The Financial Chapter includes the expected bulk water tariffs and the cost of water for each scenario. It is not Scope of this project to define the level of possible subsidies.	
36	page 137, 4.2.4 – What was the development of consumption in Swakopmund, Walvis Bay etc after the introduction of desalinated water and the respective tariff increase? Please assess and provide more information.	Yes.	Section 4.2.4 - additional paragraph addressing this added.	by HB
37	page 138, 4.3 – What is the experience in other municipalities in the region, e.g. Cape Town, Joburg, Durban etc? Can one learn from this?	Yes.	Assessments of prepaid systems installed in South Africa added, together with a literature-based review of the advantages and disadvantages of prepaid systems.	by HB

38	page 141, table 4.5 – Kindly provide the MoM and/or records of all meetings.		The Consultant could not locate this requirement in the ToR. Please clarify? Kindly note that he minutes of key meetings where the water demand and deficit projections were agreed upon with stakeholders in the CCA and CAN are provided and were appended to the Revision 2 version of the report.	
39	page 142, 4.4.2 – Kindly ask the Consultant to provide evidence whether this definition has been agreed upon with the key stakeholders.		Please refer to the minutes of the Water Demand and Supply Options Meeting with NamWater of 03 July 2019. The Consultant presented the water demand projections for the CAN as defined (Item 4.2 of the Minutes) which was accepted by NamWater. Refer to Annex 4 of these minutes for the CAN Revised definition. This was then the CAN configuration discussed with the CoW on 19 July and 06 August 2020. These minutes of July and August 2019 were appended to the Revision 2 version of the report.	
40	page 143, 4.4.3.2 – Kindly ask the Consultant to consider two additional water meters located on the inlet pipes (one for the bulk supply, one for the desalinated supply) of the terminal reservoirs.		Considered and agreed! Doubtless the scheme will be constructed in this way. Kindly note that this is a conceptualisation of supply and the purpose of showing the water meter is the demarcation of supply. It is not intended to show how water meters will be used for conducting water balances.	
41	page 150, 4.4.4.2.6 – Kindly consider the results of the EPoNa / WavE research projects funded by the German Federal Ministry of Education and Research.	Yes; Rev. 3	The results of the Outapi sanitation and reuse project under the CuveWaters initiative was included & referenced.	by HB
42	page 165, 5.3 – Kindly clarify whether these are the figures for the NRW in the bulk supply system (relation between NamWater and clients) or the overall system (including relation clients and customer). These figures are more than doubtful if they already include the NRW of the municipal distribution systems including metering inaccuracies etc.	Yes; Rev. 3	These figures for NRW are for the bulk supply system on the part of NamWater. Clarified in the report.	by HB
43	page 189, table 5.3 - Is it to be understood that the NRW in the bulk supply system (relation between NamWater and clients) must now be added to this (14.5+8 = 22.5%)? Please clarify.		Correct, if the overall NRW between source and end-consumer is considered.	
44	page 190, 5.5.1.1 – What are the quality standards and practices for the supply with “semi-purified water” for irrigation purposes? Which treatment technologies are installed? In accordance with international standards?		Queried with Walvis Bay Municipality 11/02/2020. Their reply is awaited. There are currently no Namibian standards / regulations / requirements for "semi-purified water". The CoW requires that "semi-purified water" be at least filtered and chlorinated. In Windhoek, this water supply is "restricted" and by agreement between the CoW and the user.	

45	page 206, 5.6.3 – The Consultant should consider whether the presented capita consumption rates might be a result of the low metering ratio (?) as well as the collection efficiency (?) especially in informal settlements. In some informal settlements water consumption per capita is calculated based on number and size of buckets which are carried daily from tap to house due to missing water meters (Uhlendahl et al, 2010). The overestimated specific consumption and the obviously underestimated NRW might change decision-making. The Project must include a reliable measurement campaign to verify the data (refer to 5.6.4; not included in the cost estimates). Please reconsider.	Yes; Rev. 3	Reconsidered! Low metering rates and collection efficiencies are likley to be influencing factors, especially in informal settlements. This consideration has been added / included. Kindly note that the Uhlendahl study was conducted in / for Windhoek and therefore the application of these findings to the CCA towns should be done with caution (?). Kindly note also, that in terms of the IWA methodology and that followed by assessments in/for South Africa, per capita rates for urban water use include municipal NRW. The requirement for the project costing to include a reliable measurement campaign was not located in the ToR; please clarify? Kindly note that this relates to municipal / local authority use / measurement campaigns / NRW which fall outside the scope of this study which focusses on bulk water supply on the part of NamWater. For information: Full leakage benchmarking and NRW assessments were recommended and costed for the CAN towns under the CAN Medium Term Options study of the TCE/NamWater.	by HB
46	page 221, 5.7.2.3.4 - Kindly ask the Consultant to always show the industry demand (18 Mm^3/a; mines M2) separately in all reports/studies, as this may also have to be financed or promoted separately (refer to our email of August 29). This aspect must also be reflected in the chapter on financing.	Yes; Rev. 3	Kindly refer to Table 5.11 for the CCA, Tables 6.9 and 6.10 for the CAN. Tables 9.2, 9.3 and 9.4 were added to provide the mining and non-mining water deficits for the three project scenarios as requested.	by HB

47	page 301, table 6.10 – Kindly explain how the rising Swakoppoort dam water demands will be met taking into account the need for additional treatment (RO) for Swakoppoort dam (refer to 6.3.1.4). Have the additional investment and operation costs been taken into account? As during the Inception Phase, we would like to point out that the aspect of water quality is not sufficiently considered.		Kindly note that the treatment of the Swakoppoort Dam water is a matter of ongoing investigation. A reservoir management plan for the dam is currently being compiled for NamWater (final results not yet available). A feasbility study into treatment options will be required - but it is not known whether this is included in the reservoir management plan or a separate study. It would thus be premature to suggest treatment with RO is required; this remains to be confirmed. It is possible (likely?) that other treatment options such as DAF / conventional treatment / MF or UF / chlorination / oxidation / ozonation / activated carbon may be used or required in certain combinations/sequences. It is not possible to determine additional investment and operation costs without knowing what treatment options are to be implemented / recommended. At least this aspect remains undiscriminating between the desalination and Okavango options.	
48	page 312, 6.8.3 - The Consultant evaluates the ("hostile") reaction of the stakeholders to the draft of the Inception Report as unreadiness to consider different water supply / use priorities. Please ask the Consultant to adjust the section as it is obvious that the Consultant has not notice the step by step approach insisted on by NamWater and KfW during Inception Phase. The resource modelling would go far beyond the scope and possibilities of the current FS and can only be part of further work. It was never the intention to build the facilities as draught response or emergency measures as the ToR clearly show.	Yes; Rev. 3	This seems to have been a misunderstanding: We at no time suggested that the facilities be used / built as a "drought" response or emergency measure; quite the opposite! Sentence rephrased.	by HB

NAMWATER
Namibia Water Corporation Ltd

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Comment Resolution Sheet - Final Workshop 17th of February 2021

Project :	Feasibility Study for Desalination Plant and Water Carriage System to secure Water Supply to Central Coast, Windhoek and en-route Users
Project No. :	SC/OIB/NW-01/2018 (NamWater) O992 (Consultant)
Project Client :	NamWater
Consultant :	ILF Consulting Engineers

Document Ref.	Rev No.	Rev Date	Document Subject
O992-ILF-OD-0012/REV. 4	4	19/03/2021	FS Chapter - Water Resources and Water Demand Projections: Rev. 4.

Comment Sheet Ref: O992_CS_FS_Chapter_WaterDemand_Rev4.xlsx

No.	Comments raised by the participants	Comment Incorporated	Consultant Clarification	Remarks
1	Mutandwa Mutede (NamWater): Requested assurance that mines which may crop up in future will be taken care of [in terms of water demands].	Already considered.	Different options were put forward for the water demands of mines. NamWater selected an option which provides reasonably generous water demand and which should provide some headroom for additional future demands. The water efficiency of mines can also be expected to improve over time to add to the headroom.	No update needed in the report.
2	Hennie La Cock (Rössing): Have the life of mines been considered?	Already considered.	Yes, the life of mines was considered. However, this is something which is very difficult to predict, as Rössing for example have several times already extended their life of mine expectations.	No update needed in the report.
3	John Serunda (NamWater): Was additional mining demand considered for en-route users, specifically a potential gold mine between Karibib and Omaruru.	Already considered.	Yes, this topic came up during consultations with the Local Authorities during the project, specifically with the Omaruru Municipality. At this stage there does not seem to be a strong possibility that this mine will be developed. Again, there is some headroom available in the water demand projections, and some additional operational capacity could be made available to accommodate additional demands. Also, the water use of mines tends to decrease from their initial projections as efficiency improvements are made.	No update needed in the report.
4	Gabi Schneider (Namibian Uranium Institute): [Comment]. Three mining operations provided for. A word of caution if the uranium price increases, more than three mines could be operational. Other mines might also be developed. Would the water demands then not be bigger?	Already considered.	This is difficult to predict - for example by how much and when can the uranium mine be expected to increase…? This cannot really be predicted. The other factor to consider is the balancing act between providing a lot of capacity which has a high capital cost, but then if the demand does not realise, these costs cannot be recouped from water sales, versus undersizing the infrastrucutre and having it too small. Typically, one would recommend that water demand projections are revised at five year intervals and expectations of additional demands are reevaluated at regular intervals and factored into operational plans.	No update needed in the report.
5	Henry Mukendwa (NamWater): Are there possibilities for reclamation as a source, intermediate in price between groundwater (cheaper) and desalination (more expensive). Was this considered and included in the resource mix portfolio?	Already considered.	Literature from Australia shows that potable reuse is cheaper than desalination and semi-purified water where a dual pipe system has to be retrofitted. This was used as a specific reference. Walvis Bay is already advanced in the planning of water reuse and yes, reuse was included in the demand projections according to the best information available.	No update needed in the report.