Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin:

Output 4: Water Supply and Sanitation

Wellington R.L. Masamba

Harry Oppenheimer Okavango Research Centre

July 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

SOCIOECONOMIC SERIES

TRANSBOUNDARY DIAGNOSTIC ANALYSIS OF THE BOTSWANA PORTION OF THE OKAVANGO RIVER BASIN

Output 4: Water Supply and Sanitation

Wellington R.L. Masamba

Harry Oppenheimer Okavango Research Centre

University of botswana

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Maun

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ACRONYMS AND ABBREVIATIONS

CSO	Central Statistics Office
DO	Dissolved oxygen
DWA	Department of Water Affairs
EC	Electrical conductivity
EFR	Environmental Flow Requirements
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
GDP	Gross Domestic Product
GEF	Global Environment Facility
MoA	Ministry of Agriculture
MPWWS	Master Plan for Waste Water and Sanitation
NAMPAADD	National Agricultural Master Plan for Arable Agriculture and Dairy Development
Ml/year	Million litres per year
NDP	National Development Plan
NWDC	North West District Council
NMPWWS	National Master Plan for Wastewater and sanitation
NWMPR	National Water Master Plan Review
OKAKOM	Permanent Okavango River Basin Water Commission
ORB	Okavango River Basin
ODRS	Okavango Delta Ramsar Site
SAP	Strategic Action Program
TDA	Trans-boundary Diagnostic Analysis
UFW	Unaccounted for water
WDS	Water Development Sector
WWTP	Wastewater Treatment Plant
ZAMCOM	Zambezi Watercourse Commission

EXECUTIVE SUMMARY

This report covers the water and sanitation component of the Trans-boundary Diagnostic Assessment (TDA) whose term of reference:

Assess requirements (quality, quantity, timing) of existing and planned formal water supply schemes

Assess requirements (quality, quantity, timing) of informal hosehold direct use of river water for the Botswana part of the ORB

Assess current and projected changes in sanitation services in the Botswana part of the ORB.

The findings of this work are as follows:

1. In Botswana, water responsibilities are distributed between seven different institutions
2. All the rivers in Botswana except the Okavango and the Chobe/Zambezi are ephemeral hence groundwater is a vital resource which is used in most water supply schemes
3. Urban demand is 125,200 million litres consumed (2005) and highest for domestic uses (33%) followed by unaccounted for losses (20%) then mining (19%) and institutional uses (18%). Rural demand is at 63,300 million litres/annum
4. Rural demand is 63,300 million litres per year
5. The projected water demand for irrigated agriculture in 2012 when NAMPAADD is fully implemented is 53,000 million litres/year of which 11,500 million litres/year is expected to be from groundwater.
6. The water demand for livestock is estimated at 44,500 million litres/annum while that for livestock is estimated at 6,000-10,000 million litres/annum
7. A study has estimated that the environmental flow requirement for the Okavango is 390 m^3/s in the panhandle.
8. Of the total daily domestic water output of 15,501 m^3/day for the Okavango Delta region, 13,317 m^3/day (85.9%) is from groundwater. The projected demand up to 2015 for the Delta region is 28,611 m^3/day
9. Total surface water abstractions for 2005 for the Okavango Delta region were 46,540 m^3/day with a projected abstraction of 68,074 m^3/day in 2025.
10. Water demand by settlements that draw water directly from the river is estimated at 94 m^3/day; and is therefore insignificant compared to other users.
11. Total groundwater abstraction for 2005 was 16,446 m^3/day for the Okavango Delta area and was projected to increase to 44,371 m^3/day.
12. Large scale abstractions upstream may affect water availability for various uses
13. Upstream pollution may affect water quality for various uses
14. Surface water is of good chemical quality but may be unsafe due to precence of bacteria while groundwater usually has low bacteria counts but may contain high total dissolved solids, fluoride, arsenic, chloride, sodium and iron.
15. The average percapita water usage in tourism establishments is 205 litres/day for permanent lodges, camps and 12-63 litres/day for mobile land excursions and 77-188 litres/day for houseboats.
16. Ngamiland has the largest population without any sanitation services with 76% of residents of Ngamiland West having no toilets

17. Maun is the only village with a sewage system, with one in Gumare under construction. There are sewage systems for tourist lodges and camps as well as foe a few institutions.
18. There is only one sanitary landfill located in Maun and nine other gazetted dumping sites in Ngamiland.
19. There is concern of water pollution from septic tanks (whose soakaways may sometimes be very close to the river), sewage systems with poor effluent and dumping sites.

1. INTRODUCTION

The climate of Botswana may be described as semi-arid to arid. The country is largely flat and surrounded by plateaus of Zambia to the north, Zimbabwe to the northeast, South Africa to the south and southeast and Namibia to the west. As a result of this physiography, there are no prominent barriers to the flow of moist air and orographic influences on the formation of clouds and precipitation are virtually non-existent (NWMPR, 2006, Vol 1, 2006). There is a northeast-southwest gradation of mean annual rainfall from Kasane (645.1 mm) through Maun (452.4 mm and Tsane (346.3 mm) to Tsabong (289.7 mm) and Bokspits (170.9 mm). There is also a south-north gradation along the eastern flank of the country starting from Gaborone (529.6 mm) to Mahalapye (457.7 mm) and Francistown (469.5 mm) and Nata (432.5 mm). The mean monthly maximum temperature ranges from 29.2 ºC to 37ºC in summer, and 19.8 ºC to 28.9ºC in winter. Mean monthly minimum temperatures range from 16.2 to 20 in summer and -6 to 13.6 in winter (NWMPR 2006, Vol 3).

The low rainfall and high rates of potential evapotranspiration in Botswana combined with its very flat topography results in low rates of surface runoff and low rates of groundwater recharge. The only part of the country that has measurable runoff is the area lying within the Limpopo basin in the east and a small segment draining into the Makgadikgadi Pans from the east via Nata, Motsetse, Mosope and Lephashe Rivers (viol 1). In the north, the Okavango River enters Botswana at Mohembo with a mean discharge of about 350 m^3/s, but largely dissipates itself in the Okavango Delta. The outflow from the Delta is only 4% of the inflow. The Zambezi has a large mean annual flow of 1088 m^3/s (http://en.wikipedia.org/wiki/Victoria_Falls#cite_note-WW-1).

All the rivers in Botswana except the Okavango and the Chobe/Zambezi are ephemeral hence groundwater is a vital resource. Most of the areas of the country rely on it for water supply needs. However, groundwater is a finite resource and subject to pollution and groundwater mining, hence there is need to protect it.

In Botswana, water responsibilities are distributed between seven different institutions (Table 1). For example, the ministry of Minerals, Energy and Water Recourses is responsible for development of water policies; water allocation, water resource assessment, and also for supplying water to 17 major villages whereas District Councils are responsible for provision of water to all villages not supplied by the Ministry of Minerals, Energy and Water Resources.

Table 1. List of organisations and their water portfolios for Botswana (source: Kalaote, 2006)

Organisation	Portfolio
Ministry of Minerals, Energy and Water Resources	Water policy, water allocation, Water Resources assessment, water authority for 17 major villages[1]
Ministry of Local Government (District Councils)	Provision of water at local level
Ministry of Agriculture	Agricultural Water Development

Ministry Of Health	Ensure purity of water
Water Utilities Corporation (WUC)	Water Authority for Gaborone, Lobatse, Salebi Phikwe, Francistown, Jwaneng
DEBSWANA	Water supply to Orapa, Lethlakane and Damtshaa mines
Botswana Power Corporation	Water supply to Morupule mine

[1]There are plans that WUC will take over the function of supplying water to major villages from the Ministry of Minerals, Energy and Water Resources.

The Okavango River Basin (ORB) remains one of the least human impacted basins on the African continent. Mounting socio-economic pressures in the riparian countries; Angola, Botswana and Namibia, threaten to change its present character. The Permanent Okavango River Basin Water Commission OKAKOM) therefore solicited funds from the three governments and the Global Environment Facility (GEF) and

initiated the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO The long-term objective of the EPSMO Project is to achieve global environmental benefits through concerted management of the naturally integrated land and water resources of the Okavango River Basin. The specific objectives of the project are to:

a. Enhance the depth, accuracy, and accessibility of the existing knowledge base of basin characteristics and conditions and identify the principal threats to the trans-boundary water resources of the Okavango River Basin through a Trans-boundary Diagnostic Analysis (TDA);
b. Develop and implement, through a structured process, a sustainable and cost-effective program of policy, legal and institutional reforms and investments to mitigate the identified threats to the basin's linked land and water systems through the Strategic Action Program (SAP); and,
c. Assist the three riparian nations (Angola, Botswana and Namibia) in their efforts to improve their capacity to collectively manage the basin.

The SAP will include baseline and additional actions to address priority trans-boundary issues and provide a monitoring and evaluation tool for implementation. It will also recommend the development and testing of a set of institutional mechanisms and implementation methodologies, including pilot demonstrations that explicitly link regional, national and local initiatives in land and water management. Additionally, it will involve preparation of a basin-wide framework in which trans-boundary priorities can be addressed and project interventions monitored.

The TDA will inform and guide the development of the SAP and will be a platform where trans-boundary externalities can be examined and resolved. The TDA will underpin the SAP design and indicate monitoring and reporting criteria for SAP implementation. Most importantly, the process of completing the TDA will inform policies and initiatives to be launched in preparation for SAP implementation. This report is part of the TDA with focus on irrigation.

The terms of reference for this work are:

a. Assess requirements (quality, quantity, timing) of existing and planned formal water supply schemes
b. Assess requirements (quality, quantity, timing) of informal household direct use of river water for the Botswana portion of the ORB.
c. Assess current and projected changes in sanitation services in the Botswana portion of the ORB.

2. METHODOLOGY

Information was collected from a knowledge gathering workshop, discussions with Government Officers and the literature.

2.1 Workshop

A knowledge gathering workshop was conducted on 24th – 25th February 2009. The participants had been asked before hand to prepare information on water issues (and the other TDA areas). Preliminary information was therefore obtained during the workshop. In addition to the information, participants also provided input as to what they expected to be included in this report. A second workshop was held from 15 to 16 July 2009 when feedback was provided to stakeholders and additional input sought.

2.2 Discussions with Government Officers

Additional information was obtained by visits to the Department of Water Affairs and District Council Offices in Maun.

2.3 Literature

Secondary data was sourced from the offices or libraries. Most of the information in this report is derived from various volumes of the National Water Master Plan Review Volume (NWMPR) and of the National Master Plan for Wastewater and Sanitation (NMPWWS). Additional sources are indicated in the text.

3. WATER DEMAND FOR BOTSWANA

The water demand for Botswana for urban, rural water supply, agriculture, wildlife and livestock and environment is discussed below.

3.1 Urban Water Demand

The water demand for urban Botswana for 2004/2005 is given in Figure 1 Based on NWMPR 2006 Vol 5. A total of 125,200 million litres were consumed with domestic demand accounting for the highest demand (33%). Also of importance is that unaccounted for water (UFW) account for 20% of the water demand. MWMPR 2006 vol 5 contends that a conservative estimate of UFW in Botswana lies between 40% and 50%. The Department of water affairs estimated average losses at 27% with a range of 6% at Lethlakane to 48% in Kanye, Ramotswa and Maun (NMMPR 2006 Vol 5). The UFW for Maun has been reduced to 8-14% (Tshere, personal communication).

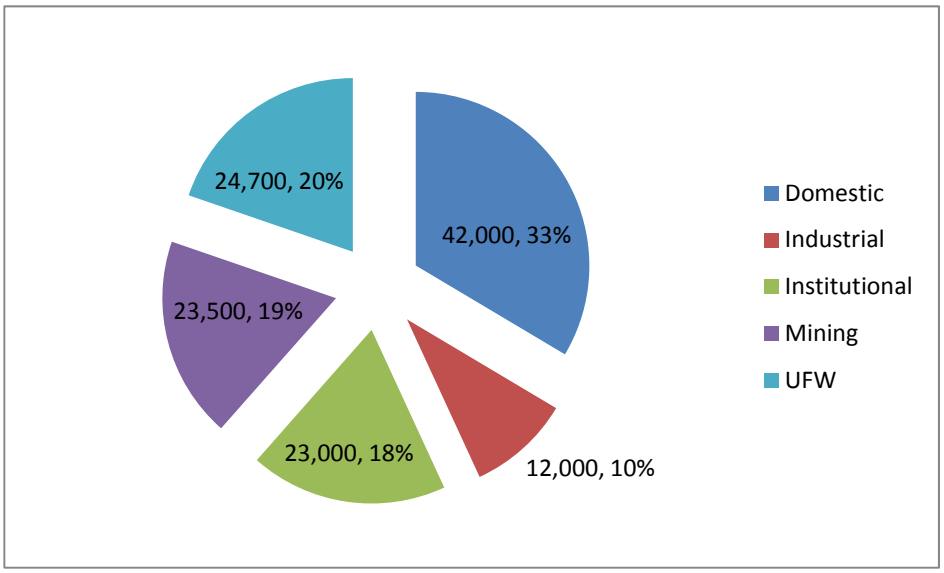

Figure 1. Urban water demand for Botswana in 2004/2005 (From NWMPR 2006 Vol. 6)

3.2 Rural Demand

The source for rural water supply has traditionally been groundwater extracted from District Council or government boreholes. Figure 2 shows the distribution of known aquifers in the country, with their estimated yields. It can be noted that the most of the aquifers lie in the South to East corridor between Lobatse/Kanye and Francistown.

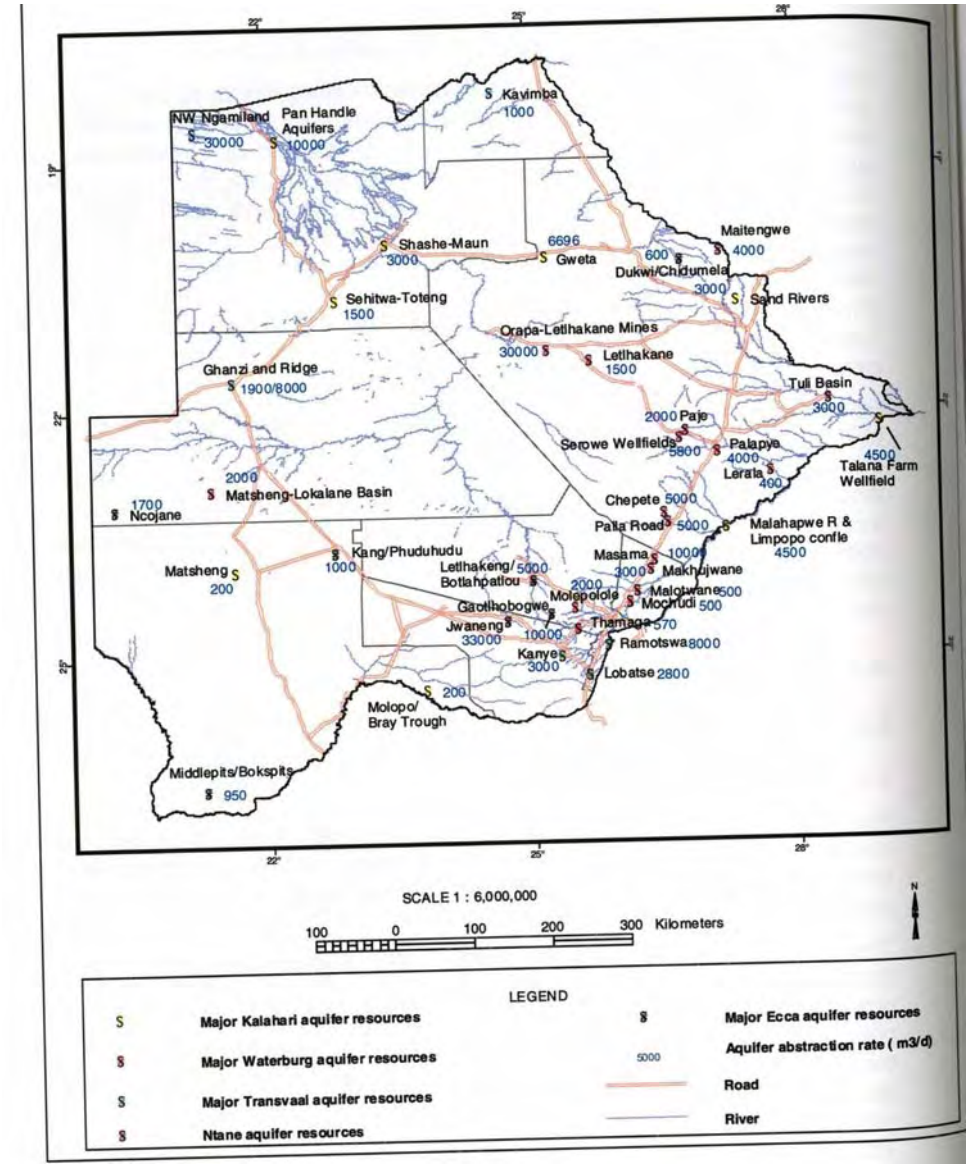

Figure 2. Major groundwater resources of Botswana (From NWMPR 2006 Vol. 1).

Figure 3 shows the abstraction rates of Kalahari aquifers of the country. The abstraction patterns differ from the distribution of groundwater resources in that it is not concentrated in the South-East corridor between Lobatse/Kanye and Francistown. Table 2 shows the regional water demand that was projected for 2005 (NWMPR 2006 Vol 6). The south and south east regions have the highest demand at about 29,000 million litres each, followed by the northern and then the western regions.

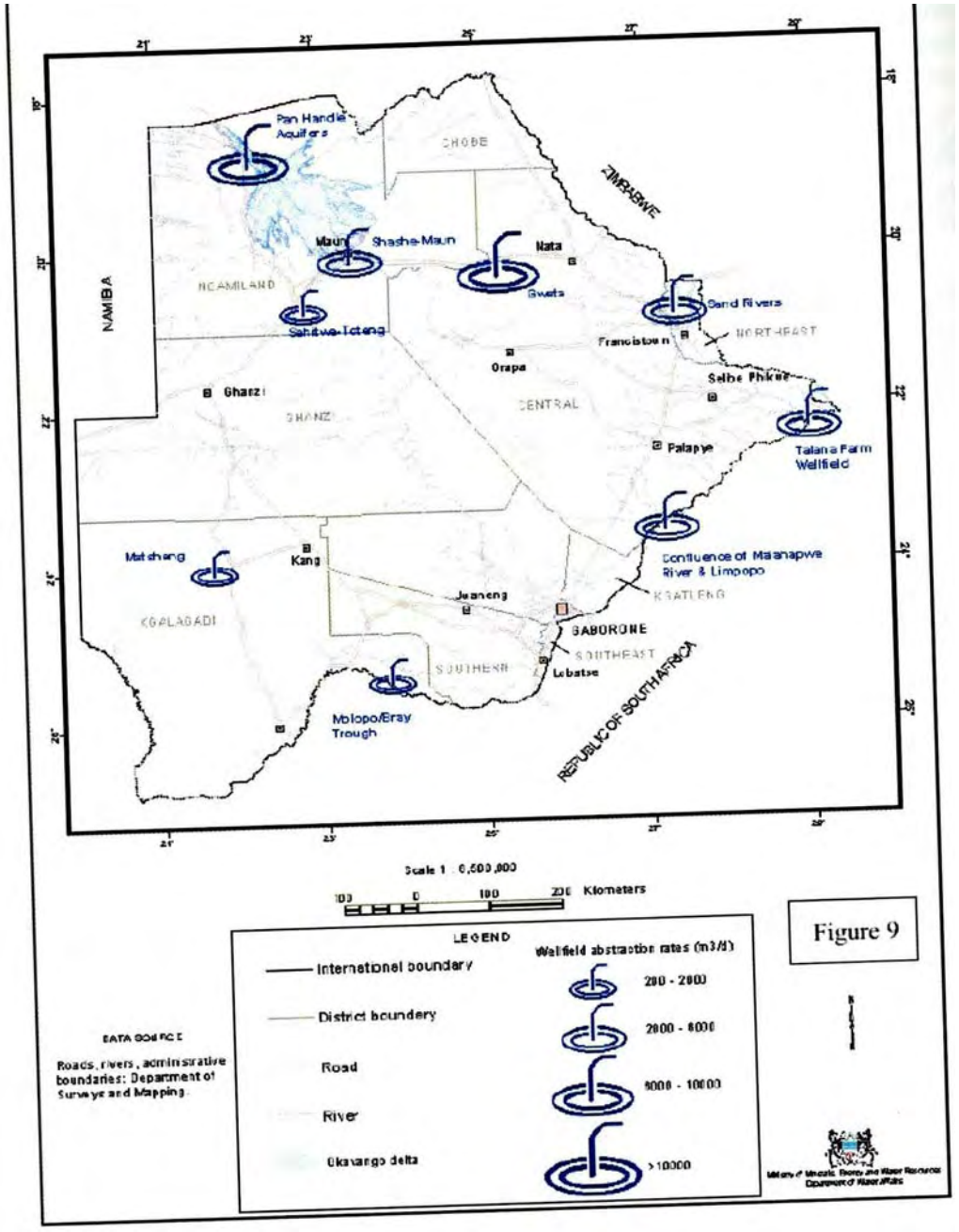

Figure 3. Major aquifer resources and abstraction rates (From: NWMPR: Vol. 4).

Table 2. Regional rural water demand for 2005

Region	Water demand (million litres)
Eastern	29,000
South East	28,500
Western	1,700
Northern	4,100
Total	63,300

3.3 Water demand for Agriculture

The projected water demand for irrigated agriculture under when NAMPAADD (see accompanying report: irrigation) is fully implemented is 53,000 million litres/year of which 11,500 million litres/year is expected to be from groundwater.

3.4 Livestock

Water demand for livestock has not been quantified. However, the NDP 8 projected that of the total water demand of 193,400 million litres for the year 2000, 23% was for livestock. This would give a water demand for livestock of 44,500 million litres for the year 2000.

3.5 Wildlife water consumption

Wildlife and wildlife based tourism are renewable resources and if wisely used and sustainably managed, will continue making an increasingly important contribution to the Botswana economy. Tourism is currently the second biggest export sector in Botswana following mining. Elephant dominate the wild water dependent animals with an appreciable number of buffalo, impala, hartebeest, wilderbeest, zebra and kudu. The NWMPR 2006 Vol 9 gives a herbivore water demand for 2001 of 10,000 million litres. Other workers have given demand of between 6,000-8,000 million litres/year (see references in NWMPR 2006 vol 9).

3.6 Environmental water requirements for the environment

While there is no doubt that the environment is a consumer of water, there is difficulty in determining the magnitude of this demand. Various environmental methods, generally called environments flow requirements (EFR) have been used for this. Environmental flows are defined as the stream flow necessary to sustain habitats, encourage spawning and the migration of fauna species to previously unpopulated habitats, enable the processes upon which succession and biodiversity depend, and maintain the desired nutrient structure within lakes, streams wetlands and riparian areas when ecosystems are subjected to flow regulation and competition from multiple water users. For Botswana, EFR assessments for some rivers are given in Table 3. (NWMPR 2006 Vol 9). For the three rivers - Nata, Thume and Shashe, flows of 5 to 6 m^3/s are needed (during high flows) in order to ensure that the environmental needs of

the rivers are met. For the Okavango, flows of 390 m^3/s are required, mainly to sustain the Okavango Delta ecosystem. Another EFR study for the region is currently underway.

Table 3. Environmental Flow Requirements of 4 rivers (NWMPR 2006,Vol 9)

RIVER	EFR (m^3/s)	METHOD
Nata	5	Flow exceeded 50% of the time
Thune	5.5	Q_{80}
Shashe, downstream of Dikgathong Dam	6.0	Q_{80}
Okavango River	390	Q_{20}

4. THE OKAVANGO DELTA AREA

4.1 Existing domestic water schemes

There are four general suppliers of water in the Okavango Delta area: (i) North West District Council for all villages other than Maun (ii) the Department of Water Affairs (DWA)for Maun (iii) tour operators for tourism facilities in areas that are not supplied by NWDC or DWA and (iv) individuals in most ungazetted settlements. The existing water supply schemes for the Okavango Delta region, with the exception of tour operators and ungazetted areas are given in Table 4. Of the total daily demand of 2709 m^3/day for the villages supplied by the NWDC, 1485 m^3/day (55%) is from boreholes. The remaining 54% is from surface water with uptake at the panhandle (Mohembo East, Shakawe, Sepoa 1 and Sepopa 2).

Of a total of 12,792 m^3/day of the daily output for Maun, only 960 m^3/day (7.5%) is from surface water, and this is only utilised when there is flow in the Thamalakane as the river sometimes dries out. Groundwater is therefore a major source of water for the region, especially Maun. Of the 15,501 m^3/day total daily output for NWDC and DWA , 13,317 m^3/day (85.9%) is from groundwater.

Table 4. Domestic water demand and production for areas supplied by the North West District Council (Data from NWDC) and Department of Water Affairs (data provided by DWA, Maun)

Village	Source	Daily demand (m^3/d)	Daily output (m^3/d)	Remarks
SUPPLIED BY NWDC				
Matlapana , Disaneng, Sexaxa, Matsaudi	Borehole	100	415	
Shorobe	Borehole	50	80	
Sankoyo	Borehole	22	25	
Chanoga	Borehole	23	75	
Phuduhudu	Borehole	23	80	
Sehitwa, Bothatogo, Bodibeng, Toteng, Legotwane, Kareng	Borehole	250	620	Many breakdowns, desalination
Makakung, Semboyo	Borehole	65	164	desalination
Tsau	Borehole	100	238	
Mababe	Borehole	12	100	
Somelo	Borehole	30	66	Poor access, aeration for iron removal
Komana	Borehole	13	58	
Makalamabedi	Borehole	21	180	Desalination
Nokaneng, Habu,	Borelole	100	87	Boreholes curved in,

				supplemented by bowsing, Iron problems
Qooshe	Borehole	11	15	Borehole dry, bowsing
Qangwa	Borehole	20	18	Supply at risk, pumping long hours
Tubu	Borehole	24	65	
Etsha 13	Surface	110	185	
Sepopa, Mokwana, Ikoga, Tamacha	Borehole	170	410	
Ngarange	Borehole	48	180	
Seronga, Gunitsoga	Borehole	155	178	
Gudigwa	Borehole	27	100	
Gani	Borehole	27	87	
Beetsha	Borehole	41	57	
Mogotho	Borehole	15	45	
Chukumuchu	Borehole	15	27	
Gumare, Etsha 1-12	Surface	600	700	
Xakao, Mohembo East, Kauxwi, Jejeda, Sechenje, Sekondomboro, Kaputura, Goa, Tobera	Surface	210	400	
Xaixai	Borehole	13	45	
Shakawe, Okusi, Nxomokao, Nxamasere, Mohembo West, Xaoga, Shaikarawe	Surface	350	400	
Nxaunxau	Surface	18	50	
Eretsha	Surface	25	15	Bowsing
Kajaji	Surface	21	0	Safe water not provided-to be bowsed and then connected
SUPPLIED BY DEPARTMENT OF WATER AFFAIRS-MAUN				
Maun	<u>Boreholes</u> Shashe Sexaxa Kunyere Tsutsubega <u>Surface</u>		 2,784 1,608 1,008 6,432	Surface water only 2% of the total. High salinity of groundwater, poor groundwater

	Wenela		960	quality. Surface water only available when there is flow in the Thamalakane River
Total			15,501	

4.2 Future Domestic water schemes

- In Maun, the Maun Groundwater Development Project Phase 2 recommended the decommissioning of the Shashe welfied (currently under use) due to salinisation and a total of 30 boreholes to be developed at Matsibe, Kunyere and Gomoti with a total abstraction rate of 26,944 m^3/day against a projected demand of 22,222 m^3/day.
- The plans for the NWDC include:
    - connection of Kajaja 1 to the Shakawe treatment. Approximately 50 m^3/day is expected to be consumed. This is expected to be completed by the end of this year, 2009.
    - Development of the Khwai water supply scheme to supply approximately 30 m^3/day. This is expected to be completed by the end of this year, 2009
    - Construction of an aeration plant at Komana
    - Construction of an aeration plant at Chanoga
    - Rehabilitation of the Shakawe treatment plant
    - Groundwater Investigation, Boreholes Drilling, Design & Construction of Water Supply at Ditshiping, to supply an estimated 30 m^3/day
    - Construction of aeration plant and rehabilitation and borehole connection at Nokaneng/Habu
    - Interconnection of Seronga, Teekae, Gunitsonga, Ndorotsha, Eretsha, Beetsha and Gudigwa to the Sepopa treatment plant. The water demand is estimated at 1357m^3/day and the project has been designed to provide 1000m^3/day.

4.3 Total present and future water abstractions

The total water abstraction was estimated during the Okavango Delta Management Planning process (ODMP 2006).

4.3.1 Surface water

Data for total surface water abstractions from the Okavango Delta based on permits issued by the DWA is given in Table 5. These abstractions are for domestic water supply, livestock, game, small scale irrigation and construction. The total permitted abstraction (2005) from the Delta is 46,540 m^3/day or 17 Mm^3/annum. This is 0.22% of the average inflows from 1987 to 2002. Future projected abstractions based on increase in population and rates of consumption is 25Mm3/annum or 0.32 % of the average inflow. It should be noted that large abstractions are from Maun which is downstream of the Okavango Delta.

Table 5. Surface water abstraction from the Okavango Delta

River	Abstraction (M^3/day)	
	2005	2025

Okavango	6,285	9,107
Thaoge	1,475	2,140
Boro	1,483	2,710
Maunachira	275	399
Khwai	148	215
Thamalakane	26,571	38,553
Nhabe	5,100	7,400
Boteti	5,203	7,549
Total	46,540	68,074

4.3.2 Groundwater

Data for surface water abstraction was also given in ODMP (2006) (Table 6). A total of 16,448 M^3/day was abstracted in 2005 and a projected 44,377 m^3/day in 2025. The 2025 figure includes 6,800 m3/day of saline water expected to be used by DML copper project near Toteng for processing copper ore (Discovery Metals Limited, personal communication). The current and future groundwater abstraction sites are shown in Figures 4 and 5.

Table 6. Groundwater abstractions in the Okavango Delta area

Location	Abstraction (M^3/day	
	2005	2025
Seronga	210	287
Ngarange	137	185
Etsha 6	387	522
Etsha 13	136	184
Nokaneng	212	286
Gumare	515	696
Sehitwa	230	310
Tsao	191	257
Toteng	234	316
DMC mine	-	6,800
Shorobe	230	310
Tsutsubega	1,643	4,026
Shashe	4,654	-
Gomoti	7,666	10,066
Kunyere	-	12,079
Matsibe	-	8,053
Total	16,446	44,371

Figure 4. Location of present groundwater abstractions (ODMP 2006)

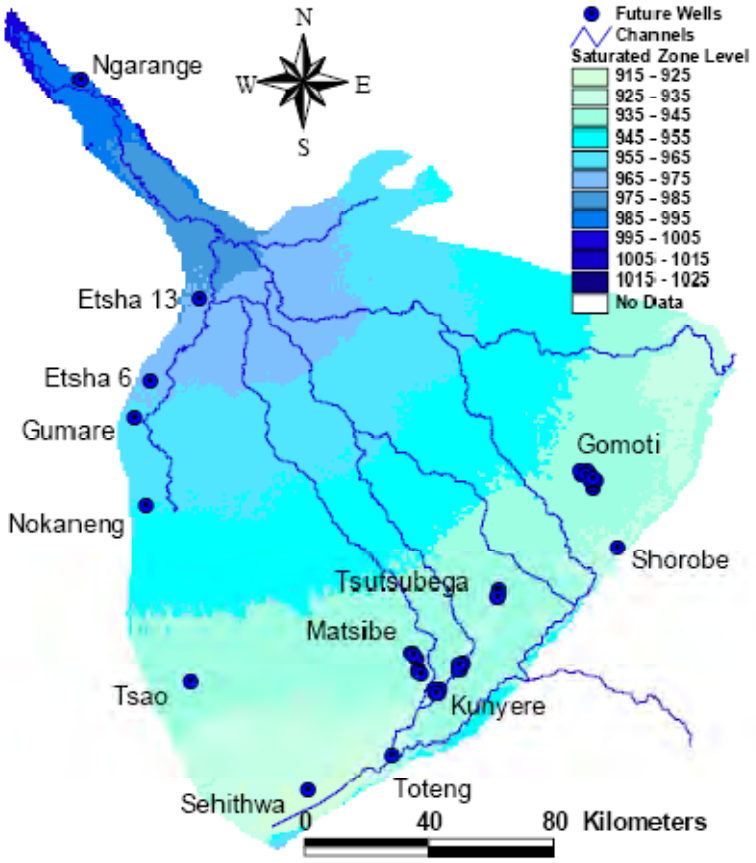

Figure 5. Location of future groundwater abstractions (ODMP 2006)

4.3 Direct Household Use

The Okavango Delta has a population of 2,688 people (CSO 2001). Settlement water consumption is not accurately known. When standpipe consumptions based on the Botswana National Wastewater and Sanitation Planning design for public standpipe (35 l/c/d) is used, this would give a daily consumption of 94,080 litres per day.

4.4 Water usage by tour operators in the Okavango Delta

A study of 40 permanent lodges and camps showed that 60% of these establishments obtained their water requirements directly from the Delta system; 10% from boreholes and 30% from hand dug wells (Aqualogic 2008). They found the average per capita water usage for permanent tourist lodges/camps to be 205 litres/day, with a range of 58 – 352 litres per capita per day. For mobile safaris, water usage ranged from 12-63 litres/capita/day for on land excursions and 77-188 litres/capita per day for house boats (Aqualogic 2008).

4.4. Surface Water Quality

Generally, the surface water of the Okavango Delta area is of good quality, having low dissolved solids and bacteria. Tables 7 shows the average results from HOORC's water quality monitoring programme on water quality for main channels at Mohembo, Sepopa, the Boro settlement and Maun. Generally, the pH is near neutral and electrical conductivity very low-ranging from 38 µS/cm in the panhandle to 127 µS/cm in Maun. Metals are generally low with lead, nickel, cobalt and cadmium less than the detection linit of the instrument used; Na (2.0 mg/l-9.4 mg/l); K (1.7mg/l-4.7mg/l); Mg (0.8 mg/l-3.3mg/l); Fe (0.08 mg/l-0.14 mg/l) and Mn (up to 0.04 mg/l). Dissolved oxygen is highest at Mohembo (6.77) and is lower downstream, probably as a result of high dissolved organic matter, which uses up oxygen upon decomposition, in downstream waters. Total nitrogen was in the range 0.23 mg/l to 0.73 mg/l; TSS (4-12 mg/l). The other parameters e.g. anions are also low. Generally, there is an increase in concentration of the water quality parameters from Mohembo to the downstream village of Maun.

Figure 6 shows the faecal coliform counts for the surface water in panhandle between Mohwmbo and Shakawe (unpublished HOORC monitoring data). The results show that the water is contaminated by bacteria and is therefore not fit for direct human consumption. Microbiological water quality was determined for the lower Delta with *Faecal coliform* (range 0 – 48 counts/ 100ml) and *Faecal streptococci* (40 – 260 counts/100ml) being lower than the panhandle (Masamba and Mazvimavi 2008). This could be attributed to the filtering effect of the Delta. However, even in the lower Delta, the water is not suitable for direct human consumption.

4.5 Groundwater

Groundwater quality is routinely monitored by the DWA around Maun for water quality. The NWDC also monitors water quality for its boreholes while the Maun groundwater project also determined the water quality in the Boro, upper Thamalakane , Kunyere, Gomoti and Matsibe welfields when investigations for extending the Maun water supply were conducted. Unlike surface water, groundwater tends to have better microbiological quality but poorer chemical characteristics. Table 8 gives the water quality of the groundwater quality of some boreholes in the Okavango Delta area. While some of the boreholes meet the Botswana Bureau of Standards drinking water specifications, others do not. Parameters that are sometimes exceeded include electrical conductivity, chloride, arsenic, sodium and iron. In some cases, the water is treated e.g. at Makalamabedi (desalination) and at for high electrical conductivity (total dissolved solids), Somelo for iron (See Table 6).

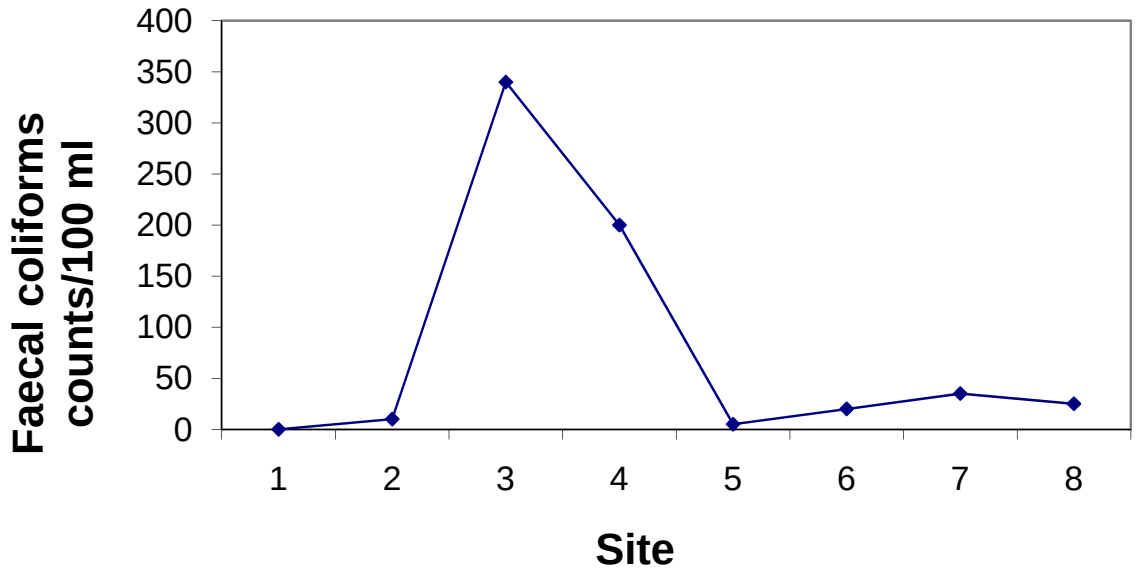

Figure 6. Faecal coliform counts for eight sites between Mohembo and downstream of Shakawe (HOORC monitoring data)

Table 7. Concentrations (mg/l unless otherwise specified) of various parameters in surface water of the Okavango Delta. pH is unitless.

	pH	**EC (us/cm)**	**DO**	**Turb**	**CO_3**	**HCO_3**	Cl	SO_4	NO_3	PO_4	**Na**	**K**	**Ca**
Mohembo	**6.84**	**38**	**6.77**	**3.92**	**0.0**	**44**	0.58	1.34	0.02	0.01	**2.0**	**1.7**	**3.0**
Sepopa	**6.74**	**39**	**3.45**	**2.29**	**0.0**	**46**	0.41	0.44	0.10	<0.01	**2.2**	**1.9**	**3.7**
Boro	**6.70**	**119**	**5.82**	**0.56**	**0.0**	**125**	0.95	0.08	0.02	<0.01	**9.0**	**4.5**	**9.8**
Maun	**6.94**	**127**	**3.48**	**9.20**	**0.0**	**129**	1.00	0.16	0.19	<0.01	**9.4**	**4.7**	**9.9**

Table 7 Continued

	Mg	**Fe**	**Mn**	**Cd, Pb, Ni, Co**	TN	TSS	DOC
Mohembo	**0.8**	**0.14**	**0.04**	**<0.01**	0.23	6.4	4.2
Sepopa	**1.0**	**0.13**	**0.01**	**<0.01**	0.32	4.4	5.2
Boro	**3.1**	**0.10**	**<0.01**	**<0.01**	0.64	4.3	10.8
Maun	**3.3**	**0.08**	**<0.01**	**<0.01**	0.73	5.0	11.8

Table 8. Groundwater quality. All concentrations in mg/l unless otherwise specified. pH is unitless (From Maun Water Resources Consultants 2004, DWA, NWDC and HOORC data).

Borehole	Location	Year sampled	pH	EC (µS/cm)	As	DOC	HCO_3	CO_3	F	Cl	K	Mg	Fe	Na
BH7188	Shashe	2005	8.24	1850	0.0027	4.1	1104	23	0.87	263	13	1.4	<0.01	
BH8786	Shashe	2005	7.64	4140	0.0094	3.1	769	0	0.72	693	20		<0.01	
BH9250	Tubu	2005	5.65	291	0.0041	25	29	0	0.24	3	6.4	0.2	7.09	
BH8022	Nokaneng	2005	6.65	1053	0.0064	6.1	294	0	0.51	4	12	19	<0.01	
BH9029	Makalamabedi	2005	10.5	7460	0.014	14.7	1699	642	16.3	1269	33	0.1	0.08	
	Makalamabedi after treatment	2005	10.1	572	0.0017	2.4	61	22	0.69	94	2.0	0.1	<0.01	
BH9834	Boro	2002	6.6	160	0.035				0.96	80	14	0.8	0.22	392
BH9826	Boro	2002	7.9	246					0.14	17	8.0	10.0	0.11	10
BH9593	Upper Thamalakane	2002	6..6	130					0.10	1.7	6.4	1.9	8.2	14
BH9595	Upper Thamalakane	2002	8.6	2950					0.5	622	15	3.9	1.9	10
BH9904	Gomoti	2002	8.3	1480	0.09				1.3	64	5.2	0.4	0.08	370
BH9900	Gomoti	2002	8.2	1480	0.36				2.20	167	2.8	0.2	0.06	339
BH9707	Kunyere	2002	7.3	2800	0.010				0.32	494	19	13	0.31	533
BH9788	Kunyere	2002	8.1	1140	0.31				2.41	34	5.3	0.40	0.29	289

5.0 ON SITE SANITATION IN BOTSWANA

The 2001 census indicated that by the World Health Organisation (WHO) definition of adequate sanitation, 77% of all households in Botswana have access to adequate sanitation. Urban areas have 95% sanitation level whereas rural areas have 51% (Botswana National Master Plan for Wastewater and Sanitation (NMPWWS) 2003, Vol. 1). These are above the average for Africa which stands at 81% for urban areas and 41% for rural areas (Table 9). Of importance is the fact that 23% of the population do not have any sanitation service -i.e. they use the bush. Botswana has defined the minimum level of sanitation to be the ventilated improved pit latrine (VIP) for houses which are not serviced by individual water connections. This implies that the pit latrine is not an appropriate sanitation option for the people of Botswana. Using this definition of adequate sanitation service, only 39% of the households have adequate sanitation service, 53% in urban areas and 18% in rural areas. Figure 7 shows a schematic indication of the sanitation for the whole country. It can be noted that Ngamiland has the worst sanitation in the country. Ngamiland only has one main wastewater treatment plant located in Maun (Figure 8). Smaller treatment plants, mainly serving institutions will be discussed in subsequent sections. Maun is also the only locality that has an engineered landfill.

Table 9. Comparison of adequacy of sanitation services in Botswana (NMPWWS 2003, Vol. 1)

%	African Continent (WHO definition)	Botswana (WHO definition)	Botswana (GOB definition)
Urban	81	95	53
Rural	41	51	18
Total	55	77	39

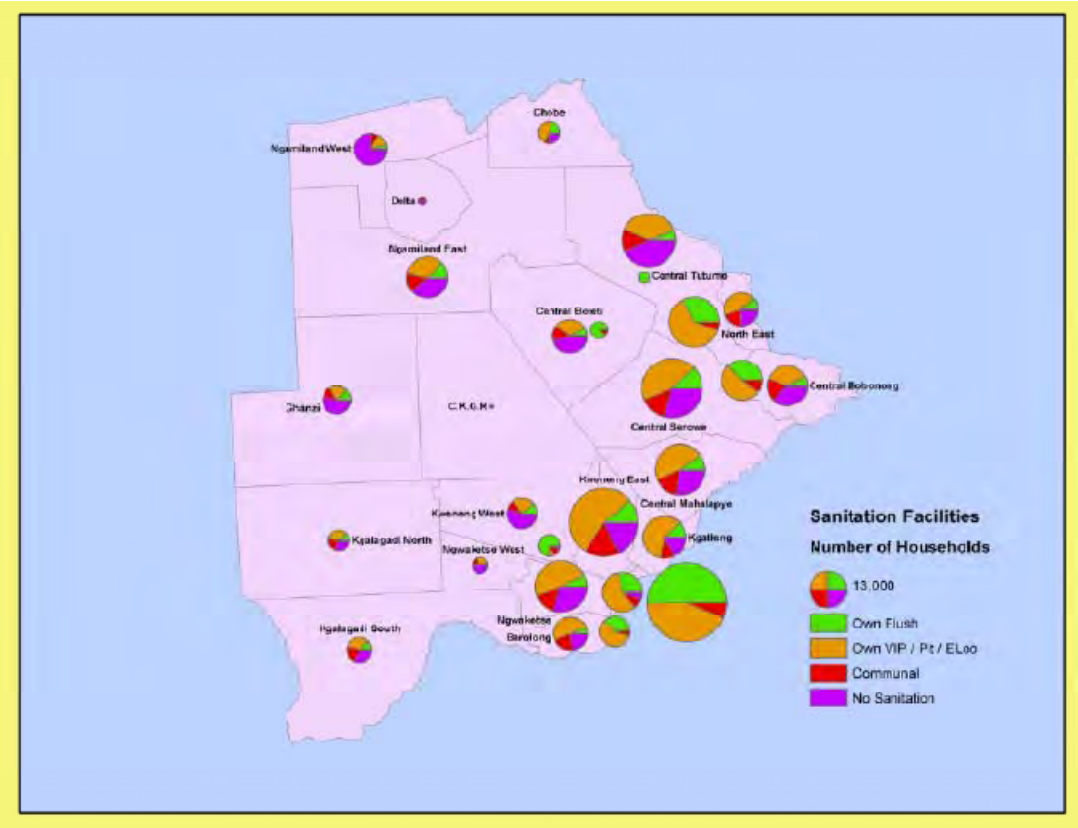

Figure 7. On site sanitation in Botswana (NMPWWS 2003, Vol. 1)

The 2001 census provides information on sewerage coverage for Botswana. This is indicated in Table 10. The national coverage is at 12.5%; with urban centres at 22% and 5% for rural areas respectively. Of the 64 major wastewater treatment plants in the country, 45 (70%) are pond type systems; the remaining 19 (30%) are made of 3 activated sludge, 1 trickling filter, 4 rotating biological contactors(RBC's), and 11 wetland systems. Their location is given in Figure 8.

Table 10. Sewarage coverage of Botswana

%	Sewer	Other Sanitation	Total
Urban	22	73	95
Rural	5	44	51
National Total	12.5	64.9	77.4

The effluent quality of the various sewage systems is given in Figure 8. The pond systems were found to be only 10% compliant with the Department of Water Affairs (DWA) effluent guideline. The RBC's achieved a 90% compliance.

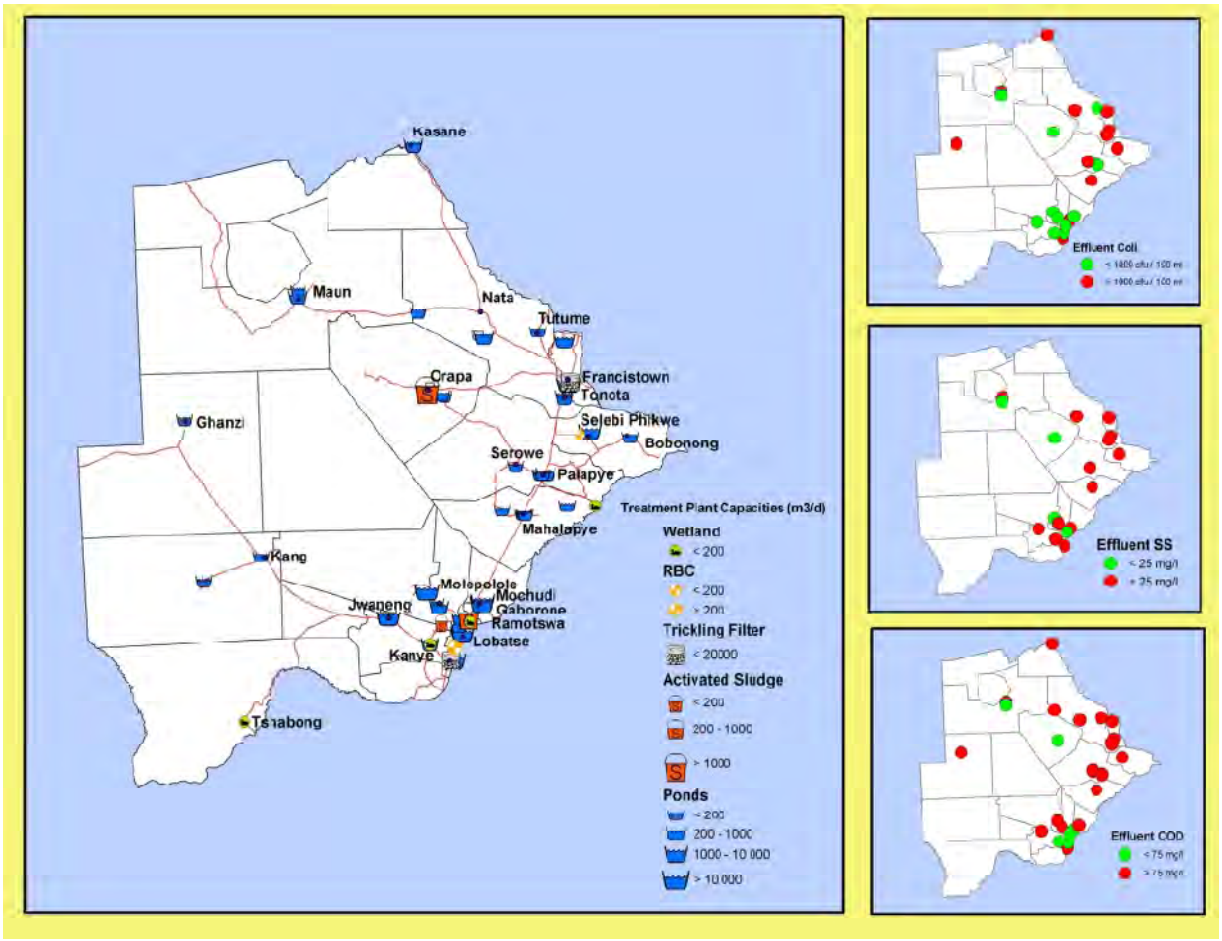

Figure 8. Main wastewater treatment plants in Botswana

6.0 SANITATION IN NGAMILAND

It can be noted that Ngamiland has the largest proportion of people without any sanitation services. Table 10 shows the percent households that own different sanitation services compared to the national average (NMPWWS 2003, Vol. 3). It can be noted that Ngamiland, is on average worse than the national average in the following cases: own flush, own VIP, own pit latrine, communal VIP, communal pit latrine, and no toilets at all; and has marginally better percentages only for own environ-loo (0.7 nationally against 1.0 in Ngamiland), communal flush (0.8 nationally against 1.7 for Ngamiland), and neighbours toilet (5.9 nationally against 6.0 in Ngamiland). Of particular concern is the fact that 53.7% of Ngamiland residents do not have a toilet at all. The problem is even exemplified when it is noted that 76% of the residents of Ngamiland West (Gumare) do not have any toilets.

Ngamiland only has one main sewage system in Maun. This consists of a vacuum tanker discharge bay, manually raked screens, degritting canals, anaerobic ponds, facultative ponds and aerobic ponds. The treated effluent is disposed of on an irrigation area, but no commercial agriculture has been established. The inflow of the plant is 400 m^3/day (NMPWWS 2003 Vol 6). The effluent quality of the treatment plant does not comply with national disposal standards (NMPWWS 2003, Vol. 6; Motsholabatho 2008). Other wastewater systems include a constructed wetland at Thuso rehabilitation Centre (10 m^3/day) and a pond system at Boro Prison designed for 100 m^3/day. The new Maun Hospital has also commissioned a wastewater treatment plant. A constructed wetland system is under construction for the Botswana Defence Force Camp at Shakawe, and another wastewater treatment plant is about to be commissioned at Gumare. Wastewater systems used in the Okavango Delta have been reviewed and while others had satisfactory performance, there were some which were poor (Aqualogic 2008). The projected wastewater generation rates for the ODRS are given in Table 12 (Aqualogic 2006).

It should be noted that sewage systems cover only a small fraction of the households, with most households relying on toilets and septic tanks. The danger of these has been shown this year, 2009, when some villages and settlements were flooded. Some soak aways were also covered by water.

Table 11. On site sanitation for Botswana and Ngamiland. Comm.-Communal; Neig.-Neighbour; E-L enviro-Loo

	Own flush	Own VIP	Own pit latrine	Own E-L	Comm. flush	Comm. VIP	Comm. pit latrine	Neig. toilet	None	Not reported
Nation	20.7	18.5	25.1	0.7	0.8	0.8	4.9	5.9	22.5	0.1
Average Ngamiland	9.3	8.0	15.9	1.0	1.7	0.6	3.8	6.0	53.7	0.1
Ngamiland Delta	2.7	0.2	0.4	0.0	36	0.2	7.6	0.2	52.5	0.0
Ngamiland East	12.7	10.6	22.5	0.4	1.1	0.5	4.5	8.3	39.2	0.1
Ngamiland West	4.3	4.4	6.5	2.0	0.9	0.8	2.4	2.7	76.0	0.1

Table 12. Progected wastewater generation rates, 2006-2011 (Aqualogic 2006)

Wastewater sources	Year					
	2006	2007	2008	2009	2010	2011
On-site systems (projected for ODRS)	1832	1850	1869	1888	1906	1925
Generation rate (m^3/day)	725	733	740	748	755	762
Projected wastewater from off-site systems (Maun) (m^3/day)	308	337	371	408	662	716
Projected wastewater from off-site systems (Gumare) (m^3/day)	21	21	21	21	21	21
% collected by on-site systems	69	67	65	64	52	51
Total (m^3/day)	1054	1091	1132	1177	1438	1499

It was estimated that the solid waste generated in the Okavango Delta area is 0.28 kg/person/day (Aqualogic 2006). Based on this, the total solid waste generated in the Okavango Delta Ramsar Site was estimated at 18,305 tonnes/year. There is only one sanitary landfill in Maun and “dumping” sites nine other villages: Tsau, Sehitwa, Toteng, Gumare, Nokaneng, Gumare, Etsha 6, Sepopa and Nxamasere. Concerns of groundwater pollution by the use of these dumping sites has been raised (Aqualogic 2006). More engineered landfill sites should be constructed in other villages located strategically around the Okavango delta Ramsar site.

7.0 CONCLUSIONS

Botswana is a semi-arid to arid country that relies heavily on groundwater. The two perennial rivers-Okavango and Chobe.Zambezi are subject to international agreements that have not been finalized. There are many institutions that are currently responsible for supplying water. The government is streamlining this by removing the water supply function from the Department of Water Affairs to the Water Utilities Corporation. This may reduce bottleneck that have existed in the water supply sector. The current and future water abstractions are expected to have only minor impact on the Okavango Delta system. Direct water draw from the river is considered to be the insignificant compared to other uses.

Of great concern for the TDA process are (i) sanitation service which are poor in Ngamiland (e.g. 54% or all residents in Ngamiland do not have a toilet) (ii) poor solid waste disposal as there is only one sanitary landfill located in Maun. Other villages and locations use gazette or ungazetted dumping sites. This has potential for groundwater pollution (iii) the main wastewater treatment plant in Maun produces effluent of poor quality. This has potential for contaminating groundwater. (iv) Use of septic tanks close to the main river/ Delta has potential to contaminate the river water.

8.0 RECOMMENDATIONS

The following recommendations can be made:

- The environmental flow requirements for the Botswana part of the ORB needs to be evaluated to ensure that water uptake from outside and within Botswana would allow for water needs at a level that is predetermined.
- The projected water abstractions in the Botswana part of the ORB can be implemented without affecting the integrity of the Botswana part of the ORB
- Upstream activities that may result in pollution should be monitored and steps put in place to ensure that the water quality is not degraded
- For the Botswana part of the ORB, the following should be done:
    - Appropriate solid waste disposal facilities should be constructed to that dumping sites which pose a threat to both ground and surface water are phased out
    - Wastewater treatment system efficiency should be improved so that danger posed from this source to water resources is reduced
    - Houses, especially those with pit latrines and septic tanks should not be built close to the river or in areas that are prone to flooding

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The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

In 1994, the three riparian countries of the Okavango River Basin – Angola, Botswana and Namibia – agreed to plan for collaborative management of the natural resources of the Okavango, forming the Permanent Okavango River Basin Water Commission (OKACOM). In 2003, with funding from the Global Environment Facility, OKACOM launched the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project to coordinate development and to anticipate and address threats to the river and the associated communities and environment. Implemented by the United Nations Development Program and executed by the United Nations Food and Agriculture Organization, the project produced the Transboundary Diagnostic Analysis to establish a base of available scientific evidence to guide future decision making. The study, created from inputs from multi-disciplinary teams in each country, with specialists in hydrology, hydraulics, channel form, water quality, vegetation, aquatic invertebrates, fish, birds, river-dependent terrestrial wildlife, resource economics and socio-cultural issues, was coordinated and managed by a group of specialists from the southern African region in 2008 and 2009.

The following specialist technical reports were produced as part of this process and form substantive background content for the Okavango River Basin Transboundary Diagnostic Analysis

Final Study Reports	***Reports integrating findings from all country and background reports, and covering the entire basin.***		
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		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009)*
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