Mainstreaming wastewater through water accounting: the example of Botswana

2006

Written by Jaap Arntzen with contributions from Kgomotso Molosiwa and Tlhaloganyo Kaisara

Disclaimer

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Acronyms

AS	Activated Sludge treatment
BNWMP	Botswana National Water Master Plan
CAR	Centre for Applied Research
CBO	Community Based Organisation
DC	District Council
DDP	District Development Plan
DWA	Department of Water Affairs
DSWM	Department of Sanitation and Waste Management
DWMPC	Department of Waste Management and Pollution Control
IWRM	Integrated Water Resource Management
EIA	Environmental Impact Assessment
FCC	Francistown City Council
GCC	Gaborone City Council
GIS	Geographical Information System
GWWTW	Gaborone Waste Water Treatment Works
JTC	Jwaneng Town Council
LA	Local Authority
LTC	Lobatse Town Council
NAR	National Asset Registry
NDP	National Development Plan
NMPSWW	National Master Plan for Sanitation and Wastewater
NRA	Natural Resource Accounting
NSWC	North-South Water Carrier
O + M	Operation and Maintenance
P	Pula (Botswana's currency)
RBC	Rotating Biological Contractors treatment
SADC	Southern African Development Community
SEEA	System for Economic and Environmental Accounting
TEA	Trade Effluent Agreement
TF	Trickling Filter Treatment
UAL	Un-Accounted Losses
VA	Value Added
WA	Water Authority
WAB	Water Apportionment Board
WARFSA	Water Research Fund for Southern Africa
WUC	Water Utilities Corporation
WWTW	WasteWater Treatment Works

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Jaap Arntzen
Gaborone

SUMMARY

Botswana has had water accounts since 2000, but the earlier accounts were restricted to surface and groundwater. Growing concerns about water scarcity and growing amounts of wastewater due to improvements in sewerage and wastewater treatment works offer opportunities for re-use and recycling that are hardly exploited to-date. Incorporating wastewater into the water accounts would contribute towards integrated water and wastewater planning within the IWRM perspective. Wastewater would be considered as an economic good instead of a waste product. The *specific* objectives of the study are to:

- Identify and quantify stocks and flows of wastewater in Botswana;
- Develop Natural Resource Accounting (NRA) as a planning tool that integrates fresh water resources and wastewater; and
- Explore economic, social and environmental benefits of using wastewater.

The planned study's activities include a review of Botswana's policies and programmes towards water management and sanitation; a review of treatment of wastewater under the SEEA structure and in water accounts of other countries; re-design of Botswana's water accounts to accommodate wastewater stocks and flows as comprehensively as currently possible; collection of wastewater data and construction of amended water accounts; and exploration of the environmental and economic impacts of different uses of wastewater (scenarios). The activities were all carried out and have led to the construction of modified and up-dated accounts. In addition, a survey was held among collectors of wastewater from the Gaborone WWTW's maturation ponds. This emerged during the study in response to the water crisis faced by Gaborone in 2004/05. It was expected that a survey of small scale re-use hold important lessons for re-use in future.

The Water Research Fund for Southern Africa (WARFSA) provided funding for the study. While the study focuses on Botswana, its findings are considered relevant to other countries in southern Africa.

The water use accounts show that water consumption amounts to 170 Mm^3 in 2003. An estimated 29.2 Mm^3 of that consumption was returned to WWTW in cities, towns and major villages (16% of water consumption) with an estimated outflow of 14.5 Mm^3 (8.5% of water consumption). The estimated amount of re-use is 3.0 $Mm^{3\ in}$ 2003, representing 11% of the outflow of WWTW and less than 1% of total water consumption. The survey of small scale re-use in Gaborone indicated that 0.1 Mm^3 may be collected, currently posing no threat to planned large irrigation schemes. The amount of 'new water' will increase in future because of introduction of treatment technologies with considerably lower water losses than the pond technology, construction of more WWTWs and more connections to the sewerage system of households and businesses.

The study found that it was possible and essential to incorporate wastewater into the water accounts as: 1. the amount of wastewater (WW) is growing much faster than water consumption, it is available close to the demand centres and it is often cheaper than reticulated water. 2. significant savings can be achieved by re-use and recycling and higher returns on investments in water and sanitation can be realised. 3. it is technically possible to incorporate wastewater into the water accounts by constructing three accounts: wastewater supply account, wastewater use account and wastewater stock account. The study used the opportunity to up-date existing use accounts of fresh water to 2003 and to start stock accounts for the country's major dams/reservoirs. The detailed results are presented in chapter 4 and appendix 2.

The National Master Plan for Sanitation and Wastewater has set the ambitious target of 96% of the outflow of WWTWs being re-used or recycled in 2030 (cf. 20% at present). This would yield significant benefits in terms of the possibility to postpone new water supply works and most likely lower water tariffs. If plans for new water supply works would not be delayed, the extra water available through re-use can be used productively with its associated economic benefits. The delay in construction of the additional capacity of the NSWC could lead to savings of over several hundreds of million Pulas in a five year period. Delay would also benefit the environment. Extra water could create value added in the range of P 300 to 1 500 million per annum and create thousands of jobs (including in small-scale home deliveries of treated waste water). Lower water tariffs would benefit domestic consumers and make the country more attractive for investors. These figures are indicative but nonetheless they demonstrate the economic importance of re-use and recycling.

Re-use is easier and safer health wise than recycling on the short run, as it is flexible and requires little extra investment, particularly small-scale re-use. Government plans currently to stimulate re-use for irrigation but the study found that re-use in different economic sectors is expected to yield higher economic benefits. Given the difference in WW treatment costs and the LRMC of fresh water, recycling of WW is expected to be viable in the medium to long-term. The current plans to expand the NSWC should not be implemented without a full assessment of the net benefits of the 'recycling option'.

The study raises several policy issues pertinent to water and wastewater management and planning:

- Re-use and recycling needs to be significantly accelerated if the policy targets are to be met and cost savings are to be achieved. Re-use is feasible in most cities and towns and some of the larger villages. Re-use and recycling should become integral parts of planning and construction of new wastewater treatment works;
- The best mix of re-use destinations needs to be determined for each WWTW. Irrigation is likely to be one of the suitable uses; others include the construction sector and gardening services for domestic users and commercial users. Re-use for cooling purposes as part of industrial processes is another possible use;
- Dedicated industrial sites for companies that could mostly use treated effluent need to be considered for Gaborone and Francistown. These could then be efficiently supplied by a dedicated pipeline;
- A feasibility study into water recycling needs to be urgently carried out for Gaborone. The Windhoek experience suggests that carefully controlled and monitored recycling is economically feasible and environmental and socially desirable. The net benefits of recycling should be compared with the net benefits of the expansion of the North-South Water Carrier;
- Small scale use of treated effluent needs to be encouraged in Gaborone and elsewhere. It is important that the collectors become more efficient and that collectors are registered and monitored to prevent health problems;
- The high costs of technologically advanced effluent treatment can be (partly) earned back by productive use of the extra outflow that is generated compared to the pond method; this does not happen at present;
- WUC needs to develop a multiple regression model to optimise the water supply from various sources (dams with inflow and different evaporation rates and later including some well fields that could be linked to the NSWC system). Optimisation refers to cost minimisation and maximisation of the water supply.

The study identified several areas for further research: better understanding of ground water recharge, economics of re-use and recycling and the performance of the small scale wastewater trade. In addition, the study identified the need to collect and store data on water quality (revival of the NAR), inflows and outflows of WWTW, inflows into dams, and inter-dam transfers.

With respect to water accounting, the study identified the need to develop more detailed stock accounts of dams (with inter dam transfers as well as imports and exports) and to separate use accounts into intermediate and final consumption. The introduction of different water quality categories and preparation of monetary accounts will require much better data.

CHAPTER ONE
INTRODUCTION

This chapter provides a brief review of Botswana's fresh water resources and wastewater before the study's objectives and approach are outlined. Section 1.1 deals with water scarcity and fresh water resources. Section 1.2 discusses the potential of wastewater re-use and recycling, and section 1.3 outlines the scope, approach and objectives of this study.

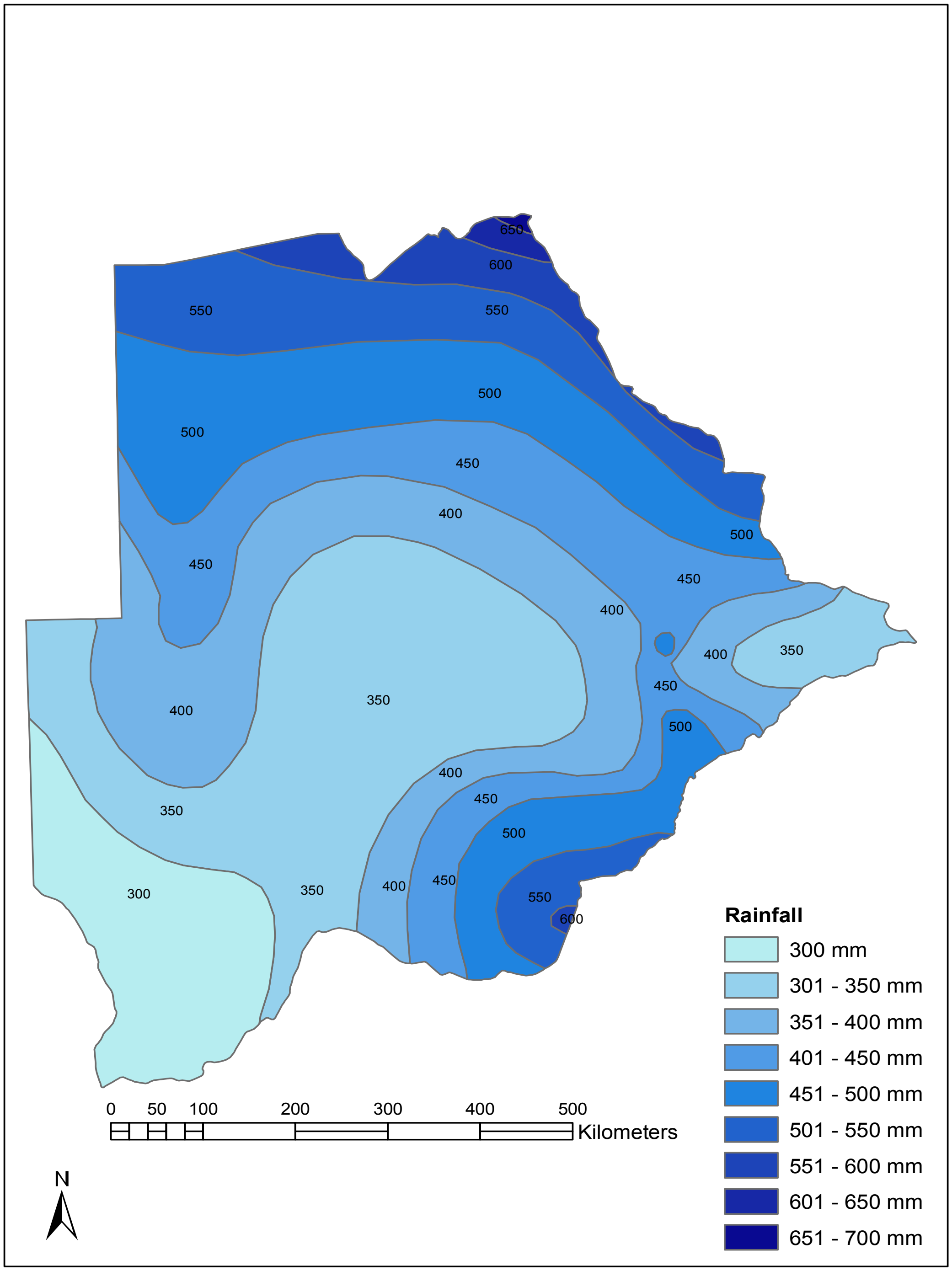
1.1 Water scarcity and fresh water resources

Water scarcity may be defined from different perspectives. *Hydroclimatological water scarcity* refers to water scarcity in semi-arid and arid areas, where evaporation exceeds rainfall. Droughts are common and often cause temporary water scarcity (seasonally and annually). *Demand scarcity* occurs when available water resources are unable to meet the demand of domestic and productive users. Botswana experiences both forms of scarcity but demand scarcity has been limited in the past due to the small size of the population and economy.

Fresh water resources refer to surface and groundwater resources, in Botswana mostly ephemeral rivers, dams and aquifers. Surface water is generally limited, and even absent in most of western and northern Botswana, except around the Okavango Delta and Chobe River. Ground water is also limited and recharge is generally low. Most of the perennial surface water resources are shared with neighbouring countries. Rainfall is low and highly variable and the evaporation exceeds the rainfall. Botswana thus experiences hydro-climatological water scarcity, severely restricting its agricultural potential. The spatial and temporal rainfall patterns are summarised in Figures 1.1 and 1.2. Rainfall is higher (up to 550 mm per annum) in eastern Botswana and towards the extreme north. The amount of rainfall is considerably lower in the west and north (250-400 mm p.a.) and a small dry pocket exist in the north east (less than 400 mm p.a.). Figure 1.2 shows that droughts are endemic and cyclical. When droughts occur, harvests fail and livestock mortality increases. For example, the severe drought of 1980-87 had a devastating impact on the national cattle herd (Figure 1.3). In contrast, the number of goats increased during the drought, which can be seen as an adaptation by livestock farmers as goats are more drought resistant.

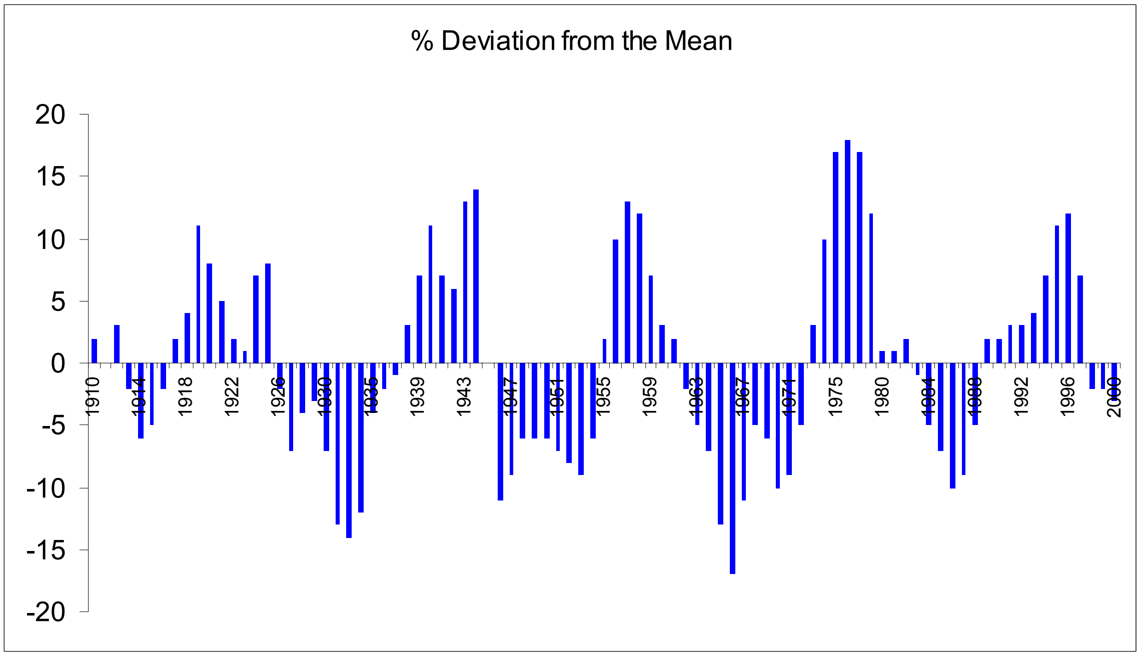
Water scarcity also refers to the inadequacy of water resources to meet demands. This type of water scarcity is becoming more common due to demand growth. *Water stress* is the mildest form of scarcity and exists when water resources are short of meeting the basic consumptive and productive needs of the population. *Water stress* is said to occur when there is less than 1700 m^3 of water available per person per annum. *Absolute scarcity* is found when water cannot meet all demands. This occurs when there is less than 1000 m^3 of water per person per year. Finally, *acute water shortage* exists when there is less than 500 m^3 per person per annum available.

Figure 1.1: Average annual rainfall distribution (in mm.)



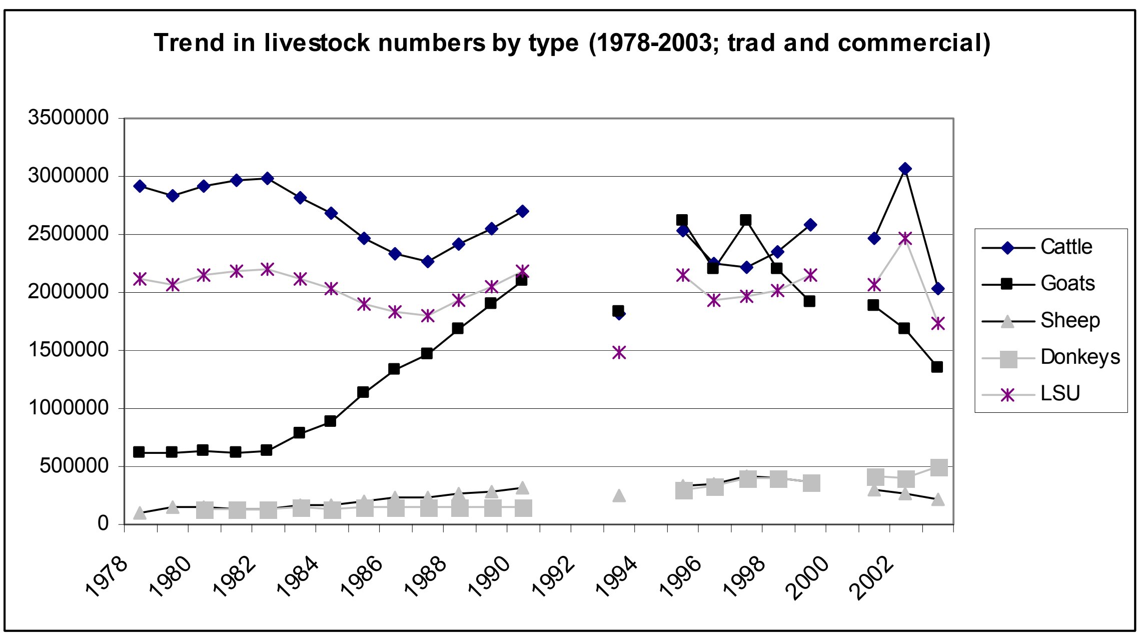
Source: Department of Surveys and Mapping, 2001.

Figure 1.2: Variations in annual rainfall (as % deviation from the mean)



Source: Tyson, 1986.

Figure 1.3:



Source: calculated from Agricultural Statistics

In some regional assessments, Botswana is not considered water scarce. For example, Ohlsson (1995) estimates the per capita water availability in Botswana at 14 107 m^3 (1990). Probably using the same data, Fruhling (1995) argues that Botswana does not experience water stress. Falkenmark and Lundvist (1997) argue that Botswana uses less than one percent of the available water resources, and is much better off than countries such as Malawi. These assessments include the large perennial resources of the Okavango and Chobe, which are shared with other countries[1]. They do not consider the spatial distribution of demand and supply with huge distances between demand and supply centres. Usually however, Botswana is recognised as one of the most water-scarce countries in southern Africa (e.g. SADC regional water strategy).

Surface water and run-off

Most rivers are ephemeral with the exception of the Okavango and Chobe Rivers in the north. The average annual run-off is estimated to be 696 Mm^3 (SMEC *et al*, 1991). However, suitable dam sites are limited, and can no longer be found in the south-eastern part of the country, where most people live.

Botswana has currently over ninety-four dams, most of which are small and used in the livestock sector. The country possesses five relatively large dams for urban water supply with a total storage capacity of 354.1 Mm^3, representing over 90% of the country's estimated total storage capacity. Several new medium sized to large dams are under construction or in the planning phase (e.g. lower Shashe, Ntimbale and Thune; Government of Botswana, 2003). No significant amounts of water are abstracted from the Okavango and Chobe Rivers due to the low population density in the areas, and minimal irrigation demands.

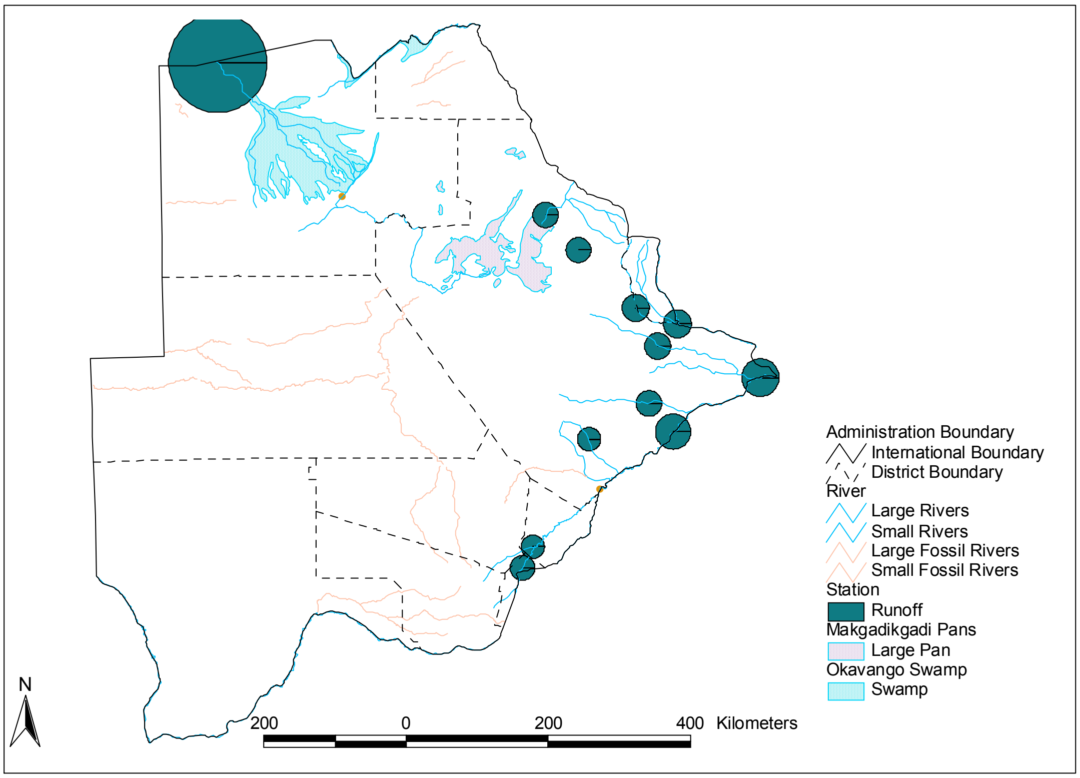
The country has six river basins, five of which are shared with neighbouring countries (Figure 1.4):

1. The *Molopo/Nossop River*, which forms the southern border between Botswana and South Africa, and flows into Orange River. However, due to the low rainfall in the basin the river has negligible flows for most of the time;
2. The *Limpopo River basin* forms the eastern border between Botswana and South Africa. Most rivers in eastern Botswana drain into the Limpopo River, including the Notwane, the Bonwapitse, the Mahalapye, the Lotsane, the Motloutse and the Shashe rivers. The basin constitutes a drainage area of some 80 000 km^2;
3. *Makgadikgadi drainage basin* to the west of the Limpopo basin. On the eastern side of the pans, the Mosope, Mosetse and the Nata Rivers all drain into the Makgadikgadi pans. The Boteti River feeds the western side of the wetland, which is part of the Okavango wetland system. The Nata River is the largest of the rivers draining into the Makgadikgadi pans. It drains a total area of 21 216 km^2, most of it in Zimbabwe;
4. *Kwando/Linyanti/Chobe Rivers* in the north of the country. The Kwando originates in Angola and enters Botswana after crossing through the Caprivi Strip in Namibia. In Botswana, it spreads out into the Linyanti swamps, which drains into the Savuti and Linyanti Rivers, eventually reaching the Chobe River.
5. *Okavango River drainage* and basin and Delta system in the northwest. This comprises the Okavango River, the Okavango Delta and its outlets. The Okavango system also extends down the Boteti River to the Makgadikgadi pans. The river and delta provide life sustenance for the local population and tourism in an otherwise dry sandy region (e.g. fishing and flood recession or *molapo* farming;

[1] There is likely to be double counting of shared resources in the assessment of individual countries.

6. *Internal drainage system*. The remaining part of the country is the *uncoordinated* internal drainage system. All runoff is lost through evaporation and seepage. In the central Kgalagadi, some fossil river channels run in an easterly direction, but these rarely carry any significant runoff.

Figure 1.4: Estimated annual run-off shared rivers (Mm³).



Source: Department of Surveys and Mapping, 2001.

Groundwater resources

The distribution of groundwater resources is highly uneven. Most groundwater resources are found in eastern Botswana. Renewable groundwater sources are very limited in western and northern Botswana, and often saline, where they exist (Figure 1.5). Groundwater resources supply most rural villages and the mining and livestock sectors. Concerns have been raised about groundwater depletion, especially around mines and large settlements. According to Ayoade (2001) four types of aquifers are found in Botswana:

- *Fractured aquifers* cover 27% of the country and are found in the crystalline bedrocks of the Archaen Basement in the east and in the karoo basalt. These have low yields with the median yield ranging between 2 and 10 m^3 per hour;
- *Fractured porous aquifers*, which cover 37% of the country, are found in Ntane and Ecca sandstones as well as in arkoses in the karoo formation. These aquifers have the highest yields;

- *Porous aquifers*, which cover 35% of Botswana, occur in sand rivers, alluvium and the Kalahari beds. These are usually high yielding and have a yield ranging between 10 and 300 m^3 per hour; and
- *Karstified aquifers* occur in the dolomite areas in south-western parts of Botswana as well as in other areas in Lobatse, Ramotswa and Kanye. Karstified aquifers account for only 1% of the land area of Botswana. These aquifers have a median yield of 4-20 m^3 per hour.

The above shows that Botswana faces serious challenges with regards to fresh water resources, which could curb future welfare and economic growth. The main challenges are:

1 A growing spatial mismatch between water resources and water demand, requiring costly transfer schemes or relocation of activities;
2 High variability of annual run-off related to highly variable rainfall patterns, limiting the safe yields of dams;
3 Lack of suitable high-yielding dam sites, especially near demand centres, leading to high evaporation rates from dams;
4 Most surface water resources are subject to the SADC Protocol on Shared water Courses, and need to be shared in a fair, equitable and sustainable way with other countries;
5 Limited groundwater resources, especially in the west, and high variations in recharge rates. Poor quality of groundwater in western and northern Botswana; and
6 Managing the growing urban and peri-urban water demand.

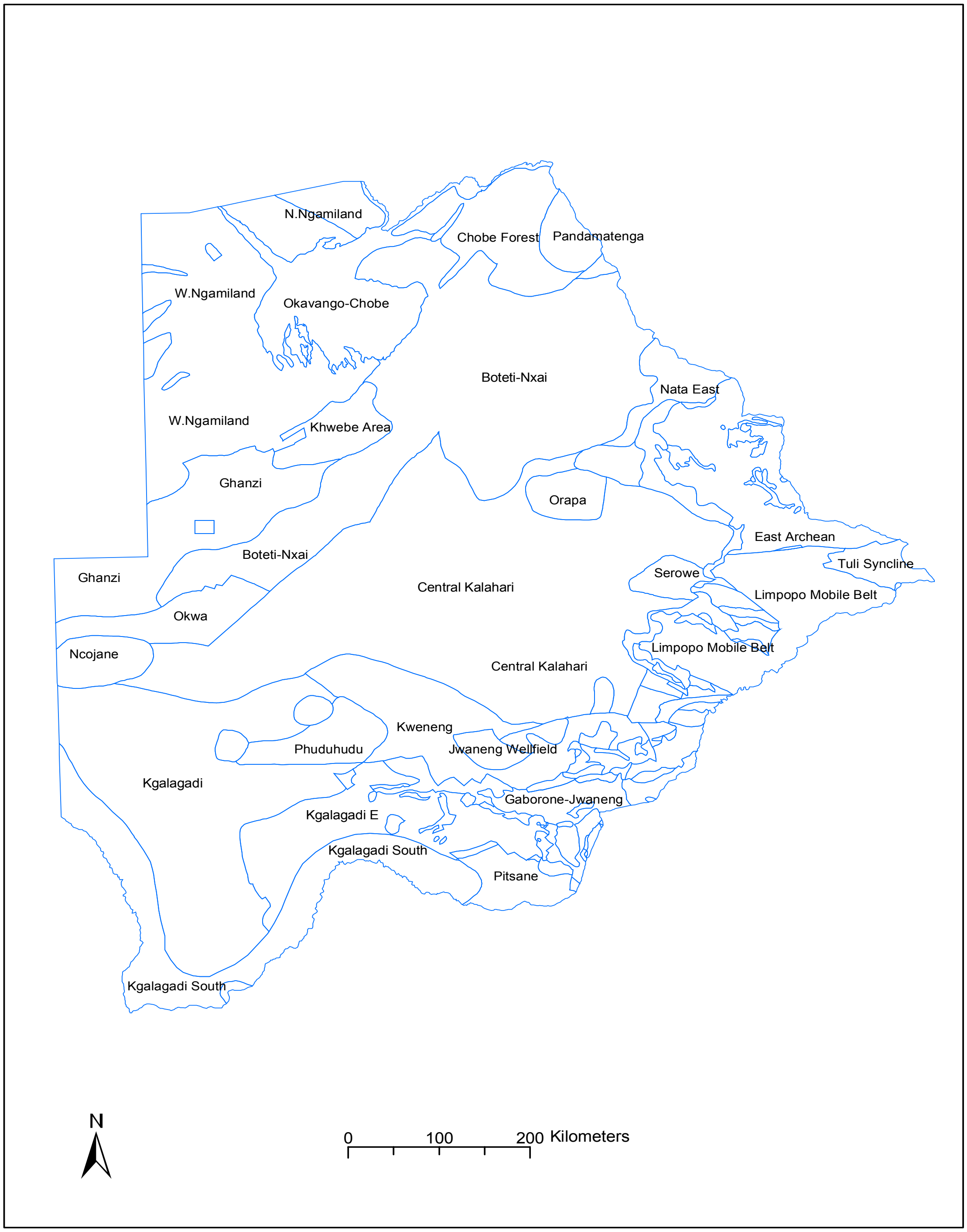
In recognition of these challenges, government and the private sector invest heavily in water development and transfer schemes. At the same, significant investments are made into sanitation and wastewater treatment works. Linking these investments would enhance their overall effectiveness and efficiency, but this is not sufficiently happening.

1.2 Growing potential of wastewater re-use and recycling

In 1991, the Botswana National Water Master Plan (BNWMP) recommended that a North-South Water Carrier (NSWC) be constructed to meet the water demand of south-eastern Botswana (SMEC *et al*, 1991). The BNWMP pointed out the growing potential of wastewater re-use and recycling, but unfortunately merely recommended that re-use and recycling of wastewater be further studied. No action was taken until the 2003 National Master Plan for Sanitation and Wastewater (NMPSWW) (SMEC *et al*, 2003). The NMPSWW found that the attitude towards wastewater could be best described as '*dispose rather than re-use'* (SMEC *et al*., 2003). Valuable time has been lost during the 1990s and early 2000s, ironically when the potential for re-use and recycling grew rapidly due to:

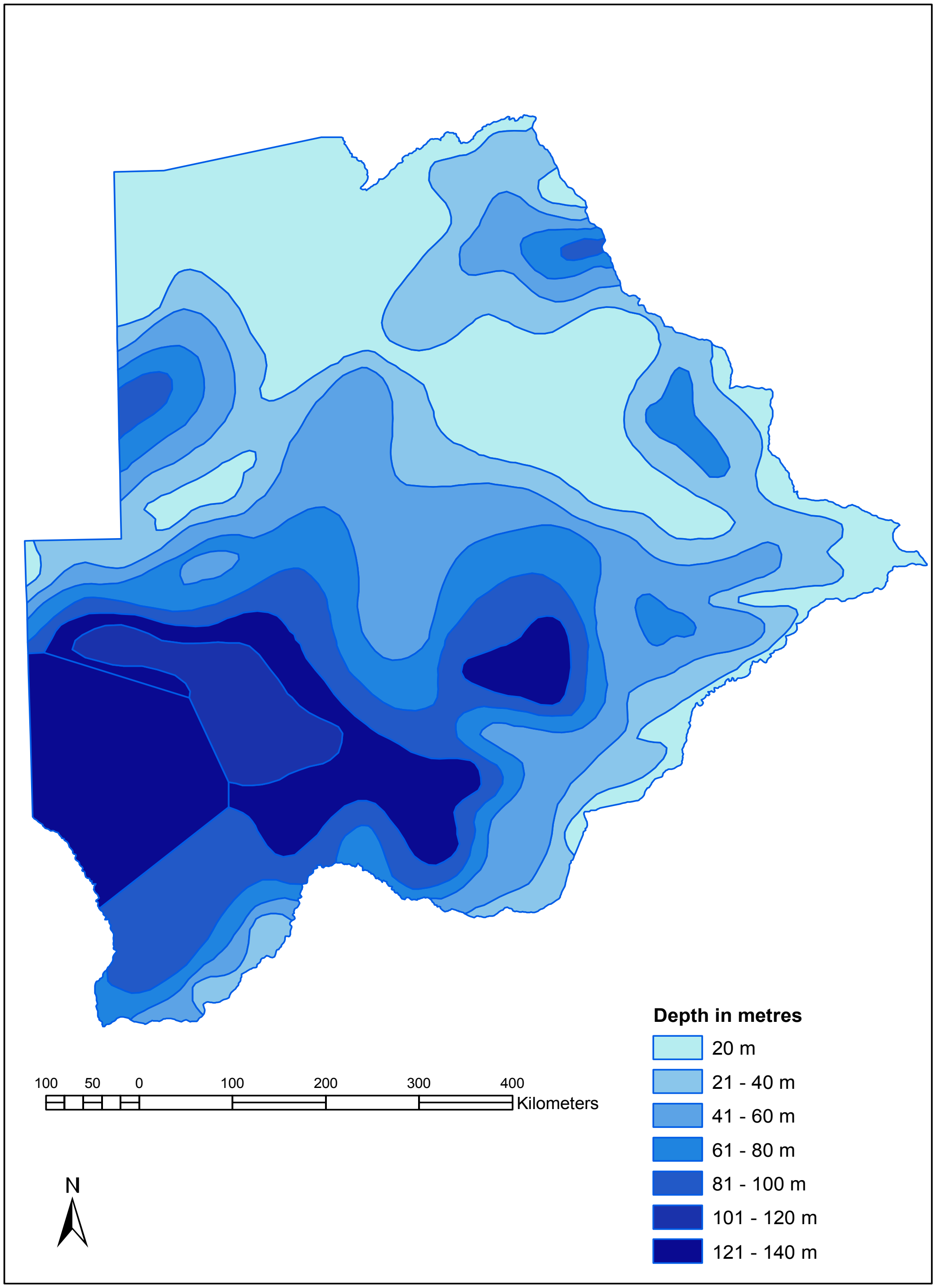
- The expansion of sewerage and wastewater treatment works (WWTW) to all urban areas and a growing number of large villages;
- The increase in households with in-house water supply that links to the sewerage system; and
- The proximity of treated wastewater close to demand centres was a major cost advantage compared to new dams and well fields that often required expensive water transfer schemes).

Figure 1.5: Major well fields



Source: Department of Surveys and Mapping, 2001.

Figure 1.6: Average depth of groundwater (metres below surface).



Source: Department of Surveys and Mapping, 2001.

Due to the construction of more sewerage systems and increasing water consumption, the amount of wastewater has increased. Over sixty four wastewater treatment works (WWTW) exist in the country. Most of these (70%) use the pond sanitation technology, which is cheap but has high evaporation losses. Other treatment technologies that are used include wetlands, trickling filters (TF) and activated sludge (AS).

Most wastewater is produced by five large WWTW located in Gaborone, Francistown, Selebi Phikwe, Lobatse and Orapa; the five plants together account for around 80% of the wastewater. The country's treatment capacity works at approximately two-third of its capacity with an estimated inflow of 61 955 m^3/day and an outflow 34 158 m^3/day (SMEC *et al*, 2003). In 2002, the inflows into WWTW were estimated to be 24.5 Mm^3 and the outflows 12.3 Mm^3 (or 'new' water; SMEC *et al*, 2003). This is 18.5% of the water demand of cities, towns and large villages. Only 20% of the outflow is re-used, mostly for watering of public gardens, golf courses and production of livestock fodder. Plans exist to re-use wastewater for irrigation around Gaborone and Francistown.

The low level of re-use and recycling is due to several constraints, including:

- Unfamiliarity with and unfavourable attitudes towards recycling and re-use;
- Continued policy bias towards supply augmentation schemes despite cost escalations; and
- Institutional separation of responsibility for wastewater treatment and potable water provision.

During the 2004/05 water crisis in Gaborone, households were encouraged to re-use 'new water' for their gardens. The construction and landscaping sectors were also encouraged to switch to 'new water' If these efforts succeed, the water crisis could have taught the country important lessons about re-use and recycling. It is expected that re-use will increase in the near future, particularly for irrigation, out of economic necessities (lower costs) and to meet the ambitious re-use targets set in the wastewater strategy.

1.3 Study objectives and approach

As argued above, the amount of wastewater is rapidly increasing, and so are the costs of conventional augmentation schemes of fresh water. Wastewater is currently under-utilised, and it is not considered as an 'economic resource'. This study aims to promote integrated water resource management in Botswana by incorporating wastewater into the tool of natural water accounts. The *specific* objectives are to:

- Identify and quantify stocks and flows of wastewater in Botswana;
- Develop Natural Resource Accounting (NRA) as a planning tool that integrates fresh water and wastewater; and
- Explore economic, social and environmental benefits for Botswana of using wastewater.

The study focuses on Botswana, but the findings are relevant to other countries that have not yet incorporated wastewater into their water accounts (e.g. Namibia and South Africa) or that plan to develop water accounts.

Botswana's current water accounts only deal with *fresh water*, i.e. ground and surface water. The study will assess ways in which wastewater stocks and flows can be incorporated into the water accounts. The activities include:

- Review of Botswana's policies and programmes towards water management and sanitation;
- Review of treatment of wastewater under the SEEA structure and in water accounts of other countries to assess the options for wastewater treatment and their (dis-)advantages;
- Re-design of Botswana's water accounts to accommodate wastewater stocks and flows as comprehensively as currently possible;
- Collection of wastewater data and construction of amended water accounts;
- Exploration of the environmental and economic impacts of different uses of wastewater (scenarios).

The Water Research Fund for Southern Africa (WARFSA) provided funding for the study.

1.4 Concluding remarks

It is remarkable for a semi-arid country like Botswana that re-use and recycling of wastewater is limited. Scarcity of fresh water resources and the growing distance between freshwater supplies and water demand centres should offer strong economic, social and environmental incentives for re-use and recycling of wastewater. Unfamiliarity with and negative attitudes towards new water, separation of institutional responsibilities for fresh water and wastewater, and continuation of the policy bias towards supply augmentation schemes, facilitated by the relative prosperity of the country, are responsible for this state of affairs. This WARFSA funded study seeks to develop a methodological tool for their integrated management within the broader context of Integrated Water Resources Management (IWRM) and is therefore timely, if not overdue.

CHAPTER TWO
WATER AND WASTEWATER MANAGEMENT AND PLANNING

2.1 Introduction

Botswana manages its water resources actively and in an organised, coordinated manner even though it does not have a water policy or up-to-date water legislation. This 'lucky' situation may be attributed to the 1991 Botswana National Water Master Plan (BNWMP), sustained economic growth and good governance, guided by National and District Development Plans. The BNWMP act as a long-term water development strategy, and has guided water planning and development since the 1990s. Nonetheless, the development and implementation of comprehensive water policy and water legislation is necessary to strengthen and broaden the scope of water management, and should therefore be a priority. The on-going review of the BNWMP is expected to produce an IWRM policy and new water legislation[2]. It should also address policy gaps such as:

- Water demand management and conservation;
- Water management decentralisation;
- Efficiency and water allocation; and
- Productive water provision outside urban areas.

This chapter reviews the literature on water and wastewater management, and tries to assemble base line information on both for Botswana. Section 2.2 discusses the major water planning efforts, followed by a discussion of water legislation and a review of the leading water management institutions. Similarly, Section 2.3 discusses the planning of wastewater management, wastewater legislation, leading institutions and qualitative aspects of wastewater.

2.2 Water planning and policies

The Botswana National Water Master Plan (BNWMP; SMEC *et al*, 1991) and National Development Plans (NDPs; Government of Botswana, 2003) form the core of Botswana's water planning, development and management. The 1991 BNWMP forecasted a significant growth in demand that could be met in most parts of the country by expanding local reticulation systems and well fields. The projections indicated that the demand could not be met in south-eastern Botswana with the country's capital Gaborone. Therefore, a multi billion Pula water transfer scheme was recommended to construct a dam in northern Botswana and transfer the water through a 400 km pipeline to south-east Botswana. The North-South Water Carrier became operational in 1999.

Botswana's strategy is to provide its citizens with reliable and affordable water to serve people's needs, especially the subsistence needs. Government efforts have focused on establishing water reticulation systems in cities, town and villages to ensure adequate access to water for domestic use and for productive sectors, based there. The Water Utilities Corporation (WUC), the Department of Water Affairs (DWA) and District Councils (DCs) are responsible for reticulated water supply in urban areas (WUC), seventeen large villages (DWA) and rural areas (over four hundred sixty villages; DCs).

[2] A new Water Act was prepared as part of the 1991 BNWMP, but the Act has never been brought to parliament for adoption. The reasons for this remain unclear.

Two inter-related policies aim to ensure that basic water needs are met. Firstly, reticulated water supply systems are constructed, maintained and -where necessary- up-graded in all settlements with more than two hundred inhabitants. The current norm is that all persons should have access to a water point within five hundred meters of their homes. Water is supplied through communal standpipes or private connections (yard and house). Secondly, water tariffs are set in such a way that basic water needs are affordable. Four use bands are distinguished, with the lowest band reflecting the basic needs (up to five m^3 per month). It is assumed that standpipes are only used for basic needs. Therefore, water from standpipes in rural villages is free, while a nominal fee is charged in urban areas, which includes other services. Water charges for the lifeline band for private connections are low, and subsidised by large users (in excess of 25 m^3 per month). Communal standpipes are currently being phased out to prevent water wastage[3].

WUC and DWA use block tariffs, based on different cost recovery principles. WUC pursues *full* cost recovery in urban areas and its tariffs are based on the long run marginal costs (LRMC). DWA tariffs for rural areas are based on partial cost recovery. The operation and maintenance costs need to be recovered together with 'part of the capital costs' (NDP8 and 9). The block tariff system attempts to keep the basic water needs affordable and discourages water wastage. In practice, cost recovery principles are not yet met, especially DWA's. Government pays a surcharge, which must be considered as an implicit government subsidy[4].

The current tariffs are presented in Table 2.1. Water tariffs are highest in urban areas such as Gaborone. Water tariffs in large rural villages that are supplied by the NSWC are higher than in large villages with their own water supply (mostly well fields).

The WUC rates are the highest due to the full cost recovery that has to be achieved. Water tariffs for rural water from the NSWC are similar to WUC charges reflecting the high costs of the pipeline. All water providers have a steep block tariff that penalises higher consumption with high tariffs. The band width differs between urban and rural areas. In rural areas, the highest tariff applies to monthly consumption above 40 m^3 compared to 25 m^3 in urban areas. In other words, the water conservation incentive is stronger in urban areas.

During a WDM training workshop in Lusaka, a comparison was made of the water tariffs in southern Africa. The results are summarised in Figure 2.1. The comparison shows that the Gaborone tariffs are the highest in the region. The differences could be attributed to differences in supply costs (some countries have sufficient water resources), differences in pricing principles (e.g. full or partial cost recovery and use of average or marginal costing), and water management decisions of the past. The last factor must explain the differences in tariffs between Gaborone and Windhoek. Windhoek has less rainfall and similar pricing principles and yet it has lower water tariffs!

Productive sectors that operate outside settlements are responsible for their own water supply. These so-called self providers are mostly livestock farmers and mining companies. Self providers apply for water rights from the Water Apportionment Board (WAB), but have to finance water development themselves. No resource charge is levied, and livestock farmers may benefit from subsidies under several agricultural subsidy schemes.

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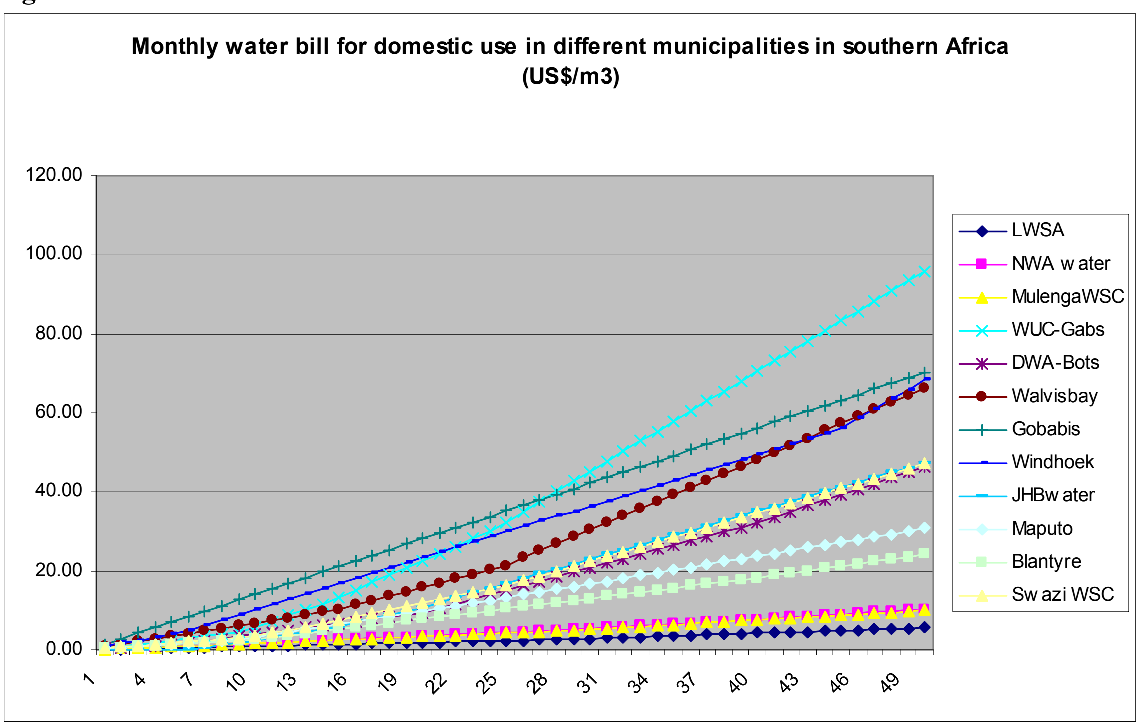
[3] This could pose problems for those who cannot afford to pay for water retain access. Water subsidies may have to be provided directly to those who cannot afford or the lifeline band may be provided free of charge (as done in South Africa).
[4] This contradicts the policy intention of phasing out subsidies.

Table 2.1: Water tariffs for Gaborone and rural villages by user band (1990-2004)

DWA tariffs for rural villages connected to the NSWC			
Monthly use band	**1990**	**2000**	**2004**
0 - 5 m^3	0.30	0.65	1.90
6-20 m^3	0.60	1.65	4.75
21-40 m^3	1.20	3.40	9.80
over 40 m^3	1.20	4.20	12.15
DWA tariffs in other rural villages			
Monthly use band	**1990**	**2000**	**2004**
0 - 5 m^3	0.30	0.65	1.25
6-20 m^3	0.60	1.65	3.20
21-40 m^3	1.20	3.40	6.60
over 40 m^3	1.20	4.20	8.15
WUC tariffs in Gaborone (domestic and business)			
Monthly use band	**1990**	**2000**	**2004**
0-10 m^3	0.65	1.45	2.10
11-15 m^3	0.65	4.40	6.40
16-25 m^3	2.60	5.60	8.15
26-40 m^3	2.60	7.75	11.30

Sources: compiled from DWA and WUC data.

Figure 2.1:



Source: WDM training workshop Lusaka July 2004.

The water planning and development strategy has been successful to the extent that to-date most people have access to reliable and affordable water. The country is therefore well placed to meet the Millennium Development Goals regarding water and sanitation. The comparison of the Population Census 1991 and 2001 shows that the percentage of households with access to piped or tapped drinking water has increased significantly during the last 25 years: 1981: 56%; 1991: 77% and 2001 87.7% (Kelekwang and Gowera, 2003). A spatial imbalance remains however. According to the Population census 2001, almost all (99.5%) urban households had access to reticulated water compared to 96.7% in large rural villages and 73.3% in other rural villages. Households without piped or tap water mostly rely on boreholes (5.1%), wells (1.8%), tankers (0.8%) or other water points (4.5%; Kelekwang and Gowera, 2003). Particularly boreholes are considered safe and reliable water sources.

Access to water has also improved in qualitative terms. A growing proportion of households have water inside their yard and/or house, and a decreasing number of households rely on public standpipes.

In brief, Botswana still largely adheres to the supply-oriented water planning approach, although the interest in water conservation, re-use/ recycling of wastewater and integrated water resource management is slowly increasing. Water planning remains largely centralised and allocative efficiency of water consumption is not yet addressed in policies. Wastewater re-use and recycling are not yet considered as an alternative or supplement to fresh water resources.

2.2.2 Water resources legislation

Water legislation is old and –as stated before- needs to be reviewed. Below, we briefly discuss the current legislation.

Waterworks Act 1962
This Act is meant to encourage and protect public water supply systems. Waterworks areas need to be delineated and gazetted and a Water Authority appointed. The Water Authority receives the water development rights and has the duty to develop a water supply system. The Water Authority (WA) has effectively the monopoly of water supply. WUC is the WA in urban areas; DWA in large villages and DCs in rural villages.

This Act gives the Minister the right to approve tariffs, and prevent water wastage, for example through the establishment of standards for unaccounted losses (UAL). The latter has not been done.

Water Act 1968
According to the 1968 Water Act, the state owns all water resources. The state has delegated water user and development rights to several water providers:

- The Water Utilities Corporation (WUC) has the duty to provide safe drinking water to urban areas in so-called *water work areas*. WUC has a monopoly in these areas; other institutions or individuals are, for example, not allowed to drill boreholes in these areas. The WUC has to break even, i.e. charge the full resource costs to end-users. Since the late 1990s, WUC has assumed responsibility for the operation of the NSWC, which supplies urban areas and several large villages;
- The Department of Water Affairs (DWA) is charged with the establishment of reticulated water supply systems in rural villages. In addition, it operates and maintains

these systems in seventeen large rural villages. Where these villages are supplied through the NSWC, DWA purchases the water from WUC; and
- The District Councils (DCs) operate and maintain the water supply systems in smaller rural villages;

Self-providers apply for surface or groundwater rights to the Water Apportionment Board (WAB). The WAB grants such rights with an abstraction ceiling and the condition that as much water as possible of the original quality is returned. Performance details of boreholes are recorded in the National Borehole Registry. Monitoring of abstraction of self-providers is inadequate. This is a major shortcoming of the country's water management system, as self-providers account for more than half of the total water consumption.

The Water Act controls access to and use of water resources. Water rights are needed to abstract, store, dam and divert water. Water rights are granted for a specific purpose (e.g. mining, forestry, industrial power generation and agriculture) of abstraction and indicate the maximum amount and period of abstraction. The abstraction ceiling varies according to the use but usually does not exceed 22.75 m^3 per day. Water rights may be cancelled if they are not used within three years or if there is too little water, for example during droughts. The rights are conditional:
- Water should be returned, when and where reasonably possible, to the body from which it was abstracted;
- As much water as possible (given the type of use) should be returned;
- Water should not be polluted.

The Water Apportionment Board (WAB) grants the water rights and keeps a record of all water rights. The penalties for non-compliance were high in 1968, but have never been adjusted and are now extremely low in real terms. Other deficiencies of the Act include:

- There is inadequate water demand prioritisation and allocation;
- It does not provide for integrated water management approach, for example, catchment area management;
- The treatment of water pollution is inadequate;
- There is no provision for management of shared water courses, i.e. the Act is not in line with the SADC Protocol; and
- The monitoring and enforcement mechanisms are inadequate.

2.2.3 Water resources institutions

Water resource planning and monitoring of use is not adequately institutionalised. No single institution is responsible for IWRM planning in the country, and no water planning and policy unit exists. The absence of a policy and planning institution has contributed towards the delay in water law reforms. Lack of such an institution has further contributed to fragmentation and gaps in water supply, use and management data.

Table 2.2: Water resources responsibilities of institutions

Type of institution	Responsibilities
I. Supply agencies	
Water authorities (WUC, DWA and DCs)	Supply planning Duty to supply reticulated water in waterworks areas Right to propose water tariffs Right to supply other users, but not at lower charges than those for waterworks areas
Water exploration and supply companies	Groundwater explorations, Borehole drilling and well field development Desalination
II. Waste water treatment agencies	
Wastewater and sanitation planning (DWWS- MoLH)	Implementation of NMPSWW Support of local government for sanitation and wastewater
Wastewater treatment authorities (City and Town Councils; District Councils)	Operation and maintenance of sewerage and wastewater treatment infrastructure Adequate disposal of treated inflows, including re-use and recycling.
III. Water management institutions	
Water Apportionment Board (national level)	Allocation of water rights Monitoring of the use of the water rights The Registrar is based in DWA
District Land Boards and sub-Land Boards	Allocate land use rights Allocate borehole drilling rights
National Conservation Coordinating Strategy Agency	Implementation of EIA legislation, including reviewing the EIAs Coordination of resource use and management (e.g. land and water)
IV. Other stakeholders	
End users	Water consumption and conservation
Non-government organisations	Advocacy and Lobbying Implementation of research and projects with Community-Based Organisations (CBO projects; e.g. Every River has its people)
V. Water Research such as University of Botswana, BOTEC and Department of Geological Survey	Research on water and wastewater issues

2.3 Wastewater planning and management

2.3.1 Introduction

Wastewater planning and management started in the 1990s. It is institutionally separated from fresh water management, making it more difficult to integrate water and wastewater management. Several institutions are involved in wastewater and sanitation services, including the Department of Sanitation and Waste Management (DSWM[5]), local authorities (Districts and Town councils), Department of Water Affairs (DWA) and the private sector. The roles of different stakeholders are summarised in table 2.3.

The DSWM coordinates and monitors sanitation and waste management and promote effective and efficient implementation of sanitation and waste projects. Local authorities take care of off-site wastewater systems and service on-site sanitation. The private sector is involved mostly with the provision of wastewater/sanitation services such as collection. The DWA monitors the discharge of wastewater and compliance with the set standards.

[5] It is now called the Department of Waste Management and Pollution Control (DWMPC)

Table 2.3: Institutional responsibilities of wastewater and sanitation

Institution	Responsibilities
DSWM (now the DWMPC)	The department is responsible for the management of wastewater resources. It is responsible for the following in particular: • Policy administration and implementation; • Implementation and monitoring of NMPWWS; • Monitoring of the wastewater and sanitation sector performance; • Coordination at central and local government levels; and • Support of sector development, particularly capacity building of local authorities
Local authorities/ Councils	The local authorities govern the wastewater produced in an area, in terms of quality and quantity. In so doing, prevention of environmental pollution is improved. LAs perform the following duties: • Operation and maintenance of off-site wastewater systems; • Deal with new water connections and sanitation; • Service on-site sanitation (only as contractor) managing trade effluent discharge matters including enforcement; and • Executing the planning of wastewater and sanitation at local level.
DWA	The DWA is responsible for the issue of discharge permits. These permits show the holder different qualities of wastewater for different applications. The department also monitors the performance in relation to discharge and enforcement to counter compliance.
Private sector	The private sector is responsible for the provision of consulting services, construction of facilities and provision of wastewater/ sanitation services like fleet management, billing and collection.

2.3.2 Policy towards wastewater

In response to perceived health and environmental risks, the Botswana Policy for Wastewater/Sanitation Management was develop to promote people's health and well-being through appropriate and sustainable wastewater/sanitation management and through mechanisms for the protection and conservation of water resources. The specific policy objectives are to (Government of Botswana 1999):

1. Create an enabling environment through institutional and organisational rationalisation and development of an appropriate legislative framework;
2. Involve local authorities, communities and users in the planning and management of wastewater/sanitation to ensure sustainability;
3. Introduce pricing and cost-recovery principles and guidelines, and design effective and sustainable operation and maintenance systems;
4. Develop national effluent discharge quality standards; and
5. Encourage re-use and recycling of wastewater.

The policy emphasises the role of economic incentives to manage wastewater, including: charges for wastewater/sanitation services, fines for non-compliance, linking effluent charges with water tariffs, and effluent agreements with companies. The policy advocates for the establishment of national effluent utilisation quality standards, and refers to the 2005 EIA-legislation as an additional instrument. In terms of institutional structure, the DSWM is responsible for the coordination and supervision for the implementation of this policy. Individual institutions such as DWA, local authorities and the private sector are responsible for specific implementation activities.

The 1991 BNWMP and the 1999 Wastewater Policy provided the incentive to prepare the 2003 National Master Plan for Wastewater and Sanitation (NMPWWS). The NMPWWS operates as the long-term strategy for wastewater treatment, re-use and recycling strategy. Its overall objective is to 'evaluate the current scenario on wastewater generation and disposal, on-site facilities and their impact on the environment, and to develop planning and implementation strategies for regulating the generation, collection and disposal of wastewater in an environmentally friendly way and acceptable manner' (SMEC *et al*, 2003, p. 3).

In 2001, 39% of the population had access to acceptable sanitary services (own flush or ventilated improved pit latrines); 23% of the population, mainly in rural areas, did not have access to any sanitation facility at all. The majority of people in urban areas (53%) have access to adequate sanitation while in rural areas this figure is much lower (18%). The average types of on-site sanitation facilities in Botswana as per the 2001 Population Census include: own flush toilet 21%; own Ventilated pit latrine 18%; own pit latrine 24% and own enviro-loo. Thirteen percent used a communal toilet. A detailed breakdown of sanitary facilities by location is provided in Appendix 2.

A review of the WWTW showed that many treatment facilities are not properly management. No reliable flow records are kept and personnel do not seem to be aware of the importance of operational procedures for running the wastewater treatment work at its designed performance level. Fieldwork conducted for this study showed that the situation has not changed much since 2002.

The most commonly found ponds technology leads to very high evaporation losses (30% to 65% of inflow), compared to for example 5% losses for the more expensive TF technology in Francistown. If wastewater is a valuable resource for re-use and recycling, evaporation losses need to be considered in the choice of technology. Baseline information about the existing WWTW is provided in Appendix 3. Another fifteen wastewater treatment projects are being planned.

The quality of outflow does not meet the re-use application guidelines set by DWA (table 2.4). The DWA standards for wastewater discharge are considered strict but with the use of pond technology in Botswana, effluent produced will not comply with the standards for wastewater discharge to the environment.

Table 2.4 DWA Guidelines for irrigation with domestic effluents

Category	Method of Re-use	Level of treatment	BOD (mg/l)	Faecal Coli forms (cfu/100ml)
A	Irrigation of trees, cotton and other non-edible crops.	Primary treatment or septic tank and waste stabilisation ponds	60	50 000
B	Irrigation of citrus fruit trees, fodder crops and nuts.	High loaded secondary treatment or waste stabilisation ponds.	45	10 000
C	Irrigation of deciduous fruit trees, sugarcane, cooked vegetables and sports fields	Secondary treatment with maturation pond or stabilisation pond systems including maturation ponds.	35	1 000
D	Unrestricted crop irrigation including parks and lawns	Low loaded secondary treatment or waste stabilisation pond systems followed by tertiary treatment (e.g. filtration) with disinfection	25	100

Source: SMEC *et al*, 2003

Figure 2.2: Trickling filters at the new Francistown wastewater treatment works

Figure 2.3: Secondary treatment pond in Selebi-Phikwe.

The NMPWWS is the foundation for sanitation and wastewater management until 2030. Therefore, it made major recommendations related to wastewater management:

- Legislation, regulations and instruments. Legislation for the wastewater and sanitation sector needs to be enacted, including the right to a clean and healthy environment; empowerment of regulators and stakeholders to protect the environment from pollution; an institutional framework aimed at providing the best service with the available resources; and institutional/stakeholder participation in the planning, design and implementation of strategies of wastewater and sanitation management; and finally efficient and equitable administration of the legislation by appropriate processes, practices and economic instruments. Proposed additional legislative instruments include: licences for the operation of sewerage and wastewater facilities; establishment of a National Asset Register (NAR) which record the performance of individual WWTW; permits for commercial discharges of effluents. Holders of these licences are bound to comply with certain conditions associated with prevention of pollution of the environment. Trade Effluent Agreements (TEAs) between industries and local authorities would be monitored.
- Wastewater plans and facilities. The NMPWWS identified settlements where wastewater services are required during the next twenty years and developed a set of strategic plans for these settlements to assist planners in coordinating services. The NMPWWS proposes that the planning and management of wastewater be extended to large villages, where most of the existing wastewater works are institutional, for example linked to prisons and hospitals;
- Promotion of re-use of wastewater. The target for 2030 is to increase re-use from 20% to 96% of the outflow (or 48% of the inflow) through agricultural re-use and reduction of losses in the treatment systems. Agricultural re-use is judged economically viable in ten cities, towns and large villages. The anticipated situation in 2030 will be: 48% of the inflows is re-used; 42% is lost through evaporation and treatment and 10% is discharged into the environment;
- Promotion of on-site sanitation. A new National On-site Sanitation Programme (NOSSP) is recommended to promote "sustainable on-site sanitation through coordination, cooperation and capacity building". The programme focuses on education and community awareness, and target an increase in service level of those who depend on pit latrines and those without access to sanitary facilities.
- Cost recovery and affordability. A staggering P 3.2 billion would be needed for implementation of the NMPWWS in the NDPs. Full cost recovery is considered not affordable for households, and the NMPWWS proposes recovery of the operational costs for households. A tariff of P290 per household per annum or P25 per month is considered affordable, and some P2.08/m^3 would be charged for collection and treatment costs (assuming a water consumption of 165 l/c/d and a return flow of 80%).

NDP 8 and 9 demonstrate the growing attention for sanitation and wastewater treatment. NDP 8 observes that if re-use of wastewater could lead to deferment of large investments in water resources development. If all wastewater would be recycled, phase 2 of NSWC could be deferred by five years. Studies were proposed to assess the possible re-use options and treatment methods. Possible re-uses include irrigation, groundwater recharge and recycling for potable usage. Studies were, however, deferred to NDP 9 following the establishment of the new Department of Sanitation and Waste Management (DSWM). NDP 9 proposed that all waterborne sanitation projects for the NDP 9 period be carried out by DSWM. DWA still needs to consider utilisation of treated wastewater as a potential water resource in the process of national planning. During

NDP 8, it was suggested that the problem of cost recovery in rural and urban areas with regard to sanitation be fully investigated. Rural people need to be made aware of the importance of paying more for their water supply and sanitation than in the past in order to reflect the scarcity of the resource and to contribute to the development costs. All NDP 9 water projects will be subjected to an Environmental Impact Assessment (EIA) studies. Proposed project on water and sanitation are listed in Table 2.5.

Table 2.5 Water and sanitation -related projects of NDP 8 and 9

National Development Plan 8 (NDP 8)	National Development Plan 9 (NDP 9)
- North South Carrier Water Project	- Investigation of the Karoo groundwater potential of the central Kalahari.
- TGLP ranches groundwater potential survey, aimed at determining water salinity and chances of hitting blank by farmers as a way to reduce drilling costs on farmers in Kgalagadi, Southern, Kweneng and Ngamiland districts.	- Determination of groundwater pollution levels and pollution reduction strategies.
- A groundwater studies and protection to establish the relationship between the saline Matsheng water and relatively fresh Gantsi/Makunda and trans-Kalahari groundwater waters	- Research on rainwater harvesting, grey water recycling, wastewater re-use, underground storage, installation of prepared meters and promotion of water conservation and demand (use) management practices.
- A feasibility and pre-design study of the Zambezi including the transfer pipeline to supplement or join the NSC	- Development of a systematic pollution control and water quality monitoring programmes.
- Updating of the NWMP and assessment of the social acceptability and economic and technical viability of wastewater re-use.	- Review of the rural water supply design manual to cover all aspects of the design for the water and wastewater systems.
- Feasibility study, design and construction of water supply and sanitation works at Ramotswa, Moshupa, Thamaga, Maun, Letlhakane, Gantsi and Tsabong.	- Upgrading of water supply systems for Thamaga, Moshupa, Tsabong, Letlhakane, Maun, Serowe, Tonota, Mahalapye and Ramotswa.
-Waterborne sanitation projects for Kanye and Molepolole	- Connection of Serowe, Kanye and Molepolole to the NSCWS.
- Completion of Mochudi, Tlokweng and Mogoditshane water and sanitation schemes.	- Sanitation projects for Gantsi, Serowe, Mahalapye, Tonota, Palapye and Mochudi
- Updating the water quality, pollution and billing databases	
- Research on water conservation projects	
- Preparation of the NMPWWS	

Sources: Government of Botswana, 1997 and 2003.

2.3.3 Wastewater availability

The NMPWWS identified sixty four wastewater treatment works in Botswana with a total capacity of 90 974 m^3/day compared with a daily flow of 61 045 m^3. Seventy percent (45) of these WWTWs use ponds type systems. The remaining nineteen (30%) are made up of three Activated Sludge (AS), one Trickling Filter (TF), four Rotating Biological Contractors (RBC) and eleven wetland systems (mostly on-site). The evaporation and production losses differ by treatment technologies. For example, AS and TF systems lose about 5%, compared to as much as 60% in the open ponds system due to evaporation. Wastewater production is associated with urban areas (Gaborone, Lobatse, Jwaneng, Francistown and Selibe-Phikwe) which account for about 80% of the inflow at the treatment plants. In 2002, the inflow into and outflow from treatment works were estimated to be 24.5 Mm^3 and 12.3 Mm^3 respectively. Only 20% of the outflow is presently applied for beneficial re-use, mostly for irrigation of golf courses and agricultural applications. There are planned wastewater re-use activities for irrigation in Gaborone and Francistown.

The NMPWWS estimated the amounts of return flows, both inflows and outflows. The estimated outflows from WWTW in 2001 and trends in future outflows are summarised in Table 2.6. It becomes clear that the outflows are substantial and may increase six fold over the next thirty years. Bearing in mind the growing fresh water scarcity and costs, continued neglect of re-use and recycling of outflows has substantial economic and environmental costs.

Table 2.6: Estimated outflow from WWTW

Year	m^3/day	Ml/year
2001	33 700	12 200
2010	83 000	30 000
2020	144 000	52 400
2030	200 000	73 000

Source; SMEC *et al*, 2003, vol.2.

Combining the assumptions regarding the inflows and outflows, we conclude that at least 25% of the water consumption of consumers that are linked up, to the sewerage network is available for re-use or recycling. The expansion of the sewerage network and the growth in water consumption will fuel further growth in outflows (cf. Table 2.4).

2.3.4 Quality of wastewater

The sampling and testing of the effluent quality is not consistent at some WWTWs and when tested, it does not conform to the set standards. Therefore, re-use should be treated with caution as the water quality is unknown and may be sub-standard. Although Botswana has effluent standards/guidelines set by the DWA, there is no proper monitoring which may result in localised pollution. The standards are considered to be strict and it is envisaged that with current trend of the use of ponds type system, effluent produced will not comply with standards of discharging into the environment. Therefore, better technologies should be employed (e.g. trickling filter).

2.4 Concluding remarks

Management of freshwater and wastewater resources is institutionally separated at central government level, contributing to the failure to consider wastewater as alternative or complement to fresh water. At the district level, the situation is better as Councils are responsible for wastewater as well as water supply projects. Meeting the targets of the NMPWWS would drastically alter the situation over the next decade or so. The spatial imbalance between supply and demand for freshwater as well as growing water scarcity provides further incentives for an integrated approach. If wastewater will be treated as a resource, the challenge of minimising treatment losses will arise. AS and RF have considerably lower losses than the most common treatment methods of ponds. The high treatment costs of RF and AS can be better justified when the ‘saved’ wastewater is re-used or recycled. Cultural attitudes towards wastewater and quality aspects need to be addressed prior to a comprehensive programme of re-use and recycling is implemented.

Figure 2.4: Flow meter in Selebi-Phikwe wastewater treatment plant.

CHAPTER THREE
WATER ACCOUNTING

3.1 Introduction

The United Nations have developed a standard System of Environmental Economic Accounting (SEEA). While few countries have fully developed SEEA systems, a brief review of the SEEA is useful for this study to understand the 'target' structure of water accounts and the best ways of incorporating treated wastewater or new water as it was called in chapter two and the BNMPSWW. Therefore, the SEEA-system is briefly discussed in section 3.2. The 'pre-study' state of water accounting in Botswana is reviewed in section 3.3 with the view to establish how wastewater accounts can be incorporated.

3.2 SEEA accounts[6]

3.2.1 SEEA objectives and scope

The System of Integrated Environmental and Economic Accounting (SEEA) is the UN's 'model' framework for natural resource accounting. The SEEA facilitates (Eurostat and UN, 2004):

- Mainstreaming of resource issues into economic decision-making;
- Evaluating resource impacts of economic development on the environment; and
- Evaluating impacts of environmental policies on the economy.

The objective of SEEA is to provide a systematic framework for the organisation of water statistics based on which resource impacts of economic development and development policies can be explored and water strategies and policies can be evaluated. The accounts can also be used in the analysis of policy options through scenario modelling (Eurostat and UN, 2004 and UN, 2006)

The construction of water accounts is challenging, but many countries are in the process of constructing part of the SEEA. Table 3.1 shows the countries, which have constructed (partial) water accounts and which parts they have developed. More developed counties have water accounts, but the number of developing countries with water accounts is growing. In southern Africa, Namibia, South Africa and Botswana have water accounts and Mozambique and Tanzania are developing such accounts. Most countries construct flow or use[7] accounts and water quality accounts. Few developing countries have water quality accounts. Only a few countries have constructed comprehensive accounts that integrate stocks and flows. Countries prioritise water aspects that are most important to them for developing the accounts. For example, in countries where water quality poses a serious problem, only water pollution accounts and accounts for wastewater treatment cost are constructed. Semi-arid countries tend to focus on use and –to a lesser extent- stock accounts as water scarcity is the policy priority.

[6] This section is primarily based on Eurostat and UN (2004). The handbook is not yet finalised and a final draft is discussed in June 2006 (UN, 2006).
[7] The terms use and flow accounts are used interchangeably in this report.

Table 3.1: Countries that have constructed water accounts.

		Flow Accounts		
	Stock Accounts	Physical Use	Monetary: cost of supplying water, water tariffs, wastewater treatment cost	Water Quality, Emissions to water
DEVELOPED COUNTRIES				
France	X	X	X	X
Spain	Partial	X	X	
Netherlands	Surface water	X	X	X
Ireland		X	X	X
Greece		X		
Finland				X
Germany		X	X	X
Sweden		X	X	X
Denmark		X	X	X
Norway			Wastewater treatment cost only	X
Australia	Partial	X	X	X
Canada	Partial	X	X	X
DEVELOPING COUNTRIES				
Botswana	Partial	X	X	
Namibia	Partial	X	X	
South Africa	Partial	X	X	
Philippines		X	X	X
Chile (for one river basin)	Partial	X	X	X
Moldova	Partial	X	X	Partial
Indonesia (Jakarta only)		X		
Turkey		X		

Source: Arntzen *et. al*, 2003.

The SEEA water accounts focus on stocks of water found in fresh and brackish surface and groundwater bodies that provide both present and future direct use benefits through the provision of raw material and that may be subject to quantitative depletion and degradation through human use.

In the SEEA system, water accounts consist of stock and flow accounts as well as water quality accounts. These accounts record physical volume, monetary value and water quality. According to Eurostat and UN (2003), the physical flows include quantity of water used for production and consumption as well as the water re-used within the economy and returned to the environment (treated and untreated). The monetary flows include current and capital expenditures for abstraction, transport, treatment and distribution of water resources as well as water-related taxes and subsidies received by households and industries. Water quality accounts include impacts on water resources caused by production and consumption activities of industries, households and government. These impacts may include emissions of pollutants into water which affects the quality of water. Below, the types of accounts are briefly reviewed.

According to the Water Accounting handbook (Eurostat and UN, 2004), return flows provide opportunities to re-use the same water if the returns are in the required location and of the right quality. Wastewater can be re-used and recycled within a plant and within a town water utility system. Other benefits of re-use and recycling of wastewater include conservation of potable water as well as reduction in costs paid by households for potable water usage.

Asset (stock) accounts
These accounts describe how the stocks of water resources are at the beginning and end of the accounting period taking into account changes in the water resources stocks that occur during the period, usually one year. There are two types of assets: economic assets (related to abstraction, mobilisation and treatment of water) and water resources. The compilation of asset accounts for water resources is easier to do in physical terms (m^3) than in monetary units (Pula or $) as water valuation is often difficult.

The stocks of water are classified according to the following categories:

<u>Environmental Asset (EA) 13 Water Resources[8] (M^3)</u>

EA. 131 Surface water

- EA. 1311 Reservoirs
- EA. 1312 Lakes
- EA. 1313 Rivers and streams

EA.132 Groundwater

Surface water embraces all water which flows over or is stored on the ground surface while groundwater includes subsurface water occupying the saturated zone. It comprises all water which collects in porous layers of underground formation known as aquifers (Eurostat and UN, 2003). Wastewater is not categorised separately, but is included depending on how it is discharged, re-used and/or recycled (see later).

The proposed SEEA stock accounts for both surface water and groundwater is shown in Table 3.2. The changes that occur during the accounting period include abstraction and return flows (brought about by human activities), recharge from precipitation, natural inflows and outflows, evaporation and other changes in volume (brought about by natural processes). The stock of wastewater can be treated under the column of ‘other water’ in Table 3.2. Recycled wastewater, i.e. wastewater that is returned to the water supply systems can be dealt with in row 2 ‘Returns to water resources’, adding to the stock of fresh water. Re-used water cannot be returned to the same water sources, and must therefore be dealt with separately as a ‘stock of uncertain or lower water quality’. A separate account would be needed.

[8] The classification excludes water in oceans and seas because the stocks of these resources are enormous. Therefore, any quantity of water abstracted all not affect the level of the stock.

Table 3.2 Stock accounts (in Mm^3)

		EA. 131 Surface	Water		EA. 132 Groundwater	Other	Total
		EA. 1311 Reservoirs	EA. 1312 Lakes	EA. 1313 Rivers			
	Opening Stocks						
1.	Abstraction from water resources (-)						
1a.	*of which*; Sustainable use						
2.	Returns to water resources (+)						
3.	Precipitation (net) (+)						
4.	Inflows (+)						
4a.	From other water resources in the territory						
4b.	From other territories						
5.	Evapotranspiration/Evaporation (-)						
6.	Outflows (-)						
6a.	To other water resources in the territory						
6b.	To other territories						
6c.	To the sea						
7.	Other volume changes						
	Discovery (+)						
	Others						
	Closing Stocks						

Source: Eurostat and UN, 2004

Flow accounts

These accounts measure the flow of water between the economy and the environment, and within the economy between water suppliers and end-users. The flow of water between the economy and the environment involves the abstraction of water from natural sources and the return of the water after being used to the environment. On the other hand, the flow of water within the economy between water suppliers and end users embraces the supply of water from one sector to the other. The flow accounts show the institutional source of water used by each sector as well as the supply and use of water classified by natural source; i.e. groundwater and surface water.

Table 3.3 shows an example of a physical water flow accounts for Sweden. The account shows distributed water, which is supplied by a water utility as well as water supplied by the environment, which the user directly obtain water from the sea, surface and ground. The amount of self provided water is much higher than the water provided by water supply agencies. The pulp and paper industry is the largest self provider. Reticulated water is sourced from surface and groundwater.

Table 3.3 Water flow accounts in Sweden (1995; Mm^3)

		Water environment	supplied by		Supply of	Use of	Total use
		Ground water	**Surface water**	**Sea water**	**distributed water**	**distributed water**	**of water resources**
1	Agriculture	66 418	70 873			0	137 291
10/14	Mining and quarrying	15 229	24 845	2 521		1 312	43 906
15/16	Food products, beverages, tobacco	10 600	7 709	29 802		25 917	74 029
17/19	Textiles, textile products, leather	913	8 307			2 459	11 679
20	Wood, products of wood, cork, straw, etc	946	15 924	1 661		1 249	19 760
21	Pulp, paper and paper products	16	975 059			3 327	978 402
22	Publishing, printing and reproduction	3	42	19		2 466	2 530
23	Coke, refined petroleum and nuclear fuel	8	117			271	397
24	Chemicals and chemical products	2 968	180 639	309 274		18 891	511 772
25	Rubber and plastic products	450	11 286	5 045		995	17 777
26	Non-metallic mineral products	3 947	6 305	1 923		2 716	14 891
27	Basic metals	2 483	160 193	188 826		8 592	360 454
28	Fabricated metals, except machinery	721	11 366	38		4 164	16 290
29	Machinery and equipment n.e.c	270	19 545			5 473	25 288
30	Office machinery and computers	42	24	2		406	473
31/32	Electrical machinery, radio, TV, etc.	1 303	1 990	1 753		3 385	8 430
33	Medical, precision, optical instruments, etc	77	44	61		1 025	1 206
34/35	Motor vehicles and other transport eq.	238	9 885	7		1 025	1 206
36/37	Other manufacturing	111	238	11		695	1 055
40	Electricity, gas, steam and hot water supply	897	68 480	44 174		6 681	120 232
41	Collection, purification, distribution of water	444 948	491 353		755 705		180 596
41/95	Other industries, excluding 90.01					86 522	86 522
	Not allocated industries	1 474	4 192	1		6 469	12 136
	Households*	88 449				527 975	616 424
	Unspecified use					38 269	38 269
	TOTAL	**642 871**	**2 068 416**	**585 118**	**755 705**	**755 705**	**3 296 405**

Source: adapted from Arntzen *et. al*, 2003

Water quality accounts

These accounts take into account the state in which a body of water is found before it is abstracted for distribution in the economy and its state before it leaves the economy and returns to the environment. Pollution occurs both during production and consumption, and normally the water quality of 'return or waste' water is lower than that of the supplied water, particularly if wastewater is not treated. The water quality accounts are important in as far as treatment of potable water is concerned. In order to provide safe drinking water, potential health hazards have to be considered. In addition, environmental impacts of water from the economy into the environment need to be considered. According to the SEAA handbook, key requirements for the construction of the water quality accounts are:

- A monitoring network with regular assessment of quality characteristics of the water courses on a sample of sites;
- A monitoring network of gauging stations that measure the volumes of water flows; and
- A GIS-software to analyse the data collected and aggregate them by river basin.

These requirements are not met by many countries, especially in the developing world. The following table shows the proposed framework for the SEEA quality accounts.

Table 3.4 Template for the structure of water quality accounts.

	Quality Classes			
	Quality 1	Quality 2	Quality 3	Total
Opening stocks				
Changes in stocks				
Closing stocks				

Source: Eurostat and UN, 2004

3.3 Water accounting in Botswana

Botswana produced its first water accounts in 2001 as part of a regional natural resource accounting project[9] (CSO/ NCSA, 2001). For Botswana, the project developed water and mineral accounts. These resources were selected because of their strategic economic and environmental importance. The accounts covered the period 1990 to 1998 and consisted mostly of physical flow or user accounts by economic sector and by water service provider (DWA, DC, WUC and self providers). Data were collected for the cost of water and the value added per m^3 in different economic sectors was estimated. The latter provided information about water efficiency in the different economic sectors. In 2003, the Centre for Applied Research (CAR) carried out a follow up project, separating surface and groundwater resources in greater detail, up-dating the accounts and initiating partial stock accounts (Arntzen *et al*, 2003). The study was funded by a global change research network (START- Washington) and also covered Namibia and South Africa. Both projects were restricted to fresh water sources, and did not address the availability and re-use and recycling options of the growing amount of wastewater. The structure and results of Botswana's water accounts are reviewed below.

Coverage of water resources

Botswana's surface water resources comprise run-off from 'domestic' rainfall and inflows from international rivers shared with other countries. The former is mostly transported through ephemeral rivers in eastern Botswana. The latter includes flows from the Okavango, Chobe, Limpopo and Molopo/Nossop Rivers, which have part of their catchment area outside the country (see chapter two). The average 'domestic' annual runoff is 1.2 mm, ranging from zero in western and central Botswana to over 50 mm per annum in the north. The total average annual surface run-off is estimated to be 696 Mm^3. Due to high evaporation rates, high variability of run-off in time and lack of suitable dam sites, less run-off is captured (Arntzen *et al*., 2003).

[9] The project covered Namibia, South Africa and Botswana, and was funded by USAID and SIDA.

The capacity, mean annual run-off and sustainable yields of the major dams found in Botswana is shown in Table 3.5. The aggregate sustainable yields are twenty percent or less of the total dam capacity. Mean annual run-off is around half the total dam capacity.

Table 3.5 Major dams found in Botswana

Dam	Capacity Mm^3	Hydrologically sustainable yields (Mm^3) BNWMP	Sust. Yields (Mm^3) WUC estimates	Mean annual runoff (Mm^3)
Gaborone	144.2	7	10	31
Letsibogo	104	16	20	57
Nywane	2.3	0.3	0.3	1.9
Bokaa	18.5	0.1	1.1	9
Shashe	85.3	22	40	84
Total	354.3	45.3	70.3	173.9

Sources: SMEC *et al,* 1991; WUC Annual Reports and WUC files

The geology and climatic conditions determine the groundwater resources (Department of Surveys and Mapping, 2000). The amount and quality of groundwater varies significantly in space and time. Groundwater collects in aquifers and is abstracted through well fields. Only a small part of the groundwater resources can be economically abstracted due to high abstraction costs, low yields, poor water quality and remoteness of aquifers in relation to demand centres (SMEC *et al*, 1991, Masedi *et al*, 1999). The estimated average annual recharge is 2.7mm, ranging from zero in western Botswana to 40mm in the north. The extractable volume of groundwater in Botswana is estimated to be about 100 billion m^3 (Khupe, 1994) with an average annual recharge of 1.6 billion m^3 or 1.6% of the extractable amount (SMEC *et al*, 1991 and Department of Surveys and Mapping, 2000). It is estimated that only 4.8% of the annual recharge can be abstracted; this would be around 76.8 Mm^3 (Arntzen *et al*, 2003), much less than the aggregate capacity of the major dams.

The accounts

This section describes the accounts as they existed prior to this study. The water accounts of Botswana were confined to *flow accounts, mostly in physical units*. There were rudimentary stock accounts for dams and groundwater. Flow or use accounts have been constructed for:

- Surface and groundwater sources;
- Economic sectors; and
- Institutional suppliers (designated water providers and self providers).

The current flow accounts cover the period 1990-2001. Monetary accounts are in their infancy due to data limitations. Rough cost estimates exist for different water providers and sources (ground and surface water). In addition, the value added per m^3 has been calculated by economic sector.

The water accounts were therefore not comprehensive (as is the case in most countries; Table 3.1) and had several gaps and weaknesses. The gaps include detailed stock accounts and monetary accounts and the absence of wastewater accounts. The weaknesses included:

- No differentiation by water quality categories. It is implicitly assumed that all water is potable or that non-potable water is not used. WUC sells potable and untreated water, but the data for untreated water are incomplete and conflicting. It is possible that treated and untreated water are sometimes mixed in the existing accounts;
- Growing transfers between water supply agencies are not adequately incorporated. For example, DWA is responsible for the water supply of sixteen rural villages, but obtains water from WUC for six of those. Therefore, the flow or use accounts should make a distinction between *intermediate* and *final* uses. The former are water transfers among water supply agencies; the latter refer to consumption by households, businesses etc. Namibia makes such a distinction in its revised accounts;
- The inflows into dams and the amount of water stored in well fields is not known/ recorded. This restricts the construction of stock accounts and for example, the life time prediction of well fields;
- The water accounts do not cover wastewater and its re-use or recycling. The growth in the sanitation sector has led to a rapid increase in the available wastewater. This limitation is the primary subject of the study.

Some findings
The findings mostly relate to use accounts for the period 1990-2001 (see CSO/NCSA, 2001 and Arntzen *et al*, 2003) and include the following:

- Water consumption grew from 140 Mm^3 in 1990 to 171.3 Mm^3. Growth has been lower than the population growth and predictions of the BNWMP;
- Water consumption grew fastest in urban areas and large villages driven by increased domestic use and rising government use;
- The share of surface water has increased due to the construction of additional dams and the NSWC. The overall reliance on groundwater has decreased from 61% in 1992 to 56% in 2001. Urban areas and a growing number of large villages depend on surface water. Small villages, mining and livestock mostly depend on groundwater; and
- WUC has become the largest water supply agency (49.6 Mm^3), producing more than DWA (10.4 Mm^3) and DCs (22.2 Mm^3) together. However, self providers, mostly in the mining and livestock sectors, provide around the same amount as WUC, DWA and DCs together (i.e. 89.1 Mm^3 in 2001).

The accounting study dealing with groundwater showed that in 2002, thirty-three well fields were developed, and another twelve were under investigation or development (Arntzen *et al*, 2003). The average annual recharge in the country was estimated to be 1.6 billion m^3, while around 75 Mm^3 was annually abstracted. The study compared the abstraction rates and estimated recharge rates for well fields and found that a third to half of the existing well fields are over-utilised, i.e. abstraction exceeds the estimated recharge. The study also found that the water table of well fields recover quickly after they are rested for some time. It was therefore concluded that groundwater depletion is a real danger if well fields are not regularly rested.

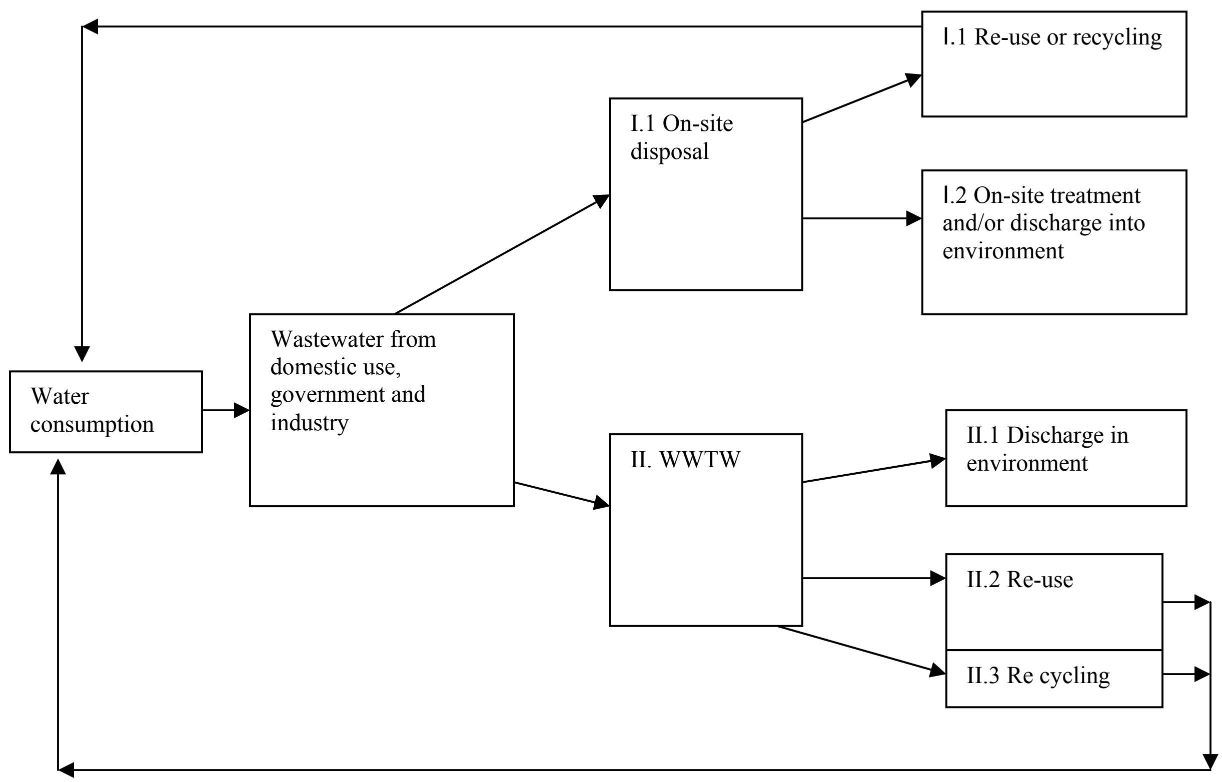
Combining the flow account by sector with the national accounts yields value added figures per m^3 for each economic sector. The average value added per m^3 is Pula 99.45 (2001 in 93/94 constant prices). This is higher than corresponding figures for Namibia and South Africa. More importantly, water is not allocated efficiently using the value added criterion, as the agricultural sector receives most water (42.4% of total consumption in 2001) and adds least value (Pula 6.08 in 2001; 93/94 prices).

As the current study has up-dated the water use accounts to 2003, the actual accounts are shown later in chapter four.

3.4 Concluding remarks

Wastewater can be discharged in the environment, re-used or recycled. This may happen on-site and off-site. The latter involves the use of sewerage systems and wastewater treatment works. The possible destinations of wastewater are summarised in Figure 3.1.

Figure 3.1: Possible destinations of wastewater



The more wastewater is being re-used and recycled, the more the circle of water consumption and supply is being closed. This happens through the reduction of water consumption of 'fresh' water resources (II.2 re-use) or through augmentation of the stock of fresh water resources (II.3 recycling). Discharges into the environment from WWTW (II.1) refer to the un-used outflow and to losses in the treatment process, mostly through evaporation and leakages. On-site WW-disposal should not be recorded in the water accounts, as there is no transaction or flow between economic agents. However, on-site re-use and recycling (I.1) will normally lead to a reduction in the consumption of fresh water.

Although few countries have done so, wastewater can be incorporated into the water accounts. Flow (or use) accounts of water would lead to *wastewater supply accounts* that cover the parts of discarded water that is treated and available for re-use or recycling. Wastewater use accounts would be constructed to reflect the destinations of the treated wastewater such as re-use, recycling and discharges into the environment. Re-use would replace use flows of fresh water and recycling would imply augmentation of freshwater supply, either by increasing the stock accounts of fresh water or by an extra use flow of treated wastewater. On-site re-use and recycling of water (within the same economic unit) should not be recorded in the supply and use accounts, while the wastewater discharged in a watercourse and re-used downstream should be recorded as a return of wastewater to the environment and as a new abstraction. Different water quality accounts can be distinguished, but this is currently not feasible in Botswana due to the absence of water quality monitoring networks (fresh water and wastewater).

Two issues will be difficult to address in the study given current data limitations and the state of the water accounts. Firstly, water quality aspects cannot be adequately integrated into the water accounts. The potential for use of return flows and recycling depends on reduction of water pollution. The main problem is its quality. The type of use (irrigation, cooling etc) of wastewater greatly determines the quality. Due to data limitations, Botswana is currently not in the position to develop water accounts for different water quality levels, as suggested in the SEEA. Secondly, monetary accounts do not exist, and data on prices and costs are inadequate. Therefore, this study will aim to add cost data on wastewater treatment for comparison with the costs of fresh water supply. However, full monetary accounts are not feasible at this stage.

The literature review did not reveal many other developing countries with wastewater accounts, possibly due to the problems with water quality aspects. In this way, this study is innovative, and could offer valuable findings for other water scarce developing countries.

CHAPTER FOUR
THE PHYSICAL WATER ACCOUNTS

4.1 Introduction

The water accounts were up-dated and expanded with wastewater accounts based on the results of the literature review. The up-date covered the years 2002 and 2003, leading to time series account data of over ten years. The expansion included three new wastewater accounts and stock accounts for the larger dams.

We discuss in this chapter the new physical water accounts. The results on monetary aspects of the accounts are discussed in chapter five. The structure and current state of the physical accounts is now as follows:

Account	Sub-account	State	Contribution of this project
Stock accounts	Dams	Newly constructed for 2001-2003	Produced by this project
	Groundwater	Existing incomplete accounts for operational well fields	No progress; beyond scope of this project
	Rivers-lakes	No accounts; few perennial rivers and lakes	No priority; beyond scope of this project
	Wastewater	Developed, but not important	Developed by this project
Flow accounts	Institution	Covers period 1990-2003	Up-dated with years 2002 and 2003
	Source	Covers period 1990-2003	Up-dated with years 2002 and 2003
	Economic sector	Covers period 1993-2003	Up-dated with years 2002 and 2003.
Wastewater accounts	WW supply	Covers period 1990-2003	Produced by this project
	WW use	Covers period 1990-2003	Produced by this project

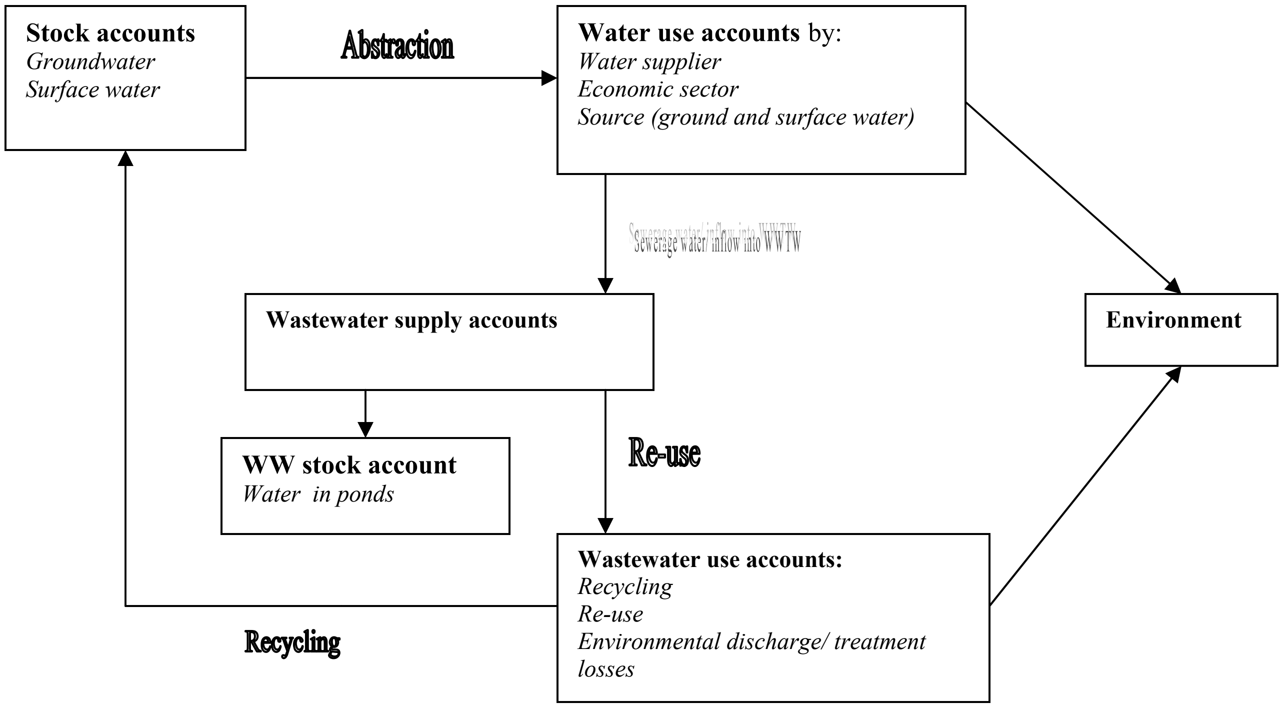
In Chapter three, the conclusion was reached that wastewater could be integrated into water accounts. Below, we briefly outline the method employed in this study.

Wastewater stock accounts indicate the amount of wastewater stored in WWTW. This is mostly wastewater in ponds.

Wastewater supply accounts indicate the sources of wastewater (e.g. domestic use, business and government). At this stage, WW supply accounts are restricted to wastewater that is treated in WWTW. The accounts are constructed for individual WWTW and for the country (as an aggregate of all WWTW). The sub accounts by WWTW are area specific.

The *WW use accounts* show how the wastewater is being used. Wastewater is linked to stock and flow accounts in the following ways (Figure 4.1)

Figure 4.1: Linkages between different accounts.



Firstly, water flows or uses generate wastewater, which is either directly discharged into the environment OR collected and treated in WWTW. In other words, flow or use accounts are related to WW supply accounts. Secondly, WW outflows from WWTW can be re-used, recycling or discharged into the environment. Re-used WW would substitute for existing fresh surface and groundwater. Therefore, the water use accounts would change by lower water uses from sectors that engage in re-use (e.g. irrigation). Recycling closes the water loop and implies a water flow towards water supply agencies, and could be treated as an ‘extra’ inflow into the dam stock account in addition to natural inflows and inter-dam transfers. As argued in chapter two, recycling is not yet practised in Botswana. Treated WW that is not re-used is discharged into the environment, usually ephemeral rivers.

Given the lack of data, it has not been possible to distinguish different water quality categories. The water quality of WW supply and use accounts is considered to be below potable drinking water standards, and only therefore only limited re-use is feasible. Recycling would require extra treatment to raise the water quality.

Stock accounts are discussed in section 4.2. In section 4.3 water use accounts are reviewed followed by wastewater supply accounts (4.4) and wastewater use accounts (4.5).

4.2 Stock accounts

4.2.1 Freshwater stock accounts

The term 'stock' relates to the quantity of surface and groundwater in a territory of reference measured at a specific point in time (Eurostat and UN, 2003). Here, freshwater stock accounts show the amount of freshwater stored in dams and aquifers at the beginning and at the end of the year, and changes therein (inflows, outflows, evaporation etc.).

Surface water sub-accounts (EA 131; see chapter 3)
The amount of water stored in reservoirs is limited due to due shallow nature of dams, leading to high evaporation, and low and unreliable rainfall. The surface water sub-accounts were constructed for the country's main reservoirs (EA *1311)*: WUC- dams (Gaborone, Bokaa, Nnywane, Shashe and Letsibogo) and for one DWA dam.

No sub accounts have been constructed for lakes/swamps (*EA 1312*) and rivers (EA 1313), as the former are rare and hardly used for economic activities (except the Okavango delta) and the latter are mostly ephemeral with the exception of the transboundary Okavango and Chobe Rivers. With the increased importance of tourism, such accounts need to be constructed in future.

WUC records the stored water volumes as well as abstraction. Surprisingly, the aggregate inflows into the dams are not recorded by WUC or DWA. The average evaporation rates are known for each dam. Therefore, the annual evaporation was estimated as the evaporation rate for each dam[10] multiplied by the (opening + closing volume)/ 2. The inflow was estimated as:

Inflow = Closing volume + Abstraction + Evaporation - Opening volume

To reflect the growth in inter dam water transfers[11], the inflow should ideally be separated into natural inflow and inflow *from* other dams (as well as inflows from treated wastewater that is recycled). Similarly, abstraction should ideally be divided into abstraction for treatment and distribution and transfers *into* other dams. Transfer inflows would then equal transfer outflows minus transfer losses. Unfortunately, current WUC data do not permit the separation of natural and inter dam inflows and abstractions.

The stock accounts are incomplete for most years in the period 1990-2004. However, the simplified version (without the transfers) could be compiled for 2001-2003 and is shown in Table 4.1. The EA 1311 sub-account demonstrates the significant fluctuations in the amount of stored surface water and reservoir inflows, even in a relatively short period of four years. Table 4.2 shows the change in water stocks of individual dams in the period 2000 to 2004.

The volume of freshwater in Gaborone dam, that supplies the south-eastern part of Botswana, has declined persistently since 2001, causing a water crisis in 2004/05. In contrast, the amount of water stored in other reservoirs has increased, with the highest growth rate in Letsibogo dam (314.5%) due to filling up of this new reservoir. The diverging dam yields suggest that safe yields[12] can be increased by operating dams as an interlinked system such as Bokaa and

[10] Gaborone dam: 1.6%, Letsibogo and Bokaa; 2%, Shashe dam 2.26% and Nnywane dam 2.3% (source: WUC). Evaporation exceeds abstraction in all dams.
[11] Two inter-dam transfers occur: Gaborone dam receives water from Bokaa dam and Molatedi dam in South Africa. NSWC from Letsibogo dam destined for Gaborone does not enter Gaborone dam but reaches end-users after treatment in Mmamashia plant north of Gaborone. Part of the water transfers from Bokaa and Molatedi dams is channelled directly into the treatment plant while another part is stored in Gaborone dam. No figures were available for the size of each part.
[12] Safe yields of dams are strategically more important than the dam capacity.

Letsibogo dams that support Gaborone dam (see also Van der Merwe, 1999 for Windhoek). In that event, a failure of one dam can be compensated by increased stocks in other dams.

Table 4.1: The surface water reservoir stock account (EA 1311; Mm^3).

All WUC dams	2001	2002	2003
Opening volume	289	319	235
Inflows	277	142	149
Abstraction	174	159	79
Evaporation	72	66	60
Closing volume	319	235	246

Source: calculated from WUC data.

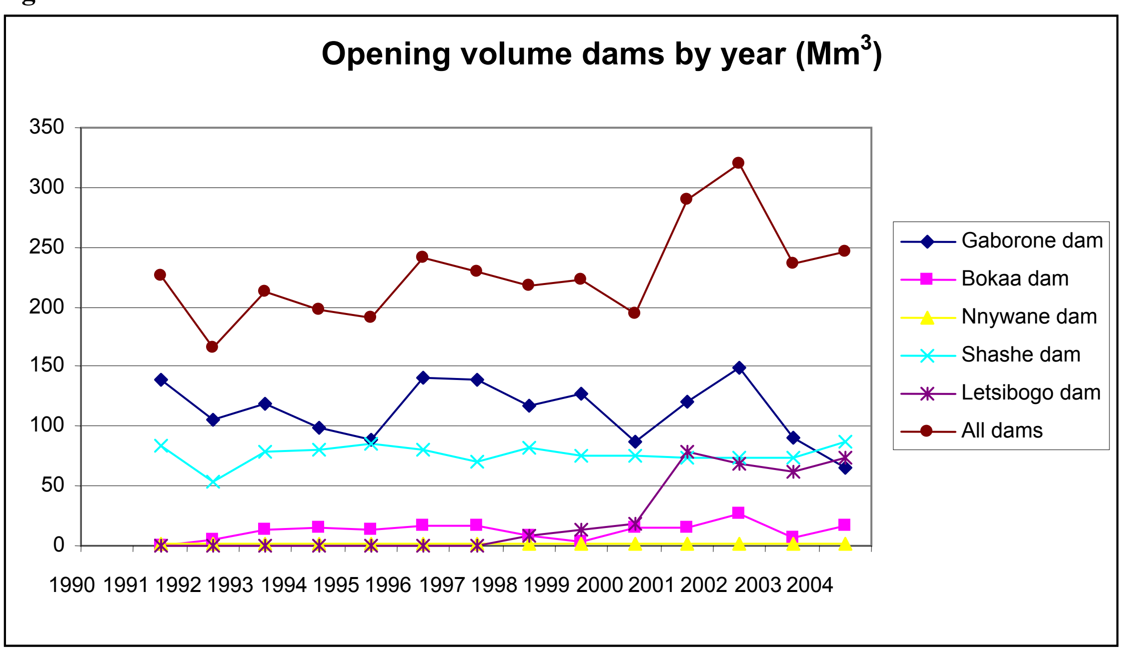
Table 4.2: Change in stored volume in reservoirs (opening volumes; in Mm^3)

Dams	2000	2004	Growth Rate (%)
Gaborone	86	66	- 23.6
Bokaa	14	16	11.9
Nnywane	1	2	57.5
Shashe	75	87	16.3
Letsibogo*	18	74	314.5
Total	195	246	

Source: Data from WUC Annual Reports

Figure 4.2 shows the trend in water volumes in the WUC dams. The total water volume in dams has increased in time due to the construction of Letsibogo dam. Gaborone, Shashe and Letsibogo are the large dams while Bokaa and Nnywane dam are small. Furthermore, the Gaborone dam has performed poorly in recent years, and its water storage has dropped below the amounts stored in Shashe and Letsibogo dams (despite the much higher capacity of Gaborone dam).

Figure 4.2



Source: this study

DWA dam
The Moshupa dam served the village of Moshupa until 2000. The village is now supplied by a well field (Kanye) and a 50 km-pipeline. It is unclear to what extent the dam is still being used; the assumption is that abstraction is zero for the period 2001-2003. The methodology used was similar to that used for the WUC dams[13]. Unlike with WUC dams, the dam level is recorded instead of the storage capacity. Therefore dam levels were converted into water volumes. Evaporation losses were calculated as volumes by multiplying the annually cumulative corresponding evaporations with the respective area extent of the water. The inflow was calculated as a residual (similar to WUC dams).

The results are summarised in Table 4.3. The sub-account for the dam shows that the dam has a very high evaporation rate, compared to the abstraction. The dam seems to be under-utilised since 2003, and its water could be used for productive uses such as small-scale irrigation and industries. Obviously, the dam is very small in comparison to WUC dams.

Table 4.3: Water sub-account Moshupa dam (DWA; 1990-2003).

	1990	1995	2000	2003
Opening volume	0.99955	0.98757	1.00064	0.98401
Inflows	0.98531	1.24746	1.16457	0.85406
Abstraction	0.19087	0.23490	0.34587	0.00000
Evaporation	0.81820	0.99582	0.82692	0.84119
Closing volume	0.97579	1.00431	0.99243	0.99688

Note: the accounts for all years are provided in the appendix.

Groundwater stocks
This study did not attempt to improve the existing, incomplete, stock accounts for groundwater EA 132; Arntzen *et al*, 2003). The existing accounts show the abstraction and recharge of operational well fields and abstraction and recharge of all individual boreholes together (mostly used by the livestock sector; see Table 4.4). The opening and closing volumes are unknown, making it impossible to estimate when well fields could run dry.

The stock accounts for groundwater are less informative for policy makers than the surface water account EA 1311, as the opening and closing volumes of well fields are unknown. This is a risky situation for a country that depends on groundwater resources. Other problems related to the groundwater stock account are that the amount of groundwater that can be economically abstracted is unknown, making it difficult to predict the life time of a well field. Moreover, recharge rates are not adequately known. Arntzen *et al* (2003) estimated the recharge for a number of well fields and concluded that abstraction may exceed recharge in fourteen out of the twenty operational well fields for which adequate data were available. In other words, most well fields are being mined. Fortunately, resting of well fields appears to lead to fairly rapid recovery of groundwater levels. Further work on recharge is urgently needed.

[13] Ditiro Moalafi designed the methodology and did the calculations for Moshupa dam.

Table 4.4: Groundwater stock accounts (EA 132; Mm^3)

		1992	1995	2001
Opening volume well fields				
	Abstraction (-)	46.3	49.8	55.7
	Recharge (+)	15.5	15.5	15.5
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume				
Opening volume individual boreholes				
	Abstraction (-)	42.1	42.6	39.7
	Recharge (+)	Likely to exceed abstraction	Likely to exceed abstraction	Likely to exceed abstraction
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume		Not known	Not known	Not known
Opening volume total developed groundwater				
	Abstraction (-)	88.4	92.4	95.4
	Recharge (+)	At least 57.6	At least 58.1	At least 55.2
	Other changes to volume of reserves (+/-)	Not known	Not known	Not known
Closing volume		Not known	Not known	Not known

Notes: well field capacity assumed constant.

Source: Arntzen *et al*, 2003.

4.2.2 Wastewater stock accounts

Wastewater stock accounts show the quantity of wastewater in wastewater treatment works at the beginning and the end of the year. Unlike with fresh water (*EA 131 and 132*), only a fraction of the wastewater is stored, mostly in ponds, and temporarily (pending maturation and discharge). Therefore, the stock of wastewater is very small in comparison to the supply and therefore WW stock accounts are far less important than the WW supply and use accounts.

In theory, the WW stock sub-accounts would have the following structure (simplified from Table 3.3).

Table 4.5: Model WW stock accounts

	Variable	Addition-subtraction
	Opening volume (1st of January)	
	Inflows into WWTW	+
	WWTW losses, incl. evaporation	-
	Outflows	-
	Closing volume (31st of December	

The inflows, outflows and WW losses are measured or can be estimated from the WW supply accounts. Unless, additional storage capacity has been constructed during the year, it is reasonable to assume that the WW-storage is the same at the beginning and the end of the year, both determined by the pond capacity.

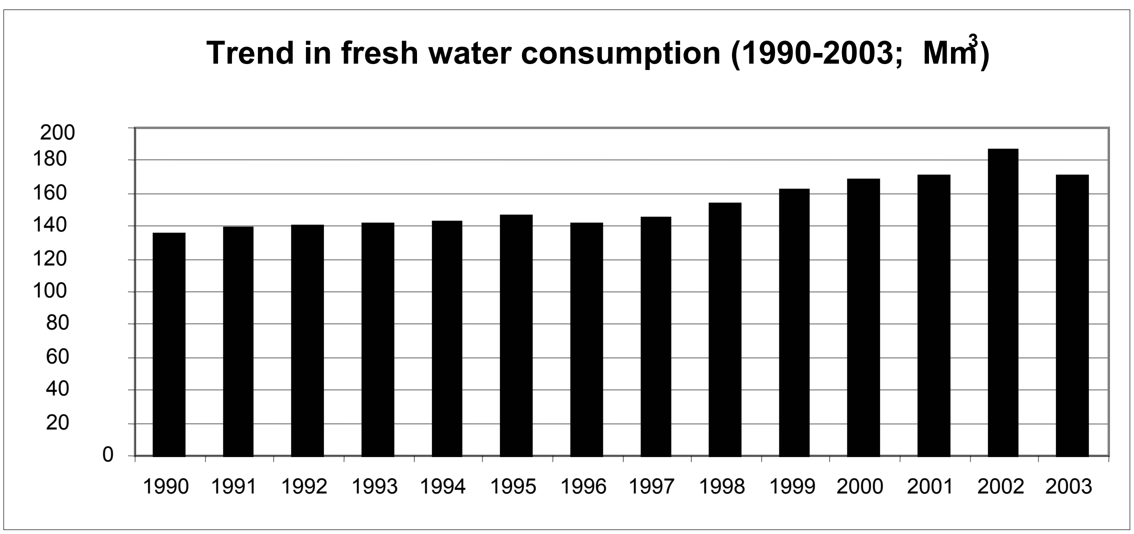
The capacity of the Gaborone and Lobatse ponds amounted to 1.5 Mm^3 (source: data collected from WWTW files). Assuming that the storage capacity of other WWTWs is similar, the total WW storage or volume could be around 3 Mm^3. This figure is very small in comparison to freshwater stocks (EA 131 and 132). The construction of detailed stock accounts for wastewater is therefore not a priority. Perhaps, the stock of WW could be meaningfully considered as a strategic reserve for exceptional emergencies.

4.3 Fresh water flow accounts

New data were used to refine and update the existing fresh water accounts to 2002. Three new data sources were available, permitting up-dates and improved estimates of water consumption by livestock, residential and industrial-government use in urban areas and large villages. Recently published Agricultural Statistics (1995-2003) were used to improve and up-date the estimated water consumption of livestock (1995-2003). Previously made assumptions about livestock numbers for that period were replaced with actual livestock figures. DWA water consumption data for large villages were up-dated until 2003/04. In addition, WUC data were up-dated until 2003 based on recent annual reports and data supplied by WUC. No changes were made in the water consumption of small rural villages, as the on-going pilot project on water consumption monitoring in rural villages has not yielded new results.

The trend in the country's water consumption is shown in Figure 4.3. Details of the flow accounts by institution (DWA, WUC, DCs and self providers), source (groundwater, surface water and rivers) and economic activities are given in Appendix 1. Figure 4.2 shows an increase in water consumption from just less than 140 Mm^3 in 1990 to 170 Mm^3 in 2003. The increase has been minimal during the 1980s (drought), but the growth resumed in the 1990s, only to level off in the early 2000s. The consumption peak in 2002 is entirely due to the high livestock figures, which seem a considerable overestimation.

Figure 4.3:



Source: this study.

4.4 Wastewater supply account

The SEEA system recommends that only off-site wastewater that passes to another economic activity or to the environment is recorded in the wastewater accounts. Therefore on-site re-use and recycling does not appear in water accounts (useful as it may be from a water efficiency perspective). The WW supply accounts are restricted to wastewater that is returned to wastewater treatment works (WWTW), as these flows can be re-used or recycled and are transferred between economic agents. The following are excluded:

1. Direct discharges of wastewater from a WW supplier into the environment. Such wastewater is usually captured in sceptic tanks, which are regularly emptied into the sewerage system[14]; and
2. Institutions that generate significant amounts of wastewater such as hospitals, prisons and schools often have an on-site WWTW. These supplies should not be included in the accounts, but obviously may have economic and environmental benefits.

Individual WW supply accounts have been prepared for each WWTW and an aggregate WW supply account has been derived from those. The developed WW supply accounts distinguish three major categories of suppliers, i.e.: domestic users, industry/ business, and government.

The major supply groups could be further sub-divided, but currently this is only done for households, which are grouped into those depending on standpipes, those with yard connections and those with house connections. A further sub-division of business and government can be made but it is currently not meaningful as the same effluent generation fraction (EGF) is used for all sectors.

The wastewater supply, received at the WWTW, is calculated based on the water consumption of each category and effluent generation fraction (EGF) or return percentages used in the NMPWWS:

- Households: 80% of the water consumption of those connected to the sewerage system enters the sewerage system (EGF is 0.8);
- Business: 55% enters the sewerage system; and
- Government: 65% enters the sewerage.

In brief, the following supply categories are distinguished.

WW supply categories	**Sub-categories**	**Effluent generation fraction (EGF) as fraction of water consumption**
Domestic users	Water from standpipes	0
	Water from individual yard connection	0
	Water in house	0.8
Business/ industry		0.55
Government		0.65

Method and assumptions
WW supply has been estimated by multiplying the actual water consumption derived from DWA and WUC by the above EGF. Further details are given below.

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[14] Leakages may cause ground water pollution problems.

For the years 1990 and 1991, WUC data for Francistown, Jwaneng and Selebi-Phikwe are not broken down into domestic use, industry/business and government. Therefore, it has been assumed that the share in water consumption of each category is the same as that of 1992 (first year with disaggregated consumption) data.

Regarding domestic use, the estimated WW supply is calculated by multiplying the domestic water consumption from standpipes yard connections and house connections by the above mentioned standard or norm factor for the return flows. It is assumed that no water from standpipes and yard connection enters the sewerage system and WWTW.

The domestic consumption data for rural villages (DWA) are subdivided into the three categories (standpipes, yards and houses), and hence readily usable. However, urban water consumption does not have this breakdown. Therefore, the urban water consumption by category was calculated as a weighted average of the population depending on three water sources (standpipes, yards and house connections) and their average water consumption, as given in the NMPWWS (SMEC *et al,* 2003):

- House connections: 165 l/d/p;
- Yard connections: 50 l/d/p; and
- Standpipes: 35 l/d/p.

The percentages of population depending with the different types of water connections were derived from the Population Census 1991 and 2001 and interpolated for the period 1991-2001 and extrapolated for the period 2002-2003. In the Population Census 1991, yard and house connection were lumped together. Therefore, the assumption was made that in the period 1991-2001 the percentage of people with a house connection in stead of a yard connection increased by 1% per annum, reflecting improved welfare and living conditions. The subsequent calculations resulted in proportions of water consumption from yards and houses for the period 1991-2003 (see Table 4.6).

Table 4.6: Estimated proportions of water consumption by type of connection for five urban centres (1991 and 2001)

	water consumption of house connections as % of total domestic use (1991)	water consumption by yard connection as % of total domestic use (1991)	consumption by house connection as % of total domestic use (2001)	water consumption by yard connection as % of total domestic use 2001	Annual growth rate in wat. cons. from house connections	Annual growth rate in wat. cons. from yards
Gaborone	56.8	14.7	78.8	13.4	7.5	3.1
F/town	36.8	15.4	66.6	18.8	7.7	3.5
Jwaneng	77.3	18.4	85.4	13.3	4.1	-0.0
S/Phikwe	46.8	22.2	67.8	22.1	3.5	-0.0
Lobatse	47.8	14.5	69.4	14.3	3.6	3.6

Regarding the government sector, WW supply has been calculated as water consumption by government multiplied by the EGF of 0.65. It is assumed that:

- All government institutions are connected to the sewerage system and WWTW;

- For the period 1998-2002, the share of the government consumption in Gaborone is the average share for the period 1990-97 (0.9153).

Regarding the industry/ business, WW supply has been calculated as the water consumption of this sector multiplied by the EGF of 0.55. It is assumed that:

- All industries and business that use water are connected to the sewerage system and WWTW;
- For the periods 1998-2002, the share of industry/business water in Gaborone is the average for the period 1990-97 (0.775);

Results
The estimated WW supply account by main category of supply is presented in Figure 4.3. The figures are presented in Table A1 in Appendix 1.

The amount of available wastewater has more than doubled in the period 1992-2003. In 1992, the total amount of wastewater received at WWTWs was 14.8 Mm^3 compared to an estimated 29.2 Mm^3 in 2003. This figure amounts to an inflow into WWTW of around seventeen percent of the total water consumption.

Government and domestic use are the primary drivers of the growth in WW supply with growth rates of 132.3% and 119.9% over the period 1992-2003 respectively. The high growth rate in government WW supply may be due to the fact that most government institutions are found in urban areas and large villages. The other reason may be that the economy of Botswana is government-oriented. In contrast, the growth rate of wastewater from industry/business is minimal at a mere 5.7% increase for an entire decade. This low figure shows that slow path of private sector development and economic diversification.

The bulk of wastewater is generated in urban areas, but the growth in WW supply from large villages has been significant in the period 1992-2003 (Figure 4.5). A distinct advantage of wastewater is that most of it is produced in a few urban centres, mostly in south-eastern Botswana. Wastewater from Lobatse, Gaborone, Jwaneng, Francistown and Selebi-Phikwe accounts for eighty percent of all WWTW wastewater (Table 4.7). Gaborone alone supplies more than half of the urban WW supply. The growth in wastewater is fastest in Gaborone and Francistown, where the amount of WW has more than doubled. Other towns recorded increase in the range of forty to ninety percent. The concentration of WW supply in urban areas can be attributed to urbanisation, improved living conditions and an increase in per capita water consumption.

Table 4.7 WW supply of major urban centres (1992 and 2003)

Major sources of WW	1992 supply in Mm^3	2003 supply in Mm^3	Growth as %
Gaborone	8.	17.11	113.6
Francistown	1.9	4.1	122.0
Selebi-Phikwe	2.2	3.1	41.9
Lobatse	0.9	1.6	87.2
Jwaneng	0.7	1.1	48.7
Total	13.6	27.0	

Source: this study.

Eight large villages now contribute to the supply of wastewater. More wastewater will be available in large villages in future due to the construction of more WWTW during the period 1992-2003[15], and an increase in water consumption increased.

Figure 4.4

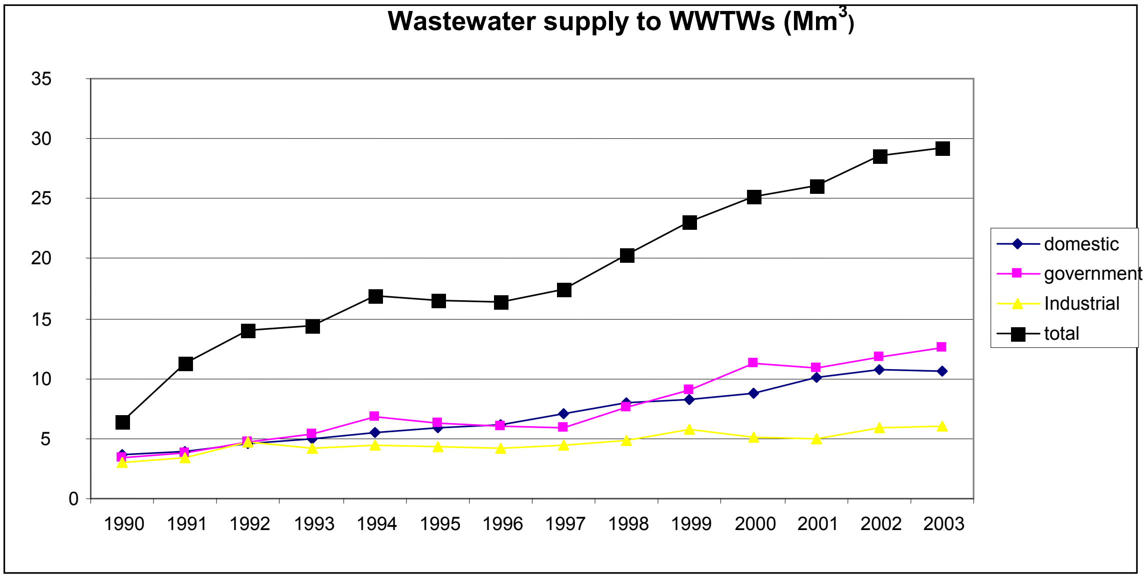
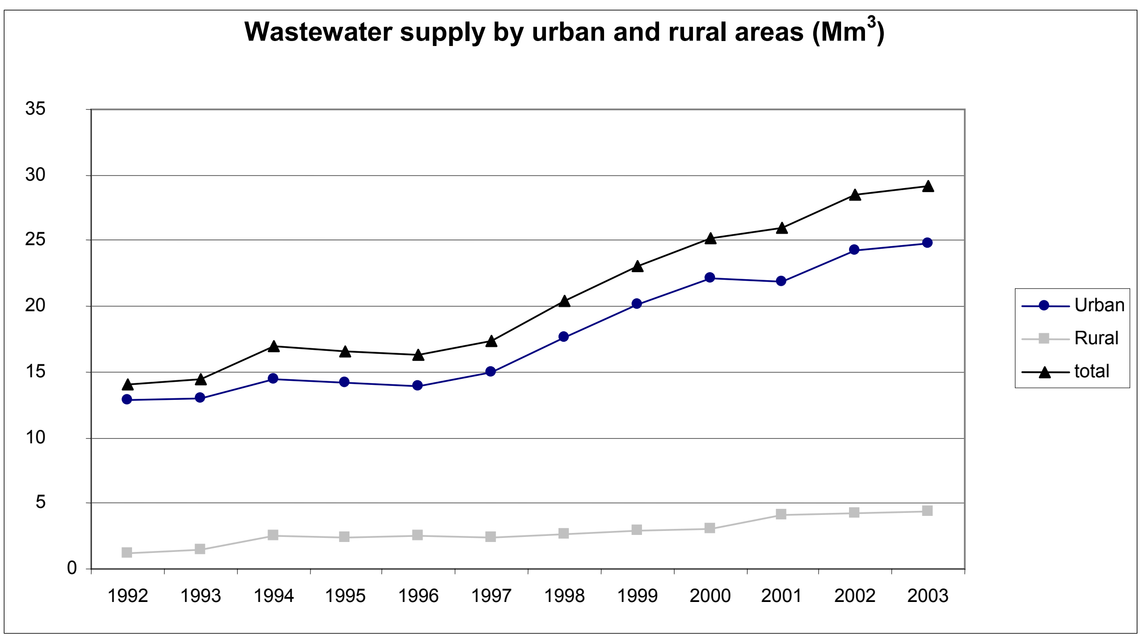


Figure 4.5:



Source: this study.

[15] Since 1992: Kasane, Mochudi, Mogoditshane, Molepolole, Tlokweng. Others include Maun (1994), Palapye (2000), Ramotswa (2001).

Sensitivity analysis

The assumptions made above appear realistic, but nonetheless it is important to check the sensitivity of the results. Two assumptions have been altered to assess their impact on the wastewater supply. Firstly, it is assumed that in rural villages only 20% instead of 100% of the households with house connections generate WW. The justification would be that many houses with an in-house water connection are not yet connected to the sewerage system. The new assumption obviously leads to a lower WW supply. Secondly, 20% of the households with a yard connection generate wastewater for the WWTW (in stead of 0%). Obviously, this leads to a higher WW supply.

The assumptions for industry/ businesses and for government were considered realistic, and no sensitivity analyses were applied to these sectors. All government and business operations can afford and will be connected to sewerage systems, if available.

The results of the sensitivity analysis are summarised in Table 4.8. The estimated wastewater generated by households shows a range of around 15% up (variant 1) and down (variant 2).

Table 4.8: Wastewater supply under different assumptions (2003).

	Baseline	**Variant 1**	**Variant 2**
Households	10,604	9,084 (-14.3%)	12,218 (15.2%)
Business/ industry	6,006	6,006	6,006
Government	12,561	12,561	12,561
Total	29,207	27,651 (- 5.3%)	30,786 (5.4%)
Urban cities-towns	24,855	26,234 (5.5%)	28,122 (13.1%)
Rural large villages	4,352	1,417 (-67.4%)	2,664 (-38.8%)

Source: this study.

4.5 Wastewater use accounts

WW use accounts show the destination of wastewater after it enters the WWTW. The following main destinations are distinguished:

- Losses in the WWTW. The treatment technology determines the percentage of losses. Losses are high for the ponds system (40 to 60%) but relatively low for the trickling filter technology used in Francistown (5%). The lower the losses are, the more water is available for re-use or recycling;
- Re-use, i.e. use of the outflow by economic sectors;
- Re-cycling, i.e. use of the outflow by water service providers such as WUC; and
- Discharges into the environment *outside the WWTW*, mostly in river such as the Notwane and Shashe Rivers.

According to the NMPWWS (SMEC *et al*, 2003), management of most WWTW is inadequate and no proper monitoring and recording systems are kept. The recommended National Asset Register (NAR) for WWTW has already broken down, and consequently data on inflows, outflows, water quality and re-use/ recycling are incomplete. Some NAR data for 2001/02 have been used, and were supplemented by fieldwork at the five major WWTW and fieldwork follow-ups (Gaborone, Lobatse, Jwaneng, Selebi-Phikwe and Francistown).

Figure 4.6: Chlorine contact tank and wastewater storage tank for recycling (F'town WWTW).

Figure 4.7: Dam with treated wastewater for re-use for the mine grounds (Jwaneng).

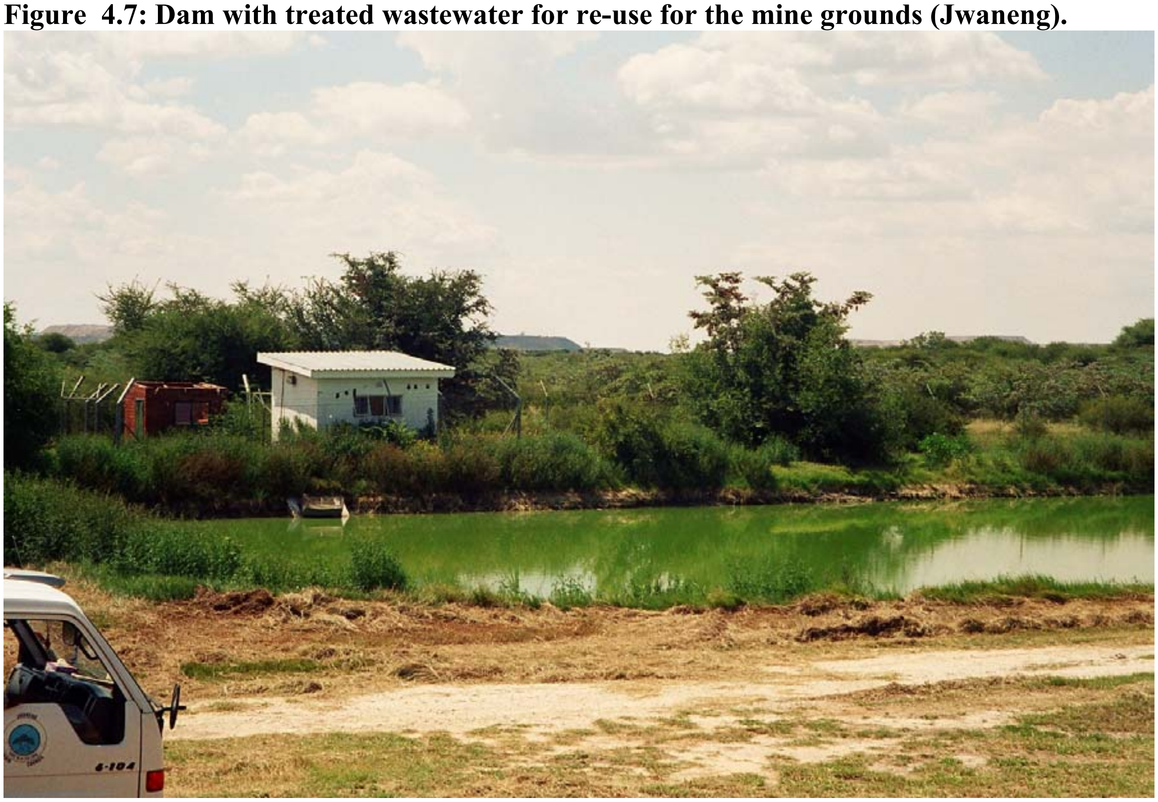


Figure 4.8: Copper nickel removal plant for re-use in irrigation.

Figure 4.8: Dam for BCL irrigation project (re-use).

Secondary and primary data show that recycling of WW is zero at present. The 2004/05 water crisis in Gaborone has renewed interest in the potential of treated WW recycling. Re-use occurs, but is still in its infancy and very small. Irrigation plans for significant re-use in Gaborone and Francistown (over 10 Mm^3) are in an advanced stage.

Regarding re-use of wastewater, the following situation analysis was prepared from the literature and fieldwork. For Gaborone, the re-use fraction was 0.064 in 2001 (NMPWWS), equally split between Botswana College of Agriculture (BCA) and the Gaborone Golf Club. The re-use fraction increases to 0.096 in 2003 due to the addition of a new re-use activity (Phakalane Golf Club). Re-use will increase drastically with the new irrigation scheme. For Lobatse, 94% of the outflow is re-used and six percent is discharged into the environment. These figures are based on the NMPSWW, and slightly differ with the WWTW statement that 100% of the outflow is being re-used. Unfortunately, no figures of re-use were provided due to an on-going payment dispute with the farmer. In Jwaneng, fieldwork showed that 100% of the outflow is being re-used; there is no discharge into the environment. The water is re-used for landscaping and gardening. In Francistown, 95% of the outflow is discharged into the river. There is no re-use as yet but an irrigation scheme is planned. In Selebi-Phikwe, the entire outflow is discharged into the river. There is no re-use at all.

The above situation has been used to estimate the WW use accounts. The use accounts consist of sub-accounts for individual WWTW and an aggregate account. The use of WW covers re-use in economic activities, WWTW losses, recycling and discharges into the environment. The total of the WW use accounts equals that of the WW supply account.

The account is provided in tabular form in Appendix 1. The main destinations, including uses, are displayed in Table 4.9. It becomes clear that processing losses in WWTW and discharges into the environment, usually rivers are most important. Together these account for close to 90% of the WW supply. Recycling is zero and re-use has grown to 10.8% in 2003.

Table 4.9: Main uses of WW supply (as % of total)

Wastewater destination	**1992**	**1997**	**2003**
Processing losses	43.7	43.0	42.2
Re-use	6.5	6.4	10.8
Recycling	0.0	0.0	0.0
Environmental discharge	49.8	50.6	47.0
Total use of WW	100.0	100.0	100.0

Source: this study.

Re-use of wastewater is increasing, but remains low as a percentage of the outflows (11.2%). The estimated total re-use increased from 0.9 Mm^3 in 1992 to 1.6 Mm^3 in 2003; a growth of 83.3% in ten years.

Current re-use is confined to agriculture and landscaping (golf courses and public parks). Most of the wastewater is used for irrigation in the country (it grew by 87.24% in period 1992-2003). For example, it is used to irrigate Lucerne in Lobatse, for watering golf courses (at Gaborone and Phakalane golf courses).The mining sector is the second large user of wastewater, but its use is also mostly for landscaping (Jwaneng mine).

As re-use is low, almost ninety percent of the outflow is discharged into rivers. Such discharges benefit the environment (vegetation and groundwater recharge) as well as down stream economic activities, particularly livestock and small-scale irrigation, but may pose pollution and health risk if the discharge is of poor quality. The actual amount of re-use of water discharged into rivers is unknown and could not be assessed by this study.

The WW use accounts indicate the use of the inflows, including WWTW losses, re-use and discharges into the environment. Their total equals that of the WW supply account. This approach has the advantages that a reduction in losses (e.g. due to changed technology) leads directly to an increase in outflow for re-use or environmental discharge. The technology is an important determinant of the treated WW available for re-use (outflow). Francistown switched from a pond system to TF technology with much lower treatment losses (5% instead of 40 to 60%). Consequently, the amount of available treated WW increased dramatically. In 1992 the outflow for Francistown and Lobatse was 1.9 Mm^3 and 0.9 Mm^3 respectively while in 2003, the outflow for the same areas was 4.2 Mm^3 and 1.6 Mm^3 respectively. The difference in growth rate is due to the switch in treatment technology. However, the potential benefit of higher WW outflows is currently wasted in Francistown, as 95% of the outflow is dumped into the river.

According to the accounts, the amount of outflows or so-called 'new water' (according to the NMPWWS) reached 14.5 Mm^3 in 2003. This estimate is fairly close to that of the NMPWWS[16].

At a later stage, WW use accounts could be broken down into potable water (for recycling) and non-potable water (for re-use and discharge). At present, this does not make sense as no wastewater is treated to potable water standards.

4.6 Concluding remarks

This chapter presented new stock accounts for reservoir surface water (EA 1311) and for wastewater together with new accounts for wastewater supply and wastewater use. In addition, existing water use accounts were up-dated to 2003.

The wastewater supply account and the wastewater use accounts are the most important additions. It must be realised that the WW supply and use accounts concern non-potable water and can therefore not be directly linked with the existing flow and stock accounts. The WW-supply account records the wastewater supply (or inflow) into the WWTW in urban areas and large villages. The account is linked to the flow accounts through data from WUC and DWA for domestic use, business/ industry and government use. Subsequently, outflows of WWTW were spilt up in the wastewater use account into re-use (there is no recycling), evaporation/ production losses and discharge into the environment. Landscaping of public and private gardens/ parks (government and mines) and irrigation for agriculture (lucerne) are the main destinations.

Re-use of wastewater has several advantages from a water management perspective. Firstly, wastewater is close to the population and water demand centres, hence transport costs are low. Secondly, Botswana has few industries that could seriously pollute wastewater. Therefore, consultation, planning (e.g. separate treatment), and monitoring could minimise the risk of serious pollution that cannot be easily treated. Thirdly, the amount of wastewater is rapidly increasing and treatment technologies are available with much lower loss rates, leaving more water for re-use and recycling. The amount of WW grows faster than the water consumption.

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[16] Assuming a growth rate in outflow of 5% p.a., the NMPWWS estimate would be 13.5 M m^3. This is 6.9% lower than our estimate.

Existing flow accounts were improved and up-dated with new data. This increases their usefulness for integrated water resource management and water planning. The new stock accounts for reservoirs need to be extended to a longer period to increase their relevancy too. Improved record keeping and data management at WUC should make this possible.

CHAPTER FIVE
COST AND BENEFITS OF WASTEWATER RE-USE AND RECYCLING

5.1 Introduction

As stated earlier, full monetary accounts do not exist for Botswana. Data limitations made it impossible to prepare such accounts as part of this project. Instead this chapter focuses on the comparison of the wastewater treatment costs with the supply costs and price of fresh water and the potential benefits that can be obtained from re-use and recycling of water. Central to the re-use debate is the allocation of wastewater to different economic sectors. The assumption that wastewater is best re-used in irrigation is critically examined.

To put the discussion in a broader international perspective, the experience of the 'shining example' of re-use and recycling (Windhoek) is first discussed in section 5.2. In section 5.3, water efficiency of sectors is examined. The findings are important to determine the optimal destination of wastewater. Section 5.4 estimates the current wastewater treatment costs, and compares these with the costs of freshwater supply. The difference would be potential savings associated with re-use and recycling. Section 5.5 summarises results from a survey of WW re-users and traders in Gaborone (April and October). The results provide indications about the economic sectors that re-use wastewater and about the employment and income generating opportunities of the small-scale WW distribution sector. Section 5.6 reviews the benefits of WW re-use and of possible re-use and recycling scenarios.

5.2 The "Windhoek" experience with re-use and recycling

The capital of Namibia is an international front runner in the re-use and recycling of treated wastewater (Van der Merwe and Haarhoff, 1999; Van der Merwe, 1999). Windhoek receives potable water from a combination of groundwater, dams and recycled wastewater. The city re-uses treated wastewater through a dual pipe system (potable and non-potable water), and reduces evaporation losses of surface water by interconnecting dams and artificial recharge. The package of water supply and demand control measures in Windhoek has kept the water tariffs at bay and below those of Gaborone (cf. Figure 2.1) even though Windhoek has lower rainfall than Gaborone and the cities use the same pricing principles. Windhoek has an average rainfall of 360 mm per annum and an average evaporation of 3400 mm per annum; corresponding figures for Gaborone are 500 and 2000 mm. Windhoek had a population of 224 500 in 1999; its main water sources are summarised in Table 5.1.

Table 5.1: Water supply sources of Windhoek

Type of water	Infrastructure	Capacity
Groundwater	Fifty boreholes	1.93 Mm^3 for a max. of four consecutive years
Surface water	Six dams (1933-1982)	Capacity of 194 Mm^3 but safe yields of 21.1 Mm^3 (only 1.48 Mm^3 if dams would operate in isolation)
Reclaimed wastewater	Reclamation plant since 1968); expansion in 2000.	Capacity of 2.9 Mm^3; expansion to 7.7 Mm^3 .

Source: Van der Merwe, 1999.

Re-use and recycling of wastewater has led to an estimated water savings of 6.7% in 1999. Several measures were taken to control costs and health risks:

- Establishment of a water use ceiling of 1.3 m^3 /m^2 /day for irrigation;
- Diversion of industrial effluent, which may be seriously polluted, from the WWTW;
- Blending of recycled and fresh water: a maximum of 35% of recycled wastewater is mixed with a minimum of 65% of fresh water;
- Stringent water quality monitoring. Water quality monitoring is expensive at 15% of the total treatment costs; and
- Location of industries and activities that re-use wastewater in a particular site that is supplied by a dual reticulation system. The pipeline with treated wastewater has a capacity of 1.2 Mm^3 per annum and serves ninety nine large consumers.

The re-use and recycling of wastewater has been very successful. The production of freshwater for Windhoek has decreased despite the rapid growth of the city. Financial savings of US$ 8.7 million per annum have been achieved associated with the postponement of new capital works and lower water production costs. There have been no negative health impacts that could be traced to re-use and recycling of wastewater. Finally, both industry and households benefited from lower increases in water tariffs than would have been necessary without re-use and recycling. The costs of water reclamation were estimated to be the same (N$ 2.40/ m^3) as the cost of bulk water supply from Namwater, which would have risen considerably without re-use and recycling of treated wastewater. For example, the costs of water abstraction from the Okavango are almost three times the costs of water reclamation (US$ 1.43 and 0.58 per m^3; van der Merwe and Haarhoff, 1995; Van der Merwe, 1999). The cost savings[17] have had significant economic and welfare benefits, which have not been quantified.

The Windhoek experience shows that:

1. Recycling and re-use of wastewater can be cheaper than building new supply systems;
2. Proper physical planning can reduce the costs of reclamation and facilitate re-use/ recycling; and
3. The choice between re-use and recycling must be an informed one, based on different options and their net benefits.

5.3 Value added per unit of fresh water

The combination of water consumption and the output by sector gives an indication of the efficiency of water consumption in each economic sector. Using this indicator, previous studies (NCSA/CSO, 2001; Arntzen *et al,* 2003) have shown that the value added per m^3 is highest in the service, construction and public sectors (over P 1000/m^3). The value added per m^3 is considerably lower in the manufacturing industry, mining and government[18] (P 100 to 300/m^3) and by far the lowest in the agricultural sector (around P 5-7/m^3).

Using recent data from the Annual Economic Report 2005, earlier findings were up-dated to 2003 (Table 5.2). The up-date shows that water use efficiency has increased in time to an average of P106/m^3 in 2003 (93/94 Pula price). This implies that more economic gains are derived from each

[17] Water demand management and artificial recharge are cheaper than reclamation (US$0.17, 0.35 and 0.58/ m^3 respectively (Van der Merwe, 1999).
[18] Prices are indicated in 1993/94 Pula values.

consumed water unit. This is encouraging as Botswana's water efficiency already exceeded that of Namibia and South Africa (Lange *et al,* 2003).

Table 5.2: Water productivity (value added per m^3 by sector; 1993/94 Pula).

User category	1993	1998	2002	2003
Agriculture	6	6	5	4
Mining	274	257	257	260
Manufacturing	194	219	144	138
Water + electricity	190	357	942	654
Construction	2,294	4,890	2,395	2,468
Trade	1,116	1,800	1,543	1,445
Hotels and restaurants	276	373	334	321
Transport + communication	2,448	3,221	2,441	2,428
Insurance, banking, business	2,421	2,884	2,577	2,666
Social and personal services	382	494	1,247	1,282
Government	236	237	270	271
Grand total	*76*	*91*	*93*	*106*

Note: NA = not applicable as domestic use does not generate direct value added.
Sources: NCSA/CSO, 2001 and this study.

Water efficiency can also be measured by the number of jobs created per m^3. In 2003, an average of around 2 800 paid jobs were created for each Mm^3. The service sectors create the largest number of jobs per Mm^3 (20 to 50 000) with government creating around 25 000 jobs for each Mm^3 consumed. Efficiency in terms of paid employment creation is much lower in industry (several thousands), mining (365) and agriculture (83). Most jobs in agriculture are self employment of farmers and informal employment. If those would be included, water efficiency in terms of employment would be over 1 500 jobs per Mm^3.

Water efficiency is an important policy consideration for the destination of treated wastewater. Re-use could boost economic growth through the extra value added and employment generated by the re-used water. For example, re-use of one m^3 in the construction sector would generate value added of P 2467.54 (in 1993/94 Pula) compared with extra value added of P 121.92 in the manufacturing industry, P 271.39 in the government sector and a mere P 5.31 in the agricultural sector[19]. Recycling of wastewater would also enhance economic growth with a value added of P 660.40 in the utilities sector and additional benefits which depend on the efficiency of the sector which uses the treated wastewater.

5.4 WW treatment costs

Treatment costs of wastewater consist of operation/ maintenance costs and capital costs. Cost data are not readily available and only a few were found for a limited number of years, reflecting the fact that water and sanitation are treated as public goods.

Operation and maintenance costs (O&M) were collected for the five large WWTW for the period 1990-2003. O&M costs refer to the WWTW *and* the sewerage system, as it proved impossible to isolate the O&M costs for the WWTW.

Data for *capital costs* were most difficult to obtain due to poor record keeping and high turn-over rate of council staff. New WWTW were constructed in Gaborone and Francistown at estimated

[19] The value added of high value irrigation crops would be much higher.

costs of P 118 million and P 44.5 million respectively. The WWTW of Lobatse, Jwaneng and Selebi-Phikwe were upgraded at an estimated total cost of P 44.5 million. No written sources for the capital expenditures could be traced, and therefore the reliability of the figures could not be verified. The following assumptions were made to estimate unit capital costs:

- New plants; capital costs are written off in twenty years;
- Up-grading: represent half of the capital costs. Therefore capital costs can be calculated as capital costs of upgrading divided by ten years.

The estimated treatment costs were used to calculate the treatment costs per unit of return flow (inflow into WWTW) and outflow (outflow from WWTW). The figures are indicative only, and must be treated with great caution. The results are summarised in Table 5.3. No time series data could be calculated.

Table 5.3: Estimated treatment costs of five wastewater treatment works (2003).

	Pula/ m^3 inflow	**Pula/ m^3 outflow**
Gaborone	0.62	1.13
Lobatse	0.63	3.27
Jwaneng	2.66	7.12
Selebi Phikwe	0.96	2.44
Francistown new plant	3.95	1.57

The results show considerable variation in treatment costs related to the:

- Treatment technology. Pond technology is relatively cheap (Selebi-Phikwe and Lobatse) compared to trickling filter technology of Francistown, but has much higher evaporation losses;
- The Jwaneng treatment costs are much higher than the costs of other WWTW using the pond technology; and
- Size of the operation: larger operations such as in Gaborone have lower unit treatment costs.

For re-use and recycling, the costs per unit of outflow are most relevant. These costs range from P1 to 7/ m^3, overlapping with the costs of raw water (P 3.65/m^3 at WUC). The unit price of treated wastewater (inflow) in Gaborone is P 0.62 and probably used as justification for the selling price of P 0.60/m^3. The price of small scale re-use of wastewater in Gaborone is on average of P 33/m^3. This price is considered excessive compared to the costs (see section 5.5). The costs of re-use are considerably lower than the price of potable water. Therefore, those end-users that do not require potable water and can efficiently organise the collection of WW would gain financially. These are typically the construction, gardening/ landscaping and irrigation sectors.

5.5 Costs and benefits of small scale re-use of WW outflow in Gaborone

5.5.1 Background of the survey

Small scale re-use of treated wastewater in Gaborone has gradually evolved in a small market. Some collectors collect for their own use, others for sale or for both own use and sale. The demand originates from households (for gardening), and companies (mostly in landscaping and construction sectors). Tenders have been issued by some Ministries for gardening services with treated wastewater.

A survey was held in 2005 among all collectors of treated WW. The survey served two purposes. Firstly, it provides ideas about the activities that could benefit most from re-use. Secondly, the survey provides insights into the operation and sustainability of the emerging 'market' in treated wastewater and associated development benefits (e.g. income and employment). The 'market' is the direct result of temporary water restrictions[20] and its future is therefore uncertain. The water restrictions were imposed in December 2004 due to the low level of the Gaborone dam (18% in October 2005). The WUC restrictions aimed at reducing water consumption by 25% (i.e. the level that can be supplied by the NSWC). Domestic users were no longer allowed to use hosepipes for gardening and car wash. Companies were encouraged to reduce water consumption by re-using treated effluent.

Surveys were held in April and October 2005 (one week each) among those collecting treated effluent from the Gaborone WWTW ponds. All collectors were interviewed using a brief questionnaire. The main findings are discussed below.

5.5.2 Survey results

Re-use of treated wastewater has increased rapidly since the introduction of water restrictions. The number of different operators tripled from twenty three in April to seventy eight in early October, and the fleet capacity of the operators increased from 142 to 584 m^3 per week[21]. The structure of the fleet also changed. While in April most water was collected by bowsers (60.9%), tankers were most common in October (70.5%). The growth in re-use is clearly visible in the increase in:

- Trucks carrying water storage tanks in the city's traffic; and
- Gardens with storage tanks next to the gate or fence for wastewater delivery.

The increase in WW trade and collection is associated with the persistent and growing water problems of the capital as well as seasonal influences (start of the hot season). The main findings are reported below.

Re-use of WW is growing, but is still small. Twenty three different collectors were interviewed in April, mostly employees of private companies (20) and government (1). In October, seventy eight collectors were interviewed, seventy one of which were employed. The average collection capacity was 6.2 m^3 in April with a range of 1 to 15 m^3. The capacity has grown to an average of 7.5 m^3 in October, or by 21%. People collect frequently, at least several times a week. The collection frequency has increased, as Table 5.4 shows. In October, 65.4% of the operators collect WW daily or several times a day; the corresponding figure for April is 39.1%. The increase can be attributed to seasonality (hot and dry in October) and/or to a structural increase. Further monitoring and research is needed to see which factor is most important.

[20] At the time of finalisation of the report (June 2006), Gaborone has had an excellent rainy season and the dam filled up to over 80%. Government has, however, decided to retain water restrictions in an effort to encourage re-use and increase water efficiency.
[21] The actual collection capacity is much higher, as most operators collect daily or several times a day.

Figure 5.1: Interview of a wastewater collector.

Table 5.4: Frequency of WW collection for small scale re-use (no)

Frequency	April	October
several times a day	6	18
Daily	3	33
Several times a week	11	22
Less frequent	3	5
Total	23	78

Source: fieldwork.

The reported average weekly amount collected decreased slightly from 60.5 m^3 in April (15 respondents) to 53.4 m^3 in October (75 respondents). This is probably an underestimate given the available fleet capacity and stated collection frequency. The amount of re-use was estimated in three ways. Firstly, according to the April survey, the average amount that has been collected in 2005 is 297.7 m^3 (nine respondents). Assuming the average applies to all 23 collectors at that time (April), the total amount collected in January-April would be 6 433 m^3 or just under 20 000 m^3 per annum. Secondly, assuming a constant level of re-use per collector/trader (78 in October) the amount of re-use could be 217 000 m^3 per annum. Thirdly, collectors pay the Gaborone City Council (GCC) for re-used effluent in advance. According to GCC-records, thirteen collectors spent a total of P 3 595 in the period January-April. Assuming that the amount paid for is collected during the period, re-use of those collectors would be 3 595 m^3 per month. Assuming the same average use for the other ten collectors, the annual re-use would be in the order of 76 000 m^3 per annum. The most recent GCC-records show that clients purchased 42 323 m^3 between January and mid October. Assuming that this level of purchases is maintained, total annual sales would be 50 to 60 000 m^3.

The above estimates for re-use vary considerably and have to be interpreted cautiously given the small number of respondents and the assumptions made. It appears reasonable to assume that small-scale re-use is in the order of 50 to 100 000 m^3 per annum. This level of re-use is around one percent of the estimated annual outflow of 6.8 Mm^3 (Table 2.4).

Re-use is both for own collection (78.3% and 88.5% in April and October respondents) and for sale (60.9% and 34.6% in April and October respondents), with several collectors combining both. The landscaping/gardening sector, irrigation/ horticulture and the construction sectors use treated effluent for own purposes, often using their own trucks. Few households directly collect treated effluent, as they do not have the required equipment.

Collection for own use is mostly for gardening purposes (78.3%; Table 5.5). Irrigation, construction, domestic use and roads are of secondary importance.

Table 5.5: Purpose of small scale re-use for own purposes in Gaborone (2005).

Purpose	April Frequency and % (N = 18)		October Frequency and % (N = 69)	
Gardening	13	72.2%	54	78.3%
Irrigation	10	55.6%	11	15.9
Domestic use	3	16.7%	8	11.6
Construction	2	11.1%	10	14.5
Roads	2	11.1%	6	8.7
Other	0		3	4.3

Source: fieldwork

Households have become the main client of sold WW (54.2% in October; Table 5.6). The market share of business has decreased, presumably because more companies are now collecting themselves (sixty five in October compared to nineteen in April). In April, Government only acted as a collector, but in October government also started to purchase wastewater. Several Ministries put out tenders for landscaping and gardening with treated wastewater.

Table 5.6: Type of clients of sold wastewater in Gaborone (2005)

Client	April		October	
	Frequency	% (n=14)	Frequency (n=24)	%
Domestic users	8	57.7%	13	54.2%
Companies	10	71.4%	7	29.2%
Government	0	0	7	29.2%

Source: fieldwork.

The average number of customers is small: eight per trader in April, and only three in October. The decrease may indicate the growing market competitiveness among WW traders, whose numbers increased from fourteen in April to sixty-one in October.

The average selling price of wastewater decreased slightly in 2005. In April the average price was P 38/m^3 (seven respondents) with a range of P 25-58/m^3.); in October the average price had slightly decreased to P 33/m^3 with a range of P 15 to 50 m^3) (twenty seven respondents). The average costs are estimated to be P 14/m^3, but this figure is the average of three respondents only (April; 0 for October); most employees did not know the costs and subsequent follow-ups with the companies did not yield much result. Our own calculation suggests that the cost price/m^3 could be around P 17/m^3 for a WW trading operation based on the following assumptions:

- One truck with a capacity of 10 m^3 delivers six loads per day;
- The average delivery distance is 30 km (round trip) at an estimated vehicle costs of Pula 5/km;
- The crew consists of one driver and two assistants at a daily costs of Pula 100;

Asked about the cost structure, petrol, vehicle and labour costs were the major costs components. The resource costs are minor (P 0.60/m^3).

Comparing the estimated supply costs[22] (P 14-17/m^3) and selling price (P 33/m^3), the profit margin is around 100%. This is confirmed by the perception that the wastewater trade is 'normal to very profitable' (Table 5.7). A caution interpretation is required given the very low response rate.

The price of treated wastewater is high for end-users who cannot collect themselves and depend on home delivery. It is however economically attractive companies with transport and labour as the charge for wastewater is much lower than WUC tariffs. Despite the relatively high costs in comparison to WUC water, fifteen out of sixteen respondents state that they will continue re-use after the WUC restrictions are lifted. Given the level of profitability and high unemployment, the question arises as to why not more traders enter the market. Possible reasons are:

- Lack of business acumen and skills;
- Lack of access to transport requirements (e.g. truck, storage tanks and generator);
- Cultural inhibitions towards the handling and use of treated wastewater;
- The new irrigation scheme may discourage traders to develop their businesses as it could absorb most of the outflow.

Table 5.7: Perception of profitability of the WW trade by traders.

Level of profit	April		October	
	No	Percent	No	Percent
Not profitable	0		0	0
Little profit	2	25%	5	17.9
Normal profit	4	50%	16	57.1
Very profitable	2	25%	7	25.0
Total responses	**8**		**28**	

Source: fieldwork.

Table 5.8 shows the supply costs and prices of waste water and water in Gaborone. The comparison of prices shows that it is attractive to purchase wastewater for those companies that have transport and labour available at low opportunity costs. The GCC rates for wastewater (P 0.60/m^3) are well below the WUC charge for raw water (P 3.65/m^3). Most end-users, for example those who require home delivery for gardening, are expected to revert back to WUC water after the restrictions have been lifted. They would achieve significant cost savings. They will continue to use wastewater *if* the market prices drops or water restrictions are kept in place. This requires a more competitive and transparent market. The supply cost comparison shows that significant savings may be achieved by re-use of wastewater if an efficient infrastructure for wastewater

[22] Covers costs of vehicle, petrol/ diesel, labour and water.

delivery can be established. The current supply costs of home delivered water (P 14.05/m^3) are higher than the average supply cost of WUC (P 6.68/m^3 in 2003). *If* infrastructure and delivery costs can be kept below P 4.43/m^3 (the difference between the current WUC unit price and the unit treatment costs of wastewater), savings can be achieved by increasing re-use and/or recycling. The greater the delivery efficiency becomes, the larger the savings will be.

Table 5.8: Synthesis of (waste) water prices and supply costs in Gaborone (2005).

Type	Price (P/m^3)	
Prices of (waste)water		
GCC selling price	0.60	
Av. purchasing price by end-users	April: 37.73	October: 33.27
WUC charges for raw water	3.65	
WUC charges for potable water (above 15 m^3)	12.50	
Costs of supply		
WUC water costs (Gaborone)	6.68	
WW treatment costs Gaborone	2.25 outflow	P 0.62 inflow
Av. cost price of WW traders	14.05	
GCC selling price of treated WW	0.60	

Sources: WUC Annual report 2003, this study.

5.6 Benefits of wastewater re-use and possible re-uses/ recycling scenarios

The literature shows that re-use and recycling may have three types of benefits:

- Postponement of investments in additional water supply schemes;
- Benefits derived from the use of the 'saved' water, i.e. additional production and economic growth and/or improved welfare through serving more households with more water; and
- Lower water tariffs, which enhances the country's competitiveness and leads to income savings for households. Re-use and recycling have given Windhoek a competitive advantage over Gaborone (see section 5.2).

Postponement of additional supply works is a well known benefit of re-use and recycling. According to NDP8, re-use of WW in Gaborone and south-eastern Botswana could lead to the postponement of the planned capacity expansion of the NSWC by five years. The first phase of the NSWC has been the biggest ever construction project undertaken in Botswana. The expenditures for the first phase were around P1.6 billion. If we assume that:

- The second phase would cost the same (conservative);
- Construction costs would be evenly spread over five years; and
- Opportunity costs of capital are 10% per annum.

The project deferment by five years can be valued at over P 500 million over a five year period. Opportunity costs of capital of 5% would still lead to savings of around P 375 million.

Major economic benefits can also be obtained from alternative use of the fresh water that becomes available. There is a growing realisation that re-use of treated wastewater could have economic benefits, but the optimal use of wastewater is rarely considered. The implicit assumption is that irrigation is the best destination. The discussion has, however, not yet considered the questions:

- Which sectors should be targeted for re-use; and
- What are the benefits of re-use as compared to recycling?

In order to optimise growth and welfare, the above questions need to be answered and a holistic strategy towards re-use and recycling needs to be developed as part of the broader integrated water resource management approach. Below, we explore the costs and benefits of re-use and recycling. Further work is needed to answer the questions in greater depth.

The amount of 'new water' or outflow from WWTW is around 14.5 Mm^3 in 2003. Currently, around ten percent of the outflow is re-used by agriculture, and landscaping, gardening and golf courses. The following sectors offer opportunities for re-use at the moment:

- Agriculture and irrigation (water consumption in the order of 70 to 80 Mm^3 per annum);
- Construction sector (around 1 Mm^3 per annum);
- Manufacturing (0.7 Mm^3 per annum);
- Government sector (2.4 Mm^3 per annum); and
- Domestic use (34.0 Mm^3 per annum, up to half or 17 Mm^3 could be used for gardening).

Irrigation and domestic use are the largest users, and could each absorb the entire amount of wastewater generated in the country[23]. Similarly, irrigation projects in urban and peri-urban areas could easily absorb the available wastewater. The amount of wastewater could not be fully absorbed by the construction and government sectors.

<u>If all wastewater would be used for domestic use</u>, no direct economic benefits would be generated. Instead, the benefits would depend on the destination of the 'released' fresh water. Using the average value (constant 93/94 prices) of P 105.94/ m^3, the gross economic benefits in terms of value added would be Pula 1.5 billion per annum. The extra costs of delivery and infrastructure need to be deducted in order to estimate the net benefits. This scenario is not fully realistic as many economic sectors require better water than the current wastewater.

<u>If all wastewater would be allocated to irrigation</u>, the gross economic benefits could amount to around P 290 million (based on an average value added of P 20/m^3, as found in Namibia (Arntzen *et al*, 2003). Once more the extra costs of delivery and infrastructure need to be deducted in order to estimate the net benefits. Clearly, exclusive re-use for irrigated agriculture does not maximise the economic benefits of re-use *unless* the value added in irrigated agriculture exceeds the country's overall average; this could only be achieved by extremely efficient irrigation of high-value products.

Given the above, the wisest choice of re-use seems to be a combination of re-use destinations. An example is presented in Table 5.7 with its economic consequences. The value added excludes indirect benefits and cost savings to companies that could be associated with re-used water. The estimate of gross benefits totals P 925 million per annum. It is difficult to estimate the impact on employment. Using the average employment rate of 2 800 per Mm^3, employment generation could be as much as 40 000 paid jobs, but much depends on the nature of the water used. The figures in Table 5.9 are indicative at best. It is clear, however, that employment creation could become a major policy consideration in the promotion and allocation of waster water for re-use.

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[23] Watering of gardens is a substantial part of domestic use (up to 50%).

Table 5.9: Possible direct gross economic benefits of a composite re-use scenario

Destination	Designated re-use amount Mm^3)	Value added / m^3 (93/94 P/m^3)	Directly associated value added of re-use (M Pula 93/94 prices)	Possible associated paid employment
Irrigated agriculture	8.0	20	160	50 - 500
Construction	0.2	2 468	494	7 000 - 12 000
Government	1.0	271	271	20 000- 25 000
Domestic use	5.3	0	None[24]	
Total	14.5		925	Around 40 000

Full recycling would require additional treatment and adjustments of the water supply systems. Given the amounts of wastewater full recycling should currently only be considered in the Gaborone and Francistown areas. The precautionary measure of Windhoek to blend one unit of treated wastewater with two units of fresh water is feasible in Gaborone, but would no longer permit substantial irrigation use. The experience of Windhoek shows that monitoring costs are significant. The additional costs would be much higher than the costs of re-use, but the benefits are also expected to be higher. Recycling would be viable as long as the extra treatment costs do not exceed the long run marginal supply costs plus the current treatment costs.

Recycling would boost the water production of WUC in urban areas and of DWA for urban villages. The gross economic benefits can be calculated as follows:

- For WUC: the amount of urban wastewater multiplied by the average value added per m^3 of WUC water;
- For DWA: the amount of rural village wastewater multiplied by the average value added per m^3 of DWA water.

5.7 Concluding remarks

While the results are not fully conclusive and more in-depth research is needed, there is strong evidence that the current practice of wastewater disposal has significant economic and social costs: opportunity costs of capital investment in water infrastructure, opportunity costs of 'lost' water and high water tariffs. Substantial benefits may be obtained form re-use and/or recycling, particularly in the five main urban centres. Potential for re-use in the large villages is also growing.

Re-use is less risky and easier to purse on the short term, as it is flexible and requires less additional investment, particularly through small-scale re-use. Re-use for irrigation is unlikely to bring the highest economic benefits in terms of value added; re-use in different economic sectors is expected to yield higher value added and employment benefits. At present, re-use is only financially attractive for companies with transport and labour with low opportunity costs. Users who require home delivery pay considerably more than the WUC tariffs, and are likely to switch back to WUC water after the water restrictions are lifted. There is need to develop a more

[24] The benefits of re-use in the domestic sector depend on the destination of the saved fresh water sources, and could be substantial.

competitive and transparent market for small scale wastewater re-use, especially for gardening purposes.

Given the difference in WW treatment costs and the LRMC of fresh water, recycling of WW must be an attractive medium to long-term option. The current plans to expand the NSWC should not be implemented without a full assessment of the net benefits of the 'recycling and re-use option'.

The choice between re-use and recycling depends on the extra treatment costs to bring treated wastewater up to potable water standards as well as on the location of the WWTW. Re-use appears most suitable for rural villages, as the amounts are relatively small and extra treatment costs required for recycling could be high, and easily exceed the rural LRMC. Irrigation, construction and watering of public gardens appear most suitable forms of re-use. In urban areas, with most WW, and the water demand centres, the benefits of recycling must be compared in greater depth with those of re-use.

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APPENDIX 1: DEFINITION OF TERMS

Abstraction: total volume of water withdrawn from a territory of reference in a given year.

Aquifer: a formation which may either be a consolidated or unconsolidated rock in which groundwater collects.

Discharge: release of wastewater into the environment (BOS 93: 2004).

Drinking or potable water: water that is suitable for drinking purposes.

Effluent: the final liquid waste from a processing facility or household (adapted from BOBS standard 93-2004, which is restricted to processing facility)

Evaporation: amount lost to evaporation during the accounting period.

Inflow: amount of water that enters the territory of reference, usually a WWTW.

Territory of reference: encompasses dams, rivers, lakes and aquifers.

Outflow (or 'new' water): volume of water that leaves the territory of reference, usually WWTW.

Return flows: amount of water that reaches a territory of reference, usually a WWTW, from other uses, e.g. wastewater

Wastewater: water contaminated with pollutants following its use or application in domestic industrial, commercial or institutional premises (BOS 93: 2004)

APPENDIX 2: DETAILS OF THE WATER ACCOUNTS

Stock account

Table A2.1: Sub account water stock Moshupa dam

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Opening volume	0.99955	0.97579	0.98807	0.99104	0.99351	0.98757	1.00431	0.99965	0.99213	0.97619	1.00064	0.99243	1.00589	0.98401
Inflows	0.98531	0.85772	1.11319	1.03830	1.13376	1.24746	1.23990	1.13627	1.13646	1.29202	1.16457	1.36184	0.95626	0.85406
Abstraction	0.19087	0.19499	0.19757	0.19946	0.20633	0.23490	0.24225	0.26566	0.28176	0.33606	0.34587	0.38624	0.00000	0.00000
Evaporation	0.81820	0.65045	0.91265	0.83636	0.93337	0.99582	1.00230	0.87814	0.87064	0.93151	0.82692	0.96213	0.97814	0.84119
Closing volume	0.97579	0.98807	0.99104	0.99351	0.98757	1.00431	0.99965	0.99213	0.97619	1.00064	0.99243	1.00589	0.98401	0.99688

Use accounts (fresh water)

Table A2.2: Water use account by institution (in 000m^3; 1992-2003)

Category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DC	20435	20611	20791	20973	21158	21345	21536	21734	21937	22151	22369	22591
DWA	7765	7715	8703	8961	9080	9374	10356	10723	10465	10413	11326	11805
WUC	25391	26973	27692	27672	28043	30661	35435	38438	41903	44585	49170	50343
Others	86661	86476	85584	88912	83009	84178	86042	91798	94363	93182	104060	85592
Total	140252	141775	142770	146518	141290	145558	153369	162693	168668	170331	186925	170332

Table A2.3: Water use account by source of water (in 000m^3; 1992-2003)

Category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
groundwater	86658	86903	87455	90609	87060	88624	91078	96898	99272	97761	107774	94605
dams	43919	45203	45746	46237	44840	47462	52653	55862	59607	62597	68698	66158
rivers	9674	9545	9569	9808	9390	9471	9638	9649	9711	9972	10453	9569
Total	140252	141651	142770	146654	141290	145558	153369	162409	168590	170331	186925	170332

Table A2.4: Water use by economic sector (000m^3; 1992-2003)

User category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Agriculture	72913	74196	72912	75216	70592	69558	71559	74802	76048	75652	82086	63420
Mining	12840	14890	15197	16551	14418	17910	18361	20857	24098	22851	25357	26751
Manufacturing	390	2289	2291	2282	2069	2559	3108	3725	3994	4392	4910	5109
Water + electricity	1240	1306	1176	1152	768	738	960	735	510	467	475	710
Construction	0	320	246	240	364	304	193	365	386	397	423	430
Trade	159	660	651	618	749	760	747	932	956	1053	1067	1175
Hotels and restaurants	227	635	624	540	546	567	535	755	803	800	804	845
Transport + communication	0	172	161	169	167	171	185	222	235	241	260	265
Insurance, banking, business	11	488	446	457	517	529	583	657	692	706	771	782
Social and personal services	0	1272	1182	1247	1176	1148	1285	1587	1680	1727	2395	2435
Government	8689	7459	9017	8693	8847	8577	10101	10347	11096	11275	11053	11502
Household use	36090	38089	38866	39352	41078	42742	45752	47603	48093	50771	57224	56908
WUC private sector	7695	0	0	0	0	0	0	0	0	0	0	0
Grand total	140252	141775	142770	146518	141290	145562	153369	162588	168590	170331	186825	170332

Wastewater accounts

Table A2.5: Wastewater supply account by area and sector (000m^3)

Urban areas	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Gaborone	7225	7399	8418	7991	7696	8250	10102	11859	12435	12599	15055	14971
Ftown	1867	2028	2217	2216	2233	2457	2722	3237	3646	3909	3826	4145
Jwaneng	712	707	779	757	778	774	786	855	844	864	1007	1059
S/Phikwe	2167	2012	2129	2313	2294	2484	2937	2952	3884	3071	2986	3076
Lobatse	856	894	888	933	893	1072	1114	1227	1284	1480	1418	1604
Large villages												
Kasane	123	146	170	232	202	224	110	178	229	251	253	275
Maun	0	0	410	308	302	403	418	391	388	450	322	303
Mochudi	139	147	151	131	178	214	279	317	400	422	545	499
Mogoditshane	574	648	1284	1204	1321	1018	1459	1025	757	1329	1406	1446
Molepolole	150	195	166	157	167	234	90	434	265	325	292	353
Palapye	0	0	0	0	0	0	0	0	409	456	454	445
Ramotswa	0	0	0	0	0	0	0	0	0	258	285	314
Tlokweng	221	269	300	315	302	293	344	603	661	633	675	716
000m^3	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Urban	12828	13040	14431	14210	13895	15037	17662	20130	22092	21922	24292	24855
Rural	1206	1405	2480	2346	2473	2386	2700	2948	3110	4125	4231	4352
Total	14035	14445	16911	16556	16368	17422	20362	23078	25202	26047	28524	29207
000m^3	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
households	4598	4958	5560	5927	6213	7080	7965	8271	8796	10110	10768	10640
government	4708	5354	6847	6322	6024	5879	7599	9079	11323	10937	11819	12561
business/ industry	4729	4133	4504	4307	4131	4463	4799	5729	5083	5000	5937	6006
Total	14035	14445	16911	16556	16368	17422	20362	23078	25202	26047	28524	29207

Note: Tlokweng and Mogoditshane are added to urban areas as their wastewater is treated in Gaborone.

Table A2.6: Wastewater use accounts (1990-2003; 000 m^3)

	User category	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
I.	Agriculture	320	335	332	349	334	401	417	459	480	554	531	600
II.	Mining	214	212	234	227	233	232	236	257	253	259	302	318
III.	Industry	0	0	0	0	0	0	0	0	0	0	0	0
IV.	Water/ Electricity	0	0	0	0	0	0	0	0	0	0	0	0
V.	Construction	0	0	0	0	0	0	0	0	0	0	0	0
V	Services	141	146	176	167	164	168	210	237	244	256	302	302
VI.	Government												
	Central govt	141	146	176	167	164	168	210	237	244	256	302	302
	Local govt	71	71	78	76	78	77	79	86	84	86	101	106
VI.	Domestic Use	0	0	0	0	0	0	0	0	0	0	0	0
VII.	Environment												
VII.1	Evaporation/ treatment losses	6127	6232	7301	7164	7055	7480	8714	9785	10540	10591	11724	11942
VII.2	Discharge in rivers	6880	7144	8362	8148	8060	8528	10093	11535	12466	13932	15126	15497
	Other outflow	34	38	42	51	47	54	38	51	60	67	65	72
VIII.	**Total use of WW**	**13929**	**14325**	**16700**	**16348**	**16135**	**17109**	**19995**	**22648**	**24372**	**26002**	**28453**	**29138**

Table A.2.7: Value added per m^3 of water (1993/94 constant prices; Pula).

User category	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Agriculture	6.50	6.43	6.67	6.73	7.05	6.37	5.53	6.07	5.91	5.41	3.71
Mining	274.44	262.04	252.18	313.36	269.56	256.93	252.12	260.45	264.69	257.08	260.22
Manufacturing	194.24	236.95	256.97	300.80	250.04	218.78	187.49	177.10	160.25	144.29	137.83
Water + electricity	190.07	222.61	228.33	366.90	409.44	357.19	500.91	796.56	895.79	942.17	653.86
Construction	2294.25	2999.12	3189.95	2269.05	2766.54	4889.56	2629.59	2565.12	2596.33	2395.36	2467.54
Trade	1116.19	1396.79	1653.76	1635.61	1631.08	1799.96	1522.98	1613.83	1570.70	1543.14	1444.62
Hotels and reastaurants	275.65	3199.90	367.99	364.84	380.04	372.69	281.75	277.32	303.24	333.64	321.38
Transport + communication	2447.82	2758.13	2649.87	2869.92	2971.32	3220.92	2739.03	2677.95	2673.90	2441.42	2428.13
Insurance, banking, business	2421.34	2821.44	3025.64	2770.76	2901.15	2883.80	2657.51	2692.61	2807.68	2577.31	2666.16

Social and personal services	381.65	435.46	436.30	497.49	511.82	494.27	415.64	1631.55	1708.88	1247.45	1281.89
Government	236.34	199.61	218.47	238.06	261.76	237.48	244.53	247.06	261.69	270.26	271.39
Grand total	75.88	90.48	80.44	90.24	92.27	91.24	91.48	98.04	98.92	93.06	105.78

Table A2.8: Household access to sanitation facilities (2001).

	Urban areas	Rural Villages				sub-total	Localities				sub-total	Total	Total
		less than 500	500-999	1000-4999	5000+	Villages	lands	CP	farms	others	localities	Rural	
Own													
Flush toilet	31.0	3.8	3.7	7.3	27.5	6.6	2.3	0.1	22.6	22.3	6.6	6.6	20.7
Improved	22.8	10.6	14.1	19.9	23.8	18.2	3.4	1.3	3.7	5.3	3.2	12.5	18.5
Pit	30.1	14.8	20.8	28.1	30.1	25.7	8.3	2.3	5.8	5.9	6.0	18.2	25.1
Environ-loo	0.5	1.0	0.7	0.5	1.0	0.6	1.5	0.4	2.3	1.8	1.3	0.8	0.7
total own	84.4	30.1	39.3	55.7	82.3	51.0	15.5	4.1	34.3	35.3	17.1	38.1	64.9
Shared facility													
Flush toilet	0.9	0.4	0.3	0.4	2.3	0.4	0.4	0.0	5.3	4.3	1.3	0.8	0.8
VIP	0.9	0.6	0.8	0.6	0.1	0.6	0.6	0.5	3.5	0.9	0.8	0.7	0.8
Pit	4.3	6.6	6.0	7.0	2.9	6.7	4.1	1.7	9.5	4.9	4.0	5.7	4.9
Neighbours	5.1	6.4	9.5	11.4	7.8	10.6	1.6	0.4	0.7	0.8	1.1	7.0	5.9
None	4.3	55.6	44.0	24.8	4.7	30.5	77.6	93.2	46.7	53.6	75.6	47.6	22.5
Unknown	0.1	0.3	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.1
Total shared	15.6	69.9	60.7	44.3	17.7	49.0	84.5	95.9	65.7	64.7	82.9	61.9	35.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Adapted from Population Census 2001 (Central Statistics Office)

Table A2.9: Proportion of households with access to water by type and location (2001)

% of hh	**Urban areas**	**Rural Villages**				**sub-total**	**Localities**				**sub-total**	**Total**	**Total**
		<500	**500-999**	**1000-4999**	**5000+**	**Villages**	**lands**	**CP**	**farms**	**others**	**localities**	**Rural**	
piped house	31.6	4.2	5.2	8.7	28.8	7.9	2.2	0.1	15.2	20.8	5.8	7.1	21.3
piped yard	37.8	10.3	16.3	24.7	38.3	22.2	6.4	0.0	23.8	8.2	6.1	16.1	28.7
Standpipe	28.7	73.9	74.6	63.1	32.1	65.8	33.4	12.3	12.5	26.4	24.7	50.2	37.7
Bowser-tank	0.1	4.4	1.4	0.4	0.2	0.9	3.3	3.2	5.6	5.9	3.9	2.1	0.9
Well	0.0	0.3	0.2	0.3	0.0	0.3	10.9	15.3	1.8	6.1	10.6	4.2	1.8
Borehole	0.1	2.3	0.4	0.3	0.0	0.4	19.3	55.9	34.3	22.6	31.3	12.2	5.1
River	0.0	3.6	0.7	0.7	0.0	0.9	11.5	7.9	1.2	5.3	8.6	3.9	1.6
dam pan	0.0	0.3	0.0	0.3	0.0	0.2	9.9	3.6	4.8	3.4	6.6	2.7	1.1
rainwater tank	0.0	0.1	0.1	0.1	0.0	0.1	0.6	0.4	0.3	0.2	0.5	0.2	0.1
spring water	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.3	0.4	0.2	0.1
Other	1.6	0.6	0.8	1.4	0.6	1.2	1.8	1.0	0.5	0.6	1.3	1.2	1.5
not known	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: adapted from CSO, 2003.

APPENDIX 3: FEATURES OF CURRENT WASTEWATER TREATMENT WORKS.

Name and location	year built	Technology	Operator	m^3/day	m^3/day	m^3/yr	m^3/day	m^3/yr
				capacity	inflow		outflow	
Gaborone Treatment Plant	1997	A S	GCC	40000	34000	12410000	18700	6825500
Otse Police College	2000	RBC	own	262	200	73000	200	73000
Moeding College	1998?	RBC	own	50	50	18250	50	18250
Ramotswa village	2001	Ponds		3000	400	146000	0	0
St. Joseph's College	1983	Ponds	own	100	100	36500	40	14600
Mokolodi Game Reserve	1996	wetlands	own	10	10	3650	10	3650
Tlokweng village	2002		SEDC			0		0
Tlokweng TTC	2000	wetlands	own	20	20	7300	19	6935
Lobatse Town	1982-1999	ponds	LTC	6200	3100	1131500	1240	452600
BMC abottoir Lobatse	1985	ponds + trickling filter	BMC	1700	900	328500		0
BMC tannery Lobatse	1985?	ponds	BMC	??	??	??	??	??
Molepolole village	1986 upgrade	ponds	KDC	345	400	146000	160	58400
Molepolole Prison	1995	ponds	own	50	30	10950	12	4380
Thamaga Prim. Hospital	2002	A S	own	45	25	9125	24	8760
Thamaga TL housing	1994	wetlands	own	5	5	1825	5	1825
Thamaga TL Research	1994	wetlands	own	5	5	1825	5	1825
BDF air base	upgrade 2000	ponds	own	1700	300	109500	300	109500
BDF	1991	ponds	own		700	255500		0
Moshupa SSS	1986/ 1996	ponds	own	80	80	29200	80	29200
Seepapitso SSS	upgrade 1996	ponds	own	100	50	18250	20	7300
Kanye Prison	1997	wetlands	own	25	30	10950	29	10585
Kanye Educ. Centre	2001	ponds	own	106	50	18250	0	0
Kanye hospital	?	RBC	own	20	20	7300	20	7300
Nat. Food FTEC	2000	wetlands	own	10	10	3650	10	3650
Ramatea College	1998	wetlands	own	15	15	5475	14	5110
Jwaneng Town	1980-1995	ponds	JTC	5000	3500	1277500	1400	511000
Jwaneng mine	1981	ponds	Debswana	150	150	54750	60	21900

Mochudi south	upgrade 1998	ponds	KDC	3500	350	127750	0	0
Mochudi north	upgrade 1999	ponds	KDC	1300	100	36500	0	0
Selebi Phikwe	upgrade 2002	ponds	STC	5000	5000	1825000	2000	730000
Madiba SSS	1990?	ponds	own	30	30	10950	12	4380
Mahalapye prison/ hosp.	1990?	ponds	own	200	240	87600	96	35040
Mahalapye Prison Coll	2000	ponds	own	100	30	10950	0	0
Sefhare Prim. Hospital	1998	ponds	own	40	30	10950	12	4380
Shoshong SSS	1996	ponds	own	100	50	18250	0	0
Moeng College	1983	ponds	own	100	100	36500	40	14600
Lotsane SSS	1989	ponds	own	100	150	54750	60	21900
BHC housing Palapye	1992	ponds	own	200	200	73000	80	29200
Palapye village	2000	ponds	CDC	1000	300	109500	0	0
Swaneng SSS	1985	ponds	own	300	300	109500	120	43800
Serowe new prison	?	ponds	own	75	150	54750	60	21900
Serowe TTC	?	ponds	own	150	150	54750	60	21900
Letlhakane SSS	2000	ponds	own	200	150	54750	60	21900
Letlhakane prison	1998	pond	own	50	30	10950	1	365
Letlhakane mine	1998	RBC	Debswana	60	60	21900	57	20805
Orapa township	1999	AS	??	3000	2500	912500	2375	866875
Matshekge SSS-Bobonong	upgrade 98?	ponds	own	100	70	25550	28	10220
Shashe River SSS	1989	ponds	own	100	100	36500	40	14600
Tonota CE	1987	ponds	own	100	100	36500	40	14600
Gweta Prim. Hospital	2001	ponds	own	71.3	50	18250	20	7300
Martin's drift border post	2001	wetlands	own	35	20	7300	19	6935
Mc.Connel and Tutume Health Centre	1989	ponds	own	100	100	36500	40	14600
Sowa township	1991	ponds	STC	370	400	146000	160	58400
Sowa mine	1990?	ponds	mine	20	20	7300	8	2920
Ftown old	?	ponds		6000	?	?	?	?
Ftown new	2002	TF	FTC	15000	6000	2190000	5700	2080500
Masunga village	?	ponds	NEDC	560	400	146000	160	58400
Maun village	1994	ponds	NDC	600	400	146000	140	51100
Boro Farm prison	2002	ponds	own	100	50	18250	0	0

Thuso Rehab centre	1994	wetlands	own	10	10	3650	10	3650
Hukuntsi prim. Hospital	1997	ponds	own	30	20	7300	0	0
Matsha College Kang	1999	ponds	own	200	150	54750	60	21900
Middlepits border post	1996	wetlands	own	35	25	9125	24	8760
Mc.Cathy rust border post	1996	wetlands	own	50	50	18250	38	13870
Tshane prison	2001	ponds	own	50	20	7300	0	0
Ghanzi SSS	1995	ponds	own	60	100	36500	40	14600
Kasane village	1992	ponds	CDC	580	500	182500	200	73000
						0		0
Total				**98674.3**	**62655**	**22869075**	**34158**	**12467670**

Source: adapted from SMEC *et al*, 2003.

APPENDIX 4: WATER STANDARDS

Drinking water standards

The Botswana Bureau of Standards has developed countrywide standards for drinking water. Water providers, whose water falls in class 3, get a limited period of time to provide water of class 2 standards.

Variable	**Unit**			
Physical and aesthetic	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable)**
Colour	TCU	15	20	50
Conductivity at 25 25 o C	S/cm	700	1 500	3 100
Dissolved solids	Mg/l	450	1 000	2 000
Odour		Not objectionable	Not objectionable	Not objectionable
PH value at 25 C		6.5- 8.5	5.5- 9.5	5.0 – 10.0
Taste	N/a	Not objectionable	Not objectionable	Not objectionable
Turbidity	NTU	0.5	5	10
Chemical requirements macro determinants	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable**
Ammonia as N	mg/l	0.2	1.0	2.0
Calcium as Ca	mg/l	80	150	200
Chloride residual	mg/l	100	200	600
Fluoride as F	mg/l	0.7	1.0	1.5
Hardness as $CaCo_3$	mg/l	20	200	500
Magnesium as Mg	mg/l	30	70	100
Nitrate as NO_3	mg/l	45	45	45
Nitrate as NO_2	mg/l	3.0	3.0	3.0
Potassium as K	mg/l	25	50	100
Sodium as Na	mg/l	100	200	400
Sulfate as SO_4	mg/l	200	250	400
Zinc as Zn	mg/l	3.0	5.0	10.0
Chemical requirements- micro determinants	**Unit**	**Class 1 (ideal)**	**Class 2 (acceptable)**	**Class 3 (max. allowable**
Aluminium as Al	µg/l	100	200	200
Antimony as Sb	µg/l	5.0	5.0	5.0
Arsenic as As	µg/l	10	10	10
Cadmium	µg/l	3.0	3.0	3.0
Chromium as Cr (total)	µg/l	50	50	50
Cobalt as co	µg/l	250	500	1000
Copper as Cu	µg/l	1000	1000	1000
Cyanide (free as CN	µg/l	70	70	70
Cyanide (recoverable) as CN	µg/l	70	70	70
Iron as Fe	µg/l	30	300	2000
Lead as Pb	µg/l	10	10	10
Manganese as Mn	µg/l	50	50	50
Mercury as hg (total)	µg/l	1.0	1.0	1.0
Nickel as Ni	µg/l	20	20	20
Selenium as Se	µg/l	10	10	10

Source: Botswana Bureau of Standards BOS 32:2000.

Wastewater standards

Determinant	Unit	Upper limit and range	Class 3 potable water	Comment
Colour	TCU	50	50	Acc
Temperature	0 C	35		NN
Total dissolved solids (TDS)	Mg/l	2000	2000	Acc
Total suspended solids (TSS)	Mg/l	25		NN
BOD_5 (max.)	Mg/l	30		NN
Faecal coliform	Counts/ 100 ml	1000		NN
COD (max)	Mg/l	75 (filtered)		
COD (max)	Mg/l	150 (unfiltered)		
Dissolved oxygen (min)	% sat.	60		
PH value at 25 C		6.0-9.0	5-10	Acc
Turbidity	NTU	30		
Chemical requirements macro determinants	**Unit**			
Free and saline ammonia as N	mg/l	10	2.0	Not acc
Calcium as Ca	mg/l	500	200	Not acc
Chloride as Cl	mg/l	600		NN
Fluoride as F	mg/l	1.5	1.5	Acc
Chlorine residual	mg/l	1.0	600	??
Magnesium as Mg	mg/l		100	NN
Nitrate as N	mg/l	22		NN
Ortho phosphate or soluble phosphate as P	mg/l	1.5		NN
Potassium as K	mg/l	100	100	Acc
Sodium as Na	mg/l	400	400	Acc
Sulphate as SO_4	mg/l	400	400	Acc
Zinc as Zn	mg/l	5.0	10.0	Acc
Chemical requirements- micro determinants	**Unit**			
Aluminium as Al	µg/l		200	NN
Antimony as Sb	µg/l		5.0	NN
Arsenic as As	µg/l	0.100	10	Acc
Boron as B	µg/l	0.50		NN
Cadmium	µg/l	0.02	3.0	Acc
Chromium VI as Cr	µg/l	0.25		NN
Chromium as Cr (total)	µg/l	0.5	50	Acc
Cobalt as co	µg/l	1.00	1000	Acc
Copper as Cu	µg/l	1.00	1000	Acc
Cyanide as CN	µg/l	0.100	70	Acc
Iron as Fe	µg/l	2.00	2000	Acc
Lead as Pb	µg/l	0.05	10	Acc
Manganese as Mn	µg/l	0.100	50	Acc
Mercury as hg (total)	µg/l	0.01	1.0	Acc
Nickel as Ni	µg/l	0.30	20	Acc
Selenium as Se	µg/l	0.02	10	Acc

Note: acc: wastewater standard is acceptable as class 3 drinking water; NN: standards are not comparable; Not acc.: wastewater does not class 3 drinking water standard.

Source: Botswana Bureau of Standards BOS 93: 2004.

Standards for discharge on perennial and ephemeral streams

By law, water resources need to be returned of a quality closest to the quality of the abstracted water. DWA has developed standards for the quality of the water discharged in streams.

Physical and aesthetic variables	Unit	Perennial	Ephemeral
Temperature	$0\ ^0C$	35	35
Colour	TCU	30	50
Conductivity at 25 o C	S/cm	700	1 500
Dissolved oxygen (% sat.)		75	75
pH		6.5-9.5	6.5-9.5
BOD		20	30
COD		30	75
Free and Saline Ammonia as (N)		1.0	10
Nitrate as (N)		2.0	-
Total Phosph. as (P)		-	1.5
Total Chloroforms/100ml		5000	20000
Faecal Chloroforms/100ml		100	500
Arsenic		1.0	0.5
Boron		-	0.5
Zinc		5.0	5.0
Copper		1.0	1.0
Phenols		0.005	0.01
Lead		0.001	0.05
Cyanide		0.01	0.1
Cadmium		1.0	0.05
Mercury		0.001	0.02
Selenium		0.01	0.05
Iron		1.0	1.0
Manganese		0.1	0.5
Sulphate		400	600
Chlorides		600	1000
Sodium		400	600
Fluorides		1.5	2.5
TDS		10000	2000
Turbidity	IUTU		
Oil and Scum		Nil	Nil
Chromium		0.05	0.5

Source: Department of Water Affairs