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Water balance, use and management in the Omaruru Basin

Authors
Amwele Elina Etuhole
Ausiku Petrus Ausiku
Ashitse Katrina Lugambo
Endjala Toivo
Haraseb Bernhardt
Iifo Fililemon
Kaatura Israel
Maswabi Rodrick
Moses Moses
Mweutota Mkwetu
Nathinge Isaac
Ncube Ntandozenkosi
Shaduka Mirjam Ndahafa
Siteketa Veronica
Thamina Diina Nandjamba

Editors
Aitana Elina Shekupe, !Ganeb Kenneth, Hamilton Bill, Lundgren Mark,
Maling Nadia, Nantanga Komeine, Parr Thomas, Pettersen Silje, Seely Mary,
Van Langenhove Guido

Date:

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The Omaruru River supports a diverse blend of agricultural activities, urban and rural settlements, vegetation and wildlife. Due to the increased water demand and water related problems arising in the area, the 12th Summer Desertification Programme investigated the water balance and management of the Omaruru catchment.

The commercial farmers in the upper Omaruru catchment are said to influence river flow to the lower catchment through the creation of farm dams. These farmers are reliant on these dams to supplement borehole recharge, as watering points for their livestock and as tourist sites for trophy hunting and photo shoots. In this study, a detailed water balance for the Omaruru catchment was created from dam surveys and satellite image analysis. This technical survey was augmented through a series of interviews with urban and rural community members, town councils, traditional leaders, government officers, and game, livestock and irrigation farmers.

The study found that the 71 farm dams in the upper catchment do not significantly affect river flow in years of average rainfall. However, they are shown to have the potential to influence river flow locally on tributaries of the greater Omaruru River and may affect river flow in a minor way in years of low rainfall. Decreasing trends in river flow over the past 30 years are more likely a result of variability in long-term rainfall patterns. The perceptions regarding water use vary widely depending on location (upstream vs downstream) in the catchment. Furthermore, there is little or no water demand management in the catchment. Individuals seldom know how much water they use and there are no water metering systems installed to help identify water problem areas. In rural areas, water point committees are often disorganised or non-existent.

There is the need for a more unified effort to enhance understanding amongst residents in the catchment regarding trends in rainfall and river flow. Also, there is a need for a system of monitoring and information sharing among basin water stakeholders to steer development in the catchment in a sustainable manner in the face of limited water resources.
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Chapter 1. Introduction

1.1 Water in Namibia

Namibia's population, agriculture and industry continue to expand at an astounding rate. Yet, with increased production and expansion, the need to manage the country's already strained water resources must move to the forefront of issues surrounding development. Water is an important economic commodity without which development cannot proceed. Decisions and policy formulation with regard to water management, and implementation of these guidelines, will effect both current and future development in Namibia.

Namibia is one of the driest countries in sub-Saharan Africa in terms of mean annual rainfall. Ninety per cent of the country's total area of 824 272km$^2$ is classified as desert, arid or semi-arid land. Coinciding with this aridity, Namibia is subject to extreme rainfall variability with mean annual rainfall between zero and 550mm. Namibia uses water from a variety of sources such as perennial rivers, ephemeral rivers, groundwater, pans and springs (Heyns et al, 1998). The Okavango, Zambezi, Kunene, Kwando-Linyanti-Chobe, and Orange Rivers along the northern and southern borders of Namibia are the country's only year-round, above-ground water sources. Additionally, none of these rivers originate inside Namibia, which makes Namibia reliant on foreign water sources. This problem is particularly apparent in the north where more than half of the Namibian population is located and is dependent on water originating in Angola (Heyns et al, 1998).

All rivers that originate in Namibia are ephemeral rivers. Ephemeral riverbeds remain dry for most or all of the year and rivers flow only after strong rainfall in the surrounding catchments. These rivers start in the highlands along a central north-south strip in Namibia where rainfall, with annual ranges between 200-400mm, is sufficiently high. Furthermore, terrain conditions such as hilly/mountainous landscapes, impermeable geology with thin surface soils and limited intercepting vegetation favour surface runoff and drainage. These rivers bring life-giving water, seeds, and sediment to areas of greater aridity and lower production in the south-west (Jacobson, Jacobson and Seely, 1996).

There are twelve major ephemeral rivers in northwestern Namibia, which support a vast variety of ecological and economical activities. Ephemeral rivers are not only important to the people living on these rivers, but also to the prosperity of the nation as a whole. Their water only supports urban and rural populations, but also wildlife, vegetation, tourism, mining, communal and commercial farmers as well as Namibia's most important, fastest growing economic centres (Windhoek, Walvis Bay, and Swakopmund). However, this heavy dependence of increasingly populated urban areas on ephemeral river water is about to deplete the limited resources of the system. Since
these rivers do not flow year round, it is necessary to construct impoundments to intercept the floods and to carry water over into dry periods. This infrastructure is expensive, however, and results in high losses through evaporation. A more efficient method is to abstract water from underground aquifers where it is readily available. This extraction from hard-rock or alluvial aquifers occurs in the form of boreholes and wells, which are constructed at cost and sometimes the water is piped great distances by water suppliers to fulfil the ever-growing needs of the people. Unfortunately, heavy abstraction from these underground sources is frequently not assessed and is probably unsustainable in many instances. To guarantee sustainable access to this essential resource for all Namibians is an enormous challenge that needs to be faced to satisfy Namibia’s basic survival, health and economic needs, which are crucial for future development across all sectors.

1.1. Variability and Scarcity of Water

One of the several constraining characteristics of Namibia’s water resources is that rainfall varies from year to year, including a few years of exceptionally above average rainfall and more years of below average rainfall. It is also variable both between climatic zones and within them. Conditions of exceptionally low rainfall (rainfall well below normal or mean) referred to as drought are thus expected, common and should be managed. For Namibia this period can be one, two, or more consecutive years. Due to occasional years of abnormally high rainfall, the historical “mean”, calculated as the arithmetic average, does not represent the most frequent rainfall pattern. The median rainfall provides a better idea of what can typically be expected during a normal year, and, since the median is often lower than the mean, Namibia frequently suffers from dry conditions although not necessarily droughts. Therefore, dry periods and occasional disaster droughts occur naturally and are normal in Namibia. A country reliant on historically variable rainfall has to plan for the years of above mean rainfall accordingly, in order to be prepared for the inevitable years of below mean rainfall (Republic of Namibia, 1997).

This variability in water availability is enhanced by the global weather phenomena known as El Niño and the Southern Oscillation (ENSO). Created by the warming of the surface water in the central Pacific Ocean, these events can disrupt rainfall patterns around the world. ENSO events were thought to be the cause of low rainfall in southern Africa in 1992/93 and 1992/93 seasons (Heyns et al, 1998).

Namibia on average receives about 250 mm of rain per year, 83% of which is lost through evaporation due to high temperatures, clear skies and low humidity. Since most of the country is semi-arid to arid, potential evaporation is almost six times greater than average rainfall and therefore more moisture evaporates from a piece of ground than falls on that place (Jacobson, Jacobson and Seely, 1995).
Of the remaining water, an additional 14% is lost through the evapotranspiration of rangelands and savannas as well as river dependent vegetation. Thus, only 3% of rainfall is available for human use. Of that 3%, approximately 2% is estimated to result in runoff that contributes to above-ground river flow. The remaining 1% enters the underground water table. The 3% that enters ephemeral rivers and the groundwater table supports 50% of the Namibian population, who inhabit 80% of Namibia (Heyns et al, 1998).

Water in Namibia is a scarce and valuable commodity and must be viewed with its variability in mind. Periods of low rainfall occur naturally and frequently in an arid country and should not be seen as an exception to the inherent water cycle. It is therefore necessary that decision-makers plan constantly for these periods of little or no rainfall.

1.1 Rainfall and runoff

The vast majority of the rainfall in the western ephemeral river catchments, where the Omaruru River is situated, comes in the rainy season from October to April. Despite the fact that occasional rainfalls may happen outside of these months, it is only during these critical summer months that strings of high intensity storms cause the rivers to flow. In semiarid and arid regions the relationship between rainfall and runoff is non-linear (Mollas and Dahm, 1992). The type of rainfall can determine whether runoff or infiltration occurs. Frequent and light rain promotes infiltration, whereas hard and fast rain produces runoff. This rather simple, general prediction further depends on the condition of the vegetation and the amount of degradation and erosion on land. Thus, a downstream farmer dependent on alluvial groundwater may not receive any recharge even in a year of good rainfall.

1.2 Water Use in Namibia

Groundwater meets 57% of Namibia's current water demand and surface water the remainder (Windhoek Consulting Engineers, 2000) (Table 1.1). Unfortunately, these water sources are not often located where they are needed. Furthermore, much of the groundwater surrounding ephemeral rivers is too saline for human use. It is therefore common to invest extensively in pipelines, inter-basin transfer, and improved water abstraction techniques.

Use of the water from ground and surface water sources can be broken up into six basic sectors: irrigation and stock agricultural, rural and urban domestic, industrial, mining, tourism and environmental use to maintain the resource. Water in each of these sectors yields different commodity returns and requires different inputs. It is the role of decision-makers to evaluate these inputs and outputs and determine where Namibia's precious
water should be invested and how development can be encouraged in areas, where water resources are present.

Table 1.1: Water consumption by sector (adapted from Windhoek Consulting Engineers, 2000)

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Consumption (Mm³)</th>
<th>% of water consumption</th>
<th>Perennial rivers (Mm³)</th>
<th>Ephemeral rivers (Mm³)</th>
<th>Groundwater (Mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban¹</td>
<td>63</td>
<td>21</td>
<td>12</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>Rural²</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Irrigation</td>
<td>136</td>
<td>46</td>
<td>63</td>
<td>41</td>
<td>32</td>
</tr>
<tr>
<td>Livestock</td>
<td>77</td>
<td>26</td>
<td>14</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>Mining</td>
<td>13</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Tourism</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>297</td>
<td>100</td>
<td>100</td>
<td>85</td>
<td>132</td>
</tr>
</tbody>
</table>

¹Urban include domestic, commercial and institutional consumers and losses
²Rural refers to domestic consumption only

1.2.1 Domestic water use

The first and inarguably most important sector of water use is human consumption. From the period of 1991 to 2001, the population growth rate for Namibia was calculated at 2.4% per annum, one of the highest in the world. The total population of Namibia is estimated at 1,830,330 (National Planning Commission, 2003) and accounts for approximately 23% of water consumption (Table 1.1). The domestic water-use figure includes activities such as lawn watering (30%), toilets (40%), bathing/showering (15%), laundry (10%), and drinking and cooking (5%). Thus, the vast majority of domestic water usage is not considered vital for human survival (Windhoek Consulting Engineers, 2000).

During the same period there has been a 6% increase in the urban population and a similar decrease in rural population (National Planning Commission, 2003). This boom in population and urban to rural shift produces significant problems for NamWater, the main bulk water provider to urban areas. One aspect is that urban areas with piped water tend to be significantly more wasteful than their rural counterparts. Urban use accounts for 19% of the total in Namibia, while rural use accounts for only 2%. It is important to note that the rural population is approximately twice as large as the urban one (Windhoek Consulting Engineers, 2000). While potable water for human use has always been regarded as a basic human right, it is necessary to take steps to reduce water wastage, particularly in the urban sector.
Urbanisation has had the positive effect of increasing the number of people who have access to safe water to 87% (National Planning Commission, 2003). However, this urban growth occurs in areas in Namibia that are not equipped with the water resources necessary to house a greater population. Windhoek, Swakopmund and Walvis Bay, where much of the development takes place, are located in the arid centre of the country or along the hyper-arid coast. These towns rely on water from the surrounding ephemeral rivers and are hence subject to the variability and scarcities associated with river flow and recharge dependence. While there are obvious economic benefits to urbanisation, development must be encouraged in areas with sufficient water resources to accommodate expansion.

Rural domestic water use departs significantly from the urban one in terms of quality and quantity. Rural water supply covers about 55% of Namibia and is generally considered good by international standards. The Directorate of Rural Water Supply (DRWS) is responsible for providing water to rural areas under communal land management, usually through the creation and maintenance of water points in the form of boreholes. It should be noted that the communities surrounding the water points have to provide for daily maintenance of the pumps and for the diesel required to operate them. The average rural inhabitant lives within two and a half kilometres of the nearest water point and therefore it is reasonable to assume that they consume less water than their urban neighbours because of the relative inaccessibility of water. However, rural users who are closer to a water point of lower quality like a hand dug well for example, tend to use the free, accessible water first before travelling to a higher quality, more expensive source (National Planning Commission, 2003).

1.2.2 Agricultural use
In terms of volume, the most significant user of water in Namibia is the agricultural sector with ~72% of the total figure (Table 1.1). Although more than half the Namibian population is engaged in agricultural practices, they only account for 11% of the GDP and produce only 50% of Namibia’s food (CIA fact book, 2003). Agricultural use is separated into livestock and irrigation. Irrigation is a relatively new field in the Namibian water sector and consumes 136Mm³ per annum, 45% of all water resources (Namibia Water Statistic report, September 2003). Traditional irrigation practices are wasteful in a hydrological sense because much of the water evaporates due to high air temperature, direct sunlight, wind, and low air moisture, before the intended plants take it up (Hillel, 1987). Although practices such as drip, microjet and subsurface irrigation can limit evaporation losses up to 80%, the majority of Namibia has yet to modernise its practices and still relies on flood irrigation (Windhoek Consulting Engineers, 2000).

Livestock water consumption accounts for 77Mm³ per annum or roughly 25% of total water consumption. This figure is largely due to widespread farming of cattle. Namibia’s number one stock and the animal with the highest rate of water consumption. Although
a shift to small stock or game farming could result in a great reduction in the amount of
water lost through stock farming, the cultural importance of cattle as a sign of wealth and
prosperity has to be taken seriously. Conversely, a switch to game farming or even
mixed livestock and game farming often allows for a greater carrying capacity on the
land due to mixed grazing practices and a lower water demand because indigenous
species have adapted to the scarce water resources. Livestock can further affect the
hydrological cycle through compacting soil surfaces and overgrazing the veld, which
leads to greater runoff and lower infiltration.

1.2.3 Mining use
Mining in Namibia accounts for 20% of the GDP and makes Namibia the fourth-largest
exporter of non-fuel minerals in Africa, the world’s fifth-largest producer of uranium, and
the producer of large quantities of lead, zinc, tin, silver, and tungsten (CIA fact book,
2000). The mining sector employs only about 3% of the population and accounts for 4%
of Namibia’s water use (Table 1.1). Water losses occur mainly from evaporation of water
used to wet mining surfaces, seepage into the surrounding environment, and
entrainment into the substrate of the mining area. Mining can be considered
economically efficient and does not use a lot of water. However, although water use is
low, mining can have other detrimental effects to the environment.

1.2.4 Tourism use
An even more efficient user of water in terms of its economic output is the tourism
industry. Tourism is Namibia’s third largest industry and second largest earner of foreign
exchange with a total water consumption of only 1% of the total per annum (Windhoek
Consulting Engineers, 2000). Tourism resorts consume 250 litres of potable water per
touirist per day, with an additional 1 500 litres per tourist per day spent on gardening
(Heyns et al, 1998). The gardening figure could be reduced significantly if indigenous
plants were incorporated into the gardening schemes.

1.2.5 Industrial use
Industry contributes 28% the GDP of the nation, creates 25 000 jobs and uses ~2% of
the country’s water (Heyns et al, 1998). Industry in Namibia mainly packages and
processes food such as meat, fish, dairy products and beer. While the country
continues to grow, industry will become a more important force to supply jobs and raise
the standard of living.

1.2.6 Environmental use
Quantification of the environmental demand for water has always been a difficult task. It
can be considered as all the water that contributes to sustain the natural environment
and the services it provides. Environmental use includes consumption and
transpiration of water by flora and fauna as well as evaporation from isolated pools
and runoff into the ocean. The benefits Namibia receives from environmental water use
are numerous but also difficult to pin down. Namibia’s tourism depends on the natural beauty of the environment, as do communities along river ways, who use the vegetation for stock fodder. It is estimated that a single mature *Faidherbia albida* (Ana) tree can produce over 250kg of pods per season, which makes them a valuable food source for stock and wildlife along the rivers (Jacobson et al, 1995).

The rivers of Namibia are linear oases of life, both in terms of natural and human life. Although it is easy to overlook the environmental water demand, one has to remember that human water usage can have an important and often detrimental impact on the quality and quantity of environmental water. Such an impact will inevitably lead to the reduction of the environmental services Namibia relies on socially and economically.

1.3 Water Management in Namibia (Literature Review)

1.3.1 National Water Policy

The legal administration of water is still primarily based on the Water Act (Act 54 of 1956) with its amendments and regulations. The Constitution has set new principles regarding ownership and utilisation. The Water Supply and Sanitation Sector Policy (WASSP) covers a wide range of issues related to protection of surface and subsurface waters from pollution and misappropriation and also emphasises the sustainable use of all social, economic and environmental resources associated with water (Heyns et al, 1998). The WASSP defines the responsibilities within the water sector, mainly for water supply.

In 1998, the government decided to conduct the National Water Report and Management Review (NWRMR). Since then, several policy papers on water management and use have been written. However, the final draft of the new national water policy is still in Parliament and has not yet been promulgated. The policy will be based on four principles formulated during the International Conference on Water and the Environment in Dublin in 1992:

- Fresh water is a finite and vulnerable resource and essential to sustain life
- Water resources development and management should be based on a participatory approach that involves users, planners and policy-makers at all levels
- Women play a central part in the provision, management and safeguarding of water
- Water has an economic value in all its competing uses and should be recognised as an economic good.
1.3.2 Population growth

The population of Namibia is expected to double every 23 years. However, even at this rate, good management by every Namibian would ensure sustainable use of water. Various measures are taken to manage the demand for water at all levels in Namibia, which include public awareness campaigns, maximum re-use of effluent, adding value to water, mandatory use of pool covers, irrigation hours, rain water harvesting, and natural and artificial aquifer recharge (Heyns et al., 1998). Namibians need to learn to use less water per capita if we are to be able to ensure that all Namibians have sufficient access in the future.

Urban water supplies are likely to be placed under the highest stress because of a rapidly increasing population, higher per capita consumption levels, remoteness of most towns from perennial rivers, and high evaporation rates in urban water-supply dams.

1.3.3 Government institutions involved in national water management

Several ministries are involved in water management in some way since water is essential to life and development, but the Ministry of Agriculture, Water and Rural Development (MAWRD) through the Department of Water Affairs (DWA) and Directorate of Rural Water Supply (DRWS) is primarily responsible. The parastatal Namibia Water Corporation (NamWater) is the main bulk water supplier.

Before independence, the supply of water to rural communities was administered by eight ethnic regional administrations. In early 1993, responsibility to supply water to rural communities was transferred to the DRWS.

In 1997, approval was given to implement a policy of Community Based Management (CBM) of rural water supplies. This change was partly due to a government policy to spread out management functions to include the regional and community level, but it was also a way to create incentives for the local communities to manage their water resources in a more sustainable and efficient manner. Responsibilities to manage and pay for water services will be progressively devolved to Water Associations and Water Point Committees. Water Point Committees will be recognised by law and be able to control consumers’ access to water points as well as organise payment for water use. The DRWS is responsible for implementing the CBM over the designated 10-year period (National Water Policy White Paper, 2000).

1.3.4 CBM and Water Point Committees

Namibia is divided into 10 water supply regions, each with a chain of water committees that originate at the local water supply point level and continue up to the district supply level. The DRWS asks communities to sign a contract that gives the communities ownership over their local infrastructure and requires them to undertake and fund routine
maintenance. For approximately every 20 water supply points, depending on distances between points and natural boundaries, there is a rural water extension officer who maintains the points or calls for external help from the DRWS's regional maintenance section if the Water Point caretaker can not handle the job.

1.3.5 NamWater

Until 1997, most urban centres with population in excess of 2 000 were supplied from state water schemes managed by the Department of Water Affairs (DWA). In 1998, Namibia Water Corporation (NamWater), a state owned enterprise, was established to take over some of the responsibilities of the DWA. NamWater supplies the water, which the DWA controls and supervises. NamWater extracts water from ground and surface resources via boreholes and dams. The water is sold as bulk water to local authorities such as municipalities, who then supply residents. NamWater's policy is to provide water of a suitable quality, in sufficient quantities on an environmentally sustainable basis, to its clients at an affordable price and to offer water related services to communities in Namibia (pers.comm. de Wet).

The commercialisation of bulk water supply improved management by phasing out state subsidies and instituting full cost recovery and generation of investment funds, and flexible planning of internal (financial, personnel, technical) and external operations (free market). As a commercial utility that operates a capital-intensive system, NamWater seeks to maximise the sale of water, even though such sales could undermine long-term strategies to conserve water (pers.comm. Van Langenhove).

1.3.6 Water controlled areas

In 1971, a legal provision was completed to bring groundwater under state control by establishing 'water controlled areas'. So far, six areas have been declared 'water controlled areas' - the Kavango River, the Karst Area, the Omaruru River, the Swakop River, the Stampriet Area and the Orange River (Windhoek Consulting Engineers, 2000). Nobody may sink, deepen or alter a borehole or well, or abstract water in such an area without a permit. However, the implementation of the permit system is currently inadequate. There is neither a mechanism to monitor the volumes of water abstracted, other than the permit requirement for feedback on volumes pumped, nor are inspections carried out on a systematic basis (National Water Policy White Paper, 2000).

1.3.7 Water as an economic good

The pricing regime will recognise the intrinsic need to supply all Namibians with access to a minimum water supply and that the 'ability to pay' is constrained by low income. Access to a minimum quantity of clean water is considered a basic human right. Water is therefore not a pure economic good. Low income and lack of access to natural resources, such as water contribute to poverty in Namibia. It is important to consider the
social aspects when addressing the issue of water resources management, water supply and allocation (National Water Policy White Paper, 2000)

1.3.8 Losses and water unaccounted for
A lot of water is lost or unaccounted for and the Government has decided that larger urban centres should not have a water loss higher than 10% of total consumption. For smaller centres a 15% loss is acceptable. Henties Bay has a 10% leakage loss, while Swakopmund has 14%, according to the town engineers. Omaruru with as much as 46% has the highest percentage of water loss in the country (Alexander and Becker, 2000). According to the town engineer, this figure is going down and water use has improved during the past year.

1.4 Site description of the Omaruru basin

There are twelve large catchments of ephemeral rivers in western and north-western Namibia. All of these rivers support a rich assemblage of vegetation and wildlife critical to agriculture and tourism. They also provide water for important towns such as Swakopmund and Walvis Bay. These rivers and their catchments are thus not only important to the people living in the region, but also to the nation as a whole (Jacobson et al, 1995).

The Omaruru River has a catchment area of approximately 13 100km². It stretches from the Etjo Mountain, over 2 080m above sea level, to Henties Bay at the coast and is 330km long. Ninety-eight per cent of the catchment is defined as agricultural area (46% commercial and 52% communal) and the last 2% is within the West Coast Recreational Area (Jacobson et al, 1995).

The Omaruru catchment has a long history of support for agricultural development. The approximately 100 commercial farms are situated in the upper catchment and the communal areas are in the middle and lower catchment. In recent years, game farms and guest farms in the catchment have played an important role in Namibia’s tourism industry (Jacobson et al, 1995). There are some examples of community-based tourism as well, especially around Spitzkoppe. Most of the Omaruru catchment is in the Erongo region, except Mount Etjo in the east, which lies in the Otjozondjupa region.

There are two larger urban centres in the catchment, Omaruru and Henties Bay, and three settlement areas, Kalkfeld, Okombahe and Spitzkoppe. Omaruru and Henties Bay have hospitals, some government offices and schools. Kalkfeld also has a hospital, and Okombahe has a clinic, two schools and a police station. Swakopmund, Uis, Arandis and Rössing Mine lie outside the catchment, but are considered to be part of the basin, as the Omdel water scheme and dam in the lower catchment supplies them with water.
Commercial farmers in the study area farm with wildlife and small and large livestock and produce vegetables, wine and bottled water. These activities require different forms of water management.

1.4.1 Population
According to Jacobson et al. (1995) the total population in Omaruru catchment was 15 917 in 1991. Population projections, based on the 1991 census, indicate that the population in the urban centres in the basin would increase from 15 917 in 1991 to 19 702 in 2005 (Windhoek Consulting Engineers, 2000). This increase in population is attributed primarily to urbanisation. Swakopmund and Arandis, which also derive water from the Omaruru catchment, lie outside the catchment and are thus not included in these figures. Based on the 2001 population census, it is only possible to obtain data for the whole Erongo region and not for the Omaruru catchment itself. The census indicates a 1.3% population growth in the region (National Planning Commission, 2003).

Water demand is a major issue in the Omaruru basin due to a rapid population growth, which results from high birth rates as well as people moving into the basin. Most of the towns and settlements are growing, but the growth rates vary. The number of commercial farm units is fairly stable, without any major changes in the past years. Neither communal farmers nor people who seek employment in the urban centres tend to migrate. When new industries establish themselves, people generally arrive from outside communities.

1.4.2 Biomes and vegetation
Three different biomes are present in the catchment: desert, semi-desert and thornbush savannah. In the west the river runs through the central Namib Desert with a sparse but diverse perennial shrub flora and with lichen fields that are unique to the area between the Omaruru and Kuiseb rivers. Further upstream the rainfall increases and the vegetation changes from desert to semi-desert, which is dominated by open grasslands. The eastern part receives the highest rainfall and consists of thornbush savannah (Jacobson et al, 1995).

1.4.3 Riparian forests
Trees are able to establish themselves along the riverbed because of a shallow water table that persists even if rainfall is low. Riparian forests can be found along the larger rivers and stand in stark contrast to the adjacent sand and rock desert in the western part of the catchment. Well adapted to the high variability in flow regimes, most trees can survive several years without river flow. If the river does not carry water for a long period, the water table will sink and the older trees may die. These riparian forests are crucial to the communities along the river in the western part of the catchments (Jacobson et al, 1995).
1.4.4 Soils
Soils are generally thin and poorly developed in the western catchments. The arid climate, with its slow weathering producing little organic material, is the main reason for this condition. Alluvial deposits form the most fertile soils in the region and in some areas the alluvials can be metres deep. However, they still have limited potential for agricultural production since they are often calcareous and saline. Only in the upper catchment can one find more developed soils, but even there the soil layer is thin and production potential is limited due to relatively low rainfall, high evaporation and water scarcity (Jacobson et al 1995).

1.5 Water issues in the Omaruru basin

1.5.1 Commercial Farmers
Commercial farmers are a diverse group involved in different farming activities. They have private ownership of the land they farm on and may export their goods. Commercial production is large-scale whereas communal production is small-scale and generally for the farmers' own consumption or for the local, informal market. Most commercial farmers rely on their private boreholes because they have often paid all costs associated with them. In water-controlled areas, all farmers have to apply for permits to sink boreholes and for the amount of water to be abstracted. However, there is currently little or no control over how much water the farmers actually use.

1.5.1.1 Irrigation Farmers
In a water-controlled area, no one is allowed to abstract water to irrigate more than one hectare without a permit from the Department of Water Affairs (Windhoek Consulting Engineers, 2000). A report in 1984 concluded that permit holders used less water than they had permits for and that permits should be adjusted down (Geohydrology, 1984a). However, according to a recent study, abstraction of water from the Omaruru Municipality Aquifer is at least as much as the obtained permits account for. (Windhoek Consulting Engineers, 2000).

The ultimate source of water for irrigation farmers is boreholes. Some farmers use this water for flood irrigation, although sprinklers and drip irrigation are becoming more common. Drip irrigation is the most water-efficient irrigation system in Namibia today, but not suitable for all types of vegetables. Sprinklers provide some cooling in the hot summer months, which is necessary for vegetables like tomatoes that are easily sunburnt. There are a large variety of different drippers and sprinklers on the market that farmers utilise with varying success rates and to different extents.
1.5.1.2 Livestock and game farmers
Livestock and game farmers need to give their animals sufficient water for drinking every day. The animals can drink water with some silt and mud and dams are thus well suited as water points for animals. Dams function as water points as they are, while water points connected to pipelines from boreholes and wells need to be constructed with additional costs.

For a game farmer a dam can create a scenic spot or landscape as well as have the potential for both hunting and photo safaris. The game will come to the water regularly, which makes a dam a suitable place for a hide and a place where tourists are most likely to see animals. The importance of dams in game farming and tourism should not be underestimated.

Most dams do not hold water the entire year, and it is necessary to have other water sources that provide water for the animals when the dams have dried out. Most farmers have boreholes, from which they distribute water through a network of pipelines to water points on the farm. Livestock farmers need to have water available in all camps in order to utilise grazing on the entire farm.

1.5.2 Major Towns
The major towns that depend on water from the Omaruru basin are Omaruru, Henties Bay and Swakopmund. Arandis, Okombahe, Uis, Kalkfeld and Spitzkoppe are smaller urban centres or settlements. Omaruru, Okombahe, Uis and Spitzkoppe are situated inside the catchment area. The others lie outside it but are still part of the basin, as they rely on the Omaruru River for their water supply (figure 1.1).
Omaruru Town Municipality is one of a small group of municipalities that operates its own bulk water scheme. Water is abstracted from four boreholes in the immediate vicinity of Omaruru and from two boreholes of the Kransberg scheme east of the town (Alexander & Becker, 2000). Omaruru has obtained an abstraction permit from the DWA and is allowed to pump up to 1 Mm$^3$ per year. It also has the highest water consumption per person per day compared with the other towns and settlements in the basin. Okombahe, Henties Bay and Swakopmund get their bulk water from NamWater. The water consumption figures of these towns are given in Table 1.2.

Table 1.2: Water consumption for some urban centres in the Omaruru basin (Jacobson et al, 1995)

<table>
<thead>
<tr>
<th>Urban centre</th>
<th>Total water consumption (m$^3$/year)</th>
<th>Population</th>
<th>Water consumed per person/day (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okombahe</td>
<td>240 000</td>
<td>1 408</td>
<td>467</td>
</tr>
<tr>
<td>Omaruru</td>
<td>855 000</td>
<td>4 851</td>
<td>483</td>
</tr>
<tr>
<td>Swakopmund</td>
<td>2 876 000</td>
<td>17 681</td>
<td>446</td>
</tr>
</tbody>
</table>
1.6 Historical Data River Flow

In order to calculate extraction figures for what could be considered sustainable utilisation of water resources in the Omaruru basin, it is critical to have a long-term understanding of river flow and its relation to groundwater recharge. There is, however, a significant lack of such data in the literature. The most accurate data available are from the DWA. There is a set of historical data extracted from reports of salt traders that covers the period from 1943 to 1964, which is included in Annex 1.

1.6.1 Records from the Department of Water Affairs, Division of Hydrology
There are four DWA hydrological river flow stations in the Omaruru basin; Omburo, Etemba, Nei-neis and Omaruru (Figure 1.2). The Omburo and Omaruru stations represent the upper catchment and the Nei-neis and Etemba stations the lower.

While these stations all characterise the catchment areas they are located in, they vary in quality and length of data collection:

- Etemba and Omburo have a hydraulic control structure, which allows reliable conversion from measured water levels to calculated flows. Omaruru and Nei-neis are open sections with changing cross-sections where such conversion is not accurate.
- Omaruru and Etemba have the longest records.

Figure 1.2: Locations of the DWA hydrological stations along the Omaruru catchment
- Omaruru and especially Nei-Neis have significant record gaps because of the layout of the recording system.
- Omburo covers only the upper-most part of the catchment and there is little contribution to river flow downstream of Etemba in most years.

Thus, Etemba has the best and most representative record for river flow in the Omaruru Basin.
Chapter 2. The Study

2.1 Objectives of the study

- To develop a water balance model of the Omaruru catchment from data collected through measuring dams and interviewing major water users in the area, such as inhabitants of towns, irrigation, livestock and game farmers and others. For dams, features such as catchment area, dam areas and volumes were determined.
- To find out how water is used and what the demands from the Omaruru are, especially by towns, commercial, communal and irrigation farmers and others.
- To determine the types of water management strategies that the users in the area apply and also identify perceptions of water users in the area and compare them to the actual measured and/or modelled situations.

2.2 Terms and definitions

- **Catchment:** A catchment is defined as the area from which rainfalls flow into a river. Catchments are separated from one another by high ground such as mountains and ridges.
- **Basin:** A basin includes the geographical area of a catchment and also groundwater aquifers entirely or at least partially within the catchment area. It may also include areas outside the catchment that rely on it as their water source, either through extended groundwater systems or by transfer of water between geographical catchments.
- **Commercial farmer:** They can be involved in a large variety of farming activities. Commercial farmers have private ownership of the farmland and exclusive rights to use this land. They are usually large-scale producers and sell products to national markets or for export.
- **Communal farmer:** They are involved in small-scale production for own consumption or for sale at the local, often informal, markets. A communal farmer does not have property rights on grazing areas but might have exclusive rights to use an area close to the homestead for cultivation.
- **Aquifer:** Thick layers of sand or other porous (penetrable) material contained within non-porous (not penetrable) rock that can hold water and serve as a source of groundwater.
• **Sustainable use**: Use of natural resources in such a manner that the supply of that resource is not diminished or lost.

• **Equitable access**: Fair or just access but not equal access to resources for all individuals.

• **Arid**: An area where the mean annual rainfall is less than 250mm; rainfall is seasonal, highly variable from year to year, and evaporation is high.

• **Semi-arid**: An area with a mean annual rainfall between 250-600mm; rainfall is seasonal, highly variable from year to year, and evaporation is high.

2.3 Methods

2.3.1 Dam census overview

The goal of the dam census was to determine the capacity of all dams in the Omaruru catchment area. This was done through a multi-step approach.

1. A set of 16 initial earth, concrete and excavated dams were surveyed in the Omaruru upper catchment in order to determine their depths, surface areas and maximum capacities. The technique used in this experiment was the standard land surveying technique of levelling. The dam parameters (e.g. depth, surface area and total capacity) were measured with a Pentax AL-capacity dumpy level and a standard survey tripod and staff. The X, Y absolute values and Z values (reduced level) were calculated from the survey data, imported into ArcView GIS 3.3 and then used to create a contour map of the dam. The surface areas for each dam were determined with Arcview by digitising an April 2001 satellite image and 1975 topographic maps (Metzler, 2003).

2. The capacity of two additional dams was estimated through length, width and depth measurements. Length was considered as the distance from the main inflow channel to the dam wall, width from between the banks of the basin and depth with respect to the spillway. The average depth is estimated as half the depth at the deepest point. A further dam was approximated by marking the estimated full supply contour and the current water contour. The level difference between the two contours was calculated, as was the maximum depth.

3. The remaining dams that were not surveyed were located on existing topographic and satellite images. The most recent set of topographic maps is from 1974 and thus omits the majority of the newly built dams. From these maps we were able to locate 54 dams. On the satellite image, which was taken in 1990, we located 70 dams.

4. To check the reliability of satellite image locations and dam functionality, a DWA helicopter-borne survey measured the surface areas of the dams by
marking the contour of the dams. These flights occurred right after a flood event and thus the dams were assumed to be at full capacity.

5. Using the 16 initial surveyed dams as a baseline, a regression analysis was performed to come up with a line of best fit that gave a general equation for the relationship between surface area and volume.

6. After calculating the surface areas off the satellite image, the volume was calculated using the surface area volume relationship. In this manner, the capacity of all the dams in the catchment visible from the satellite image was calculated.

2.3.2 Basin Modelling

Information for modelling the water balance of a single dam:

1. Catchment areas: The catchment areas were determined using the same methodology as for the surveyed dams. Dam streams or tributaries for each dam were digitised on the satellite images to determine the dam catchment area. Excel was used to calculate the monthly supply and to determine the period in which the dam can hold water. On the same spreadsheet, the volume of each dam was determined by multiplying the dam area obtained from the satellite map with the total depth/height of the contour.

2. Inflows: The annual runoff for each dam was determined by multiplying the catchment area for the dam with annual unit runoff.

3. Evaporation: The total evaporation was calculated based on accepted figures from the rainfall map of Namibia (Department of Water Affairs, 1999).

4. Abstraction: Abstraction from each dam was determined based on figures for the average consumption rates per head of livestock.

5. Total water balance: The water balance (total outflow and inflow) of water from the upper stream to downstream of the catchment was determined, based on the inflow and outflow models for each identified dam on the river.

2.3.3 Inflow Modelling

The catchment areas were entered into an excel spreadsheet to interpret how, in an average year, the catchment areas contribute to the inflow. The parameters of the inflow model included dam basin constant, initial storage, catchment area, annual unit runoff, annual runoff, and monthly runoff percentages. The dam basin constant is the ratio between the area of the dam and its full supply volume. It has a physical meaning relating the area of the dam and its shape at any storage level. Generally, as the area and depth of the dam increases (large storage capacity) the dam basin constant approaches zero.

It is important to note that since runoff is variable among the years, annual unit runoff values were determined for the low, medium and high years of runoff. The
statistical quartiles at 20, 50 and 80% were calculated from the 1970 to 2002 annual runoff data to represent the low, medium and high runoff years.

The coefficient factor used to estimate the calculated catchment area was determined by the equation:

\[
\frac{\text{area of the catchment in m}^2}{\text{volume of the catchment in m}^3} = \text{area of the catchment in m}^2 / \text{volume of the catchment in m}^3
\]

Annual runoff was calculated by the equation:

\[
\text{annual runoff} = \text{annual unit runoff} \times \text{catchment area} \times 100
\]

Annual unit runoff is calculated by the equation:

\[
\frac{\text{catchment area in m}^2}{\text{annual runoff in m}^3}
\]

The inflow model was used to determine the water balance for each individual dam, and for the catchment as a whole. For instance inflow (rainfall, interception) = outflow (evaporation, abstraction, infiltration). The initial storage was assumed as zero before the first inflow. The inflow was determined by choosing an annual runoff figure and a monthly net rainfall in percentage. The outflow from a dam was determined if the sum of the initial storage and the inflow was greater than the capacity of the dam. The final storage of a dam was calculated as the difference between the remainder and abstraction.

2.3.3.1 Dam model interpretation

Parameters such as volume, area, dam basin coefficient, monthly supply, abstraction and evaporation were investigated. The minimum, maximum, average and median of each of these parameters were calculated in order to make assumptions about how much water an average dam in the Omaruru catchment can supply and the proportion between the water that evaporates and is abstracted. Correlations between area, volume and the rest of the parameters were calculated to explain interdependence of variables.

2.3.4 Water demands and supplies overview.

Twelve commercial farmers in the basin were interviewed about water usage on their farms. Through the interviews, the number of game and livestock was estimated. This number was multiplied by specific animal’s daily water consumption. Consequently, the monthly water demand for the game and livestock was estimated (737 m³) and used in the model for the Omaruru basin upstream of Etemba hydrological station.

Six irrigation farmers in the basin were interviewed to determine irrigation water usage. Additionally, information on irrigation permits for the area was obtained from the Ministry of Agriculture to check for consistency. Human water consumption was also estimated by multiplying the total number of people in the area with the 15 litres an average person consumes per day. For additional
information on human consumption, we interviewed town residents, town council members and Namwater.

2.3.5 Vegetation / Infiltration Survey

2.3.5.1 Infiltration survey
The rate at which water infiltrated the soil in the Omaruru basin was investigated for each dam surveyed. The six infiltration replications were performed equally spaced in a circle around and 100 m away from each dam. Each test consisted of 200 mL of water poured into a uniform 500 mL hollow cylinder placed firmly on top of the soil to prevent seepage. Care was taken not to disturb the natural composition of the soil surface. Infiltration rate was determined as the volume of water (200 mL) over the time it took the water to disappear completely into the soil.

2.3.5.2 Vegetation survey
Vegetation descriptions were completed on 12 of the surveyed dams. These surveys were performed at or near the infiltration survey points at each surveyed dam. A description of the dominant and sub-dominant vegetation species was made by categorising them into groups. Woody plants with a height of less than or equal to 3 m were classified as bushes or shrubs, while those taller than 3 m were considered trees. Any vegetation group constituting less than 10% of the total were excluded from the description. The surveys were performed at 100 m intervals in a circle around and 100 m away from each dam. GPS points were taken at every description and at points of interest such as livestock/game trails, gullies and rill erosions.

2.3.6 The interview process
Interviews were used as one method to gather information on water management in the catchment. Different groups and stakeholders were interviewed. Town engineers in the municipalities of Henties Bay, Swakopmund and Omaruru, the village councils in Uis and Okombahe, commercial farmers in the upper catchment and communal farmers in the lower catchment are examples of some interview participants.

Open-ended questions were used to give the interviewee free range to answer questions in his/her own words. Different questionnaires were developed for each group of stakeholders. Commercial farmers were divided into two groups: irrigation farmers and livestock/game farmers, each with different questionnaires.
Most of the questions concerned water use and quality, and by whom and how they were supplied with water. Some of the questions were general and on all questionnaires, while others were more specific for one group. While talking to farmers, both commercial and communal, the goal was to get an overview of how access to water, water management and water supply influence and are influenced by farming activities. Interviews with local authorities and municipalities gave important information on their responsibilities in water distribution and management.

Interviews were conducted during four trips to different areas in the basin. During the first field trip, town engineers in Henties Bay and Swakopmund were interviewed. During the Omaruru trip, 16 commercial farmers in the upper catchment, the town engineer and the agricultural extension officer were interviewed. On the third field trip the goal was to get a good overview of the communal areas around Okombahe, and the village councils in Uis and Okombahe were interviewed, together with residents in the villages and communal farmers in the lower catchment area. The fourth field trip was a short trip to Kalkfeld to look at the water shortage that the settlement was experiencing. One representative for NamWater, the local councillor and one resident from Kalkfeld were interviewed during this trip. Information was also gathered through conversations with employees in different divisions within the DWA throughout the whole study.

Appointments were made in advance for most interviews, except for the communal farmers and residents in Okombahe and Uis. The questionnaire for town residents consisted of just a few questions, so that it was possible to conduct a small interview on the street, without taking up too much time. Although interviews were flexible, one person was responsible for asking the questions in the questionnaire, while the rest of the group was responsible for recording the answers. An interview team normally consisted of three to six people. Translators were used when interviewing communal farmers and residents in Uis, Okombahe and Spitzkoppe. The questions were translated from English to Damara.
3.1 Dam census

3.1.1 Topographic map and satellite image analysis

A correlation analysis was done on both estimated/digitised areas from the topographic map and the satellite image to see what area correlated most strongly with the results from the physical land survey of the dams (considered true area) (Figure 3.1). From the correlation, the highest correlation coefficient (R) was found from the satellite image area although both were high.

\[
\begin{align*}
\text{Correlation between true area and topographic area} \\
& y = 1.1457x \\
& R = 0.9594
\end{align*}
\]

\[
\begin{align*}
\text{Correlation between true area and satellite area} \\
& y = 0.9671x \\
& R = 0.9714
\end{align*}
\]

*Figure 3.1: Results from the correlation of satellite and topographic images with true areas*
The R value for the satellite image is 0.9714 compared to 0.9594 for the topographic map. Since the satellite image gives a somewhat better fit, those data are used to determine dam area.

3.1.2 Area/volume extrapolation
Because the satellite image analysis can only give an estimate for the surface area of the dams, an extrapolation for the volume of the dams is necessary. This was based on a correlation analysis of the surface area and volume of the surveyed dams. The best-fit equation was $y = 0.0000011x^2 + 0.614604x$, with R value of 0.9946 (Figure 3.2).

![Correlation between true area and volume](image)

*Figure 3.2: Results of the correlation analysis between dam area and dam volume in the surveyed dams*

3.1.3 Runoff of the DWA hydrological stations along the Omaruru catchment
There appears to be a general decrease in runoff over the measurement period at Omburo and Etemba stations. This is indicated by the trend line in figure 3.3. It is noteworthy that if one wants to look only at the runoff reaching the lower catchment from the upper catchment, the Etemba station would be the best because it has the longest and most representative record for river flow in the Omaruru Basin. Moreover, there is little contribution to runoff downstream of the Omburu station.
3.1.4 Dam Modelling

The inflow model was part of the larger dam model and set up the assumptions of how individual dams functioned in the rest of the catchment and dealt with four main factors: dam capacities, evaporation, abstraction and storage. Data show that on a typical dam, unit runoff increase (i.e. an increase in inflow to the dams) correlates to an increase in the amount of water allocated to outflow (Figure 3.4). Similarly, proportion of water losses to evaporation decrease as runoff increases.

Comment: Why are the correlation coefficients identical? It appears suspicious. I have calculated these correlation coefficients several times in excel and I got the same value for both stations. Should I remove them from the graph?
Outflow (m$^3$) • Evaporation (m$^3$) • Abstraction (m$^3$) • Storage (m$^3$)

Figure 3.4: Relationship between proportion of outflow, evaporation, abstraction and storage at different unit runoff values for a typical dam

During poor rainfall periods, the majority of water that flows into dams is lost through evaporation (40%), abstraction (32%) and downstream runoff (22%) (Table 3.1). However, when rains are good or moderate, the majority of runoff that enters a dam contributes to outflow. In years of moderate rainfall, 52% of water entering the dams contributes to downstream outflow while the remaining 48% is stored, abstracted and lost through evaporation. In good rainfall periods 66% of water flows downstream and only 34% will be withheld. It should be noted that these figures are only the average case for the water use values. The “problem” dams generally tend to be those that do not comply with typical or average water use allocations and thus are statistical outsiders in terms of holding back large percentages of inflow water in their catchments.

Table 3.1: The effect of dams on the water flow in their totalled catchment area

<table>
<thead>
<tr>
<th>Unit runoff</th>
<th>Low (3mm)</th>
<th>Medium (10mm)</th>
<th>High (20mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflow to all dams (m$^3$)</td>
<td>1,016,089</td>
<td>3,386,963</td>
<td>6,773,926</td>
</tr>
<tr>
<td>Outflow from all dams (%)</td>
<td>22</td>
<td>52</td>
<td>66</td>
</tr>
<tr>
<td>Volume Withheld (%)</td>
<td>78</td>
<td>48</td>
<td>34</td>
</tr>
<tr>
<td>Evaporation from all dams (%)</td>
<td>41</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>Abstraction from all dams (%)</td>
<td>32</td>
<td>13</td>
<td>7</td>
</tr>
</tbody>
</table>

- Area of Omaruru basin upstream of Etemba hydrological station: 2,809 km$^2$
- Catchment area of farm dams: 339 km$^2$
- Percentage of the Omaruru basin covered by farm dam catchments: 12%
- Number of farm dams in catchment: 70
- Average capacity of a farm dam: 39,610 m$^3$
- Total capacity of all farm dams: 2,812,330 m$^3$

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3.1.5 Dam model interpretation/basin modelling

The model based on catchment areas, volumes of the dams, abstraction, evaporation and annual runoff values was used to determine the effect of farm dams on the flow of the river. A general overview of the data collected from the model is summarised in Table 3.2.

From Table 3.2, with the assumptions made by the dam model, one can see that the amount of water withheld by the dams (2-5% of total basin runoff) is relatively small compared to the total runoff for the catchment. Similarly, the totalised areas of the individual dam catchments above Etemba hydrological station cover only 12% of the Omaruru basin. However, the amount of water withheld by the dams is significant for these localised catchment areas as shown in Table 3.1. In years of low rainfall/runoff, the dams withhold 78% of the water coming into their catchments. In years of high runoff, they withhold 34% of runoff in their catchments.

Table 3.2: The contribution of farm dams to entire river flow from upstream down to Etemba station

<table>
<thead>
<tr>
<th>Annual unit runoff (mm)</th>
<th>Inflow (m³)</th>
<th>Water withheld by dams (%)</th>
<th>Evaporation (%)</th>
<th>Abstraction (%)</th>
<th>Storage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>16 854 000</td>
<td>~5</td>
<td>2.5</td>
<td>1.9</td>
<td>0.3</td>
</tr>
<tr>
<td>10</td>
<td>56 180 000</td>
<td>~3</td>
<td>1.8</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>20</td>
<td>112 380 000</td>
<td>~2</td>
<td>1.4</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

During poor rainfall years, dams withhold about ~5% of the total available runoff for the basin whereas the rest (~95%) is outflow (runoff). This figure for water withheld decreases to ~2% in years of good rainfall (Table 3.2).

3.1.6 Infiltration Rate

The infiltration rate was obtained at 12 of the 15 surveyed dams by dividing the amount of water used by infiltration time. The infiltration rate depends on the soil type, with an average of 4.0 m/s (0.014 m³/hour). The hollow cylinder used in this test covered an area of about 0.00442 m² (π x (0.0375 m)²). Thus, the infiltration rate per unit area amounts to 3.268 m³/hour (m³/m²/hour). This would translate into an infiltration of ~4 671 Mm³/hour for the entire Omaruru catchment in which the measurements where taken.

Comment: What proportion of rainfall would this constitutes? In dry, average and wet years? This was based solely on the 200 m³ of water used in the test. I'm not too sure what this test was meant to indicate. This figure is far too large, larger than the runoff, which ought to be larger. All in all, I seem not to understand the practicality of the test/figure. Please help!
3.2 Water Demand in the Omaruru Basin

3.2.1 Water demand for the entire Basin

The most recent estimates of water use in the Omaruru basin have total water demand placed around 3.5 Mm$^3$/annum. The main increase in water usage is predicted to come from the urban centres, with other sectors tending to maintain or decrease consumption (Table 3.4).

Table 3.4: Prediction of water demand in the Omaruru basin for 2005 and 2015, known values for 1999 (Windhoek consulting engineers, 2000)*

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2005</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industrial</td>
<td>other</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>29,337</td>
<td>1,616,572</td>
<td>1,645,909</td>
</tr>
<tr>
<td>2005</td>
<td>32,078</td>
<td>1,827,558</td>
<td>1,859,538</td>
</tr>
<tr>
<td>2015</td>
<td>37,228</td>
<td>2,135,183</td>
<td>2,172,411</td>
</tr>
</tbody>
</table>

* All values in m$^3$

3.2.2 Urban Water Use – Water Consumption

The main consumers of urban water for the Omaruru Basin are located outside the basin on the coast. Outside basin use accounts for 70.4% of total urban water consumption. This figure includes the towns of Henties Bay, Swakopmund, Arandis, and other private coastal users (Figure 3.5).
While the towns of Henties Bay (Figure 3.2. A) and Omaruru (48% increase from 1995 to 1999 (Alexander and Becker, 2000)) have noticed a general increase in their overall water consumption rates over time, others like Swakopmund have not noticed an increase in recent years (Figure 3.2 B).
3.2.3 Urban Water Use – Tariff Structure
Urban water use accounts for over 50% of the total annual consumption in the basin, and the water demand in these areas is likely to increase steadily in the coming years. However, both Henties Bay and Swakopmund use effluent water as well and thus the abstraction only accounts for a part of the total water
consumption in these two towns. Omaruru (Figure 3.7), Swakopmund and Henties Bay all have a scaled tariff structure to encourage efficient use of water. The tariffs and the structures, however, vary.

The scaled tariff is used to discourage high water consumption, by increasing the cost of water as consumption increases beyond the level necessary for basic human consumption. There is an additional basic service tariff at N$20.00 per month for all connected clients.

From figure 3.7 the scale is almost flat for the first 10 m$^3$, and then it becomes steadily steeper as the cost per m$^3$ increases. Many households manage on 10 m$^3$ month, unless they have a large garden. For a household of four, 10 m$^3$ water per month equals 83 litres per person per day. In Omaruru each client has a water meter to measure the monthly water consumption that is read by the municipality every month. The meter is installed close to the house so the clients can track water consumption rates.

Swakopmund has a different tariff system. They have a basic tariff that includes 8 m$^3$ of water. For 2003-2004 the basic tariff in Swakopmund was N$36.30 per month. The scaled tariff in Swakopmund thus begins at 9 m$^3$ water per month.

All municipalities stressed that water in Namibia does not have a cost attached to it. The inhabitants only pay for the water services provided by NamWater and the municipalities. None of the municipalities is making a profit on water, however, they are rather trying to reduce their losses through their tariff systems. All municipalities have problems with water loss, but the amount of unaccounted for water varies from town to town.

Projections based on data from the Department of Water Affairs show that the total production from schemes in the Omaruru river aquifer and the Omdel aquifer has not increased markedly over the period from 1997 to 2002 (Figure 3.8). Also shown in Figure 3.8 is the estimate of 8.0 Mm$^3$/annum as the average production possible for the entire aquifer system.

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Figure 3.2: Omaruru scaled tariff structure
3.2.3 Communal farming water use

How many livestock and what type of livestock each communal farmer had, was difficult to determine. This was partly because the farmers do not want to provide this information, and partly because ownership of livestock is a complicated issue, and many farmers look after other’s livestock and do not include these when being asked about total livestock numbers. It was uniformly agreed however that livestock were the main users of water on communal farms.

Water used for domestic purposes accounts for a substantial part of the total water consumption in communal areas, but again is difficult to quantify. For people that use prepaid water meters, it is possible to find out how much water they use based on how much they pay. But most people interviewed use a combination of water sources.

There are several gardens in the communal areas in the basin, but many of them are no longer cultivated due to water shortages. For instance, the communal gardens in Okombahe are no longer producing because of lowering alluvial aquifer water tables and boreholes that have dried up in the past years.
3.2.4 Commercial farming use

Agricultural production in the basin includes:
- Livestock (both large and small stock)
- Wildlife
- Tourism/lodges and game farms/guest farms
- Irrigation – vegetables, grapes, citrus

There are just over 100 commercial farm units in the catchment. Several of the farms are involved in tourism, and this often involves large gardens, a swimming pool, and thus uses significantly more water than an average household.

Most commercial farmers in the Omaruru basin rely on their private boreholes, but many also have farm dams as an addition. Farm dams are normally used as water points for livestock and game. Some dams are situated close to boreholes and serve to recharge the boreholes. None of the farmers interviewed abstracted water directly from the dam to use for domestic purposes, although the majority used dams to recharge the borehole from which they abstracted water for domestic purposes.

In water controlled areas all farmers have to apply for permits to sink boreholes and for the amount of water that the farmers want to abstract. At the moment there is little or no control on how much water the farmers actually abstract.

Figures and interviews showed that wildlife generally use less water than livestock. It was also evidenced by a number of farmers interviewed that there is a common belief that wildlife feed on different types of vegetation than livestock, leading to the belief that a piece of land can hold more wildlife than livestock if there is a good mix of species.

Livestock and game farmers keep animals as their main farming activity. While a livestock farmer normally keeps animals for meat and dairy production, a game farmer focuses on tourism, especially trophy hunting. Game farmers often use dams to create a scenic spot or landscape, with potential for both hunting and photo safaris.

Both types of farmer needed to provide water, evenly distributed over the whole farm, throughout the year, to maximise the grazing/browsing potential. Livestock and game farms were normally large, because of limited grazing and browsing potential.
There are commercial farms that are purely involved in irrigation. The type of irrigation varies, and water consumption is determined by this, and more importantly, by the size of the irrigated fields. From our interviews, sprinklers, centre pivots and drip irrigation are used in the basin to differing degrees. Different cultivars have different water requirements, and use of mesh nets was seen to reduce the water consumption in a number of cases. Irrigation farmers were found to produce different vegetables or fruits according to season. Temperature and especially frost determined what products could be grown. The irrigation farms are all located close to the Omaruru River and use water from the alluvial aquifer.

3.2.5 Residents
Residents in urban centres have easier access to water compared to many people in rural areas. Municipalities or village councils provide the water. Some towns have experienced water shortages, which has led to water restrictions, such as only providing water for some hours per day or the introduction of higher tariffs. According to the municipalities, most houses have water installed, but in informal settlement areas communal standpipes are still common. Residents use water mainly for domestic purposes and for their gardens.

3.2.6 Municipalities and village councils
Both types of local authorities interviewed had responsibilities for providing water for residents. Omaruru municipality is in charge of the whole process, which ranges from drilling boreholes to distributing water throughout the town. NamWater supplies Uis, Henties Bay, Swakopmund and Arandis and therefore the towns only have to distribute the water to the residents. Kalkfeld is a settlement area and has an agreement with the Ministry of Regional and Local Government and Housing. The Ministry provides water for free for the residents, but the quantity is limited, and water demand is higher than supply at the moment.

3.2.7 All groups
Almost all groups agreed that there is a water shortage in the Omaruru basin and that there are problems with the current water supply system.
Chapter 4. Discussion

4.1 Dam model discussion

4.1.1 Inflow modelling

The results of the inflow modelling indicate that individual dams can reduce the amount of water that leaves the dam up to 78% in a year of low runoff. In years of high runoff this figure was reduced to 34%. From this analysis, a strong argument can be made for the effect of dams on river flow in areas that receive little runoff from the surrounding micro-catchment. The idea of a catchment is critical in this discussion. The larger area known as the Omaruru Basin is all the land that will contribute its runoff to the flow of the Omaruru River. However, there are hundreds of smaller tributaries to the larger river with their own individual catchment areas. This is an important distinction to make when thinking about the effect of individual farm dams on river flow. While the farm dams make relatively little difference to the flow of the Omaruru river, a large farm dam placed at a key control point along a tributary with a small catchment area may be able to withhold the entire flow of the river at the point, even in years of good runoff.

Such was found to be the situation in Kalkfeld. The municipality of Kalkfeld supports a population of nearly 3 500 residents with a water consumption of only 1 800m$^3$/month due to water restrictions, while the town of Omaruru, 60km away with a population of 5 000, uses around 80 000 m$^3$/month. According to the Kalkfeld municipality, the restrictions on water were put in place during the past three years after the construction of a pair of farm dams immediately upstream from the town. There are at least four farm dams within a 5km radius of the town and town's boreholes. Although it cannot be said that these dams have directly contributed to the drying of three of the town's six boreholes in the last three years, it does raise the question of why a town like Omaruru has consumption per capita that is roughly 30 times greater than that of Kalkfeld.

One possible answer is that Omaruru is in a much better location. While Kalkfeld is only 60km away, it is not, like Omaruru, located on the main river channel. The water resources in Kalkfeld are so limited by its location on the edge of the greater Omaruru basin that the balance of water can be adversely affected by the addition of a farm dam of only 20 000m$^3$. Such a dam would do little to affect the flow of the whole river, but can have a significant impact on a small-scale water balance. The question remains whether promoting development in a town like Kalkfeld can be considered responsible in a water-strapped portion of an arid country?

Solutions for an area must be made on an individual basis. Some farmers hold water in their farm dams for a short period of time (24-48 hours) to allow for underground recharge. The water is then allowed to flow downriver through an outlet pipe. This enables the farmer to store water underground that can be accessed later by boreholes.
located at the base of the dam. It also significantly decreases the loss of water through evaporation, which can account for a 40% loss of water entering farm dams along the Omaruru in years of poor runoff. While such a situation may not be reasonable for farmers who need standing water for game and tourism, it may be a good solution to allow for water sharing among neighbours in water-stressed regions of the river.

It is especially important to think of alternative methods of water storage in an arid environment like Namibia. There is a mean potential evaporation in the western catchments of 3 000mm per year for open water surfaces like farm dams. This potential is six times that of the annual rainfall and thus water that fills dams is rapidly lost to the atmosphere after a flood and not available for most of the year. Furthermore, the high evaporation rates leave behind highly saline soils and cause a shift in vegetation to salt tolerant trees and shrubs in the surrounding area. Thus, solutions for water storage that incorporate short retention time in dams, or underground storage (i.e. sand dams) are, although expensive, essential for the future of sustainable farming in Namibia.

4.1.2 Dam model interpretation
As the data from the dam model suggests, dams have only a small effect on the flow of the entire river. Even in low flow years, the farm dams can only claim 5% of the total annual runoff. This figure decreases to 2% in years of good runoff. This result is a product of two key result areas. First, the catchments of the farm dams cover only 12% of the entire area of the basin. Thus, 98% of the land on which rain falls in the basin will contribute directly to river flow. It should be noted here that farm dams tend to be placed in areas where they will receive amounts of runoff disproportionate to the size of their catchment area (next to mountains/hills). Second, the percentage of total runoff held back by the dams is only 5% in low runoff years and 2% in high runoff years. Thus, while dams located on side channels may affect flow in their local micro-catchment, runoff in the main channel is only affected in a minor way by the presence of farm dams.

4.1.3 Rainfall variability
Although the dams may not significantly disrupt main channel flow, it does not mean that river flow is not declining and that there is no reason for concern about farm dams. One important point to keep in mind when analysing water in an arid country is that water is not only a scarce commodity, but a highly variable one as well.
From Figure 4.1, an average 35% deviation from the mean annual rainfall of 325mm can be expected in the Omaruru basin. In years of exceptional variation, such as in 1996 when only 159mm was received, or in 1976 when the basin saw 697mm of rainfall, a deviation from the mean of over 100% is possible. Because of this stark variability in rainfall, the mean is not a good indicator for the amount of rainfall that can be expected in the basin. It is more useful to know the range of rainfall expected in the region and therefore be able to prepare for both the highest and lowest rainfall years. In the case of the Omaruru basin, such a figure would be 103 – 697 mm of rain per annum.

With its very variable climate, the Omaruru region, and in fact most of Namibia, must be prepared for drought conditions at any time. Disaster drought, when drought relief is mobilised, is defined as the low rainfall that occurs one year in twenty. Figure 4.1 shows that there are numerous periods in the last 50 years when the Omaruru basin experienced rainfall below the long-term mean and perhaps a few ‘disaster’ droughts. And while it is hard to predict when such a period will occur, precautions should be taken to assure the future sustainability of farming in Namibia. De-stocking and rotational grazing are important techniques that should be employed to ensure that veld condition does not deteriorate due to erosive grazing in normally dry years.

In addition to the wide annual variability in rainfall, there has been a trend of decreasing rainfall (Figure 4.1). While a decline of average rainfall of 50mm over the past 50 years may seem alarming, it is impossible to make any statements about the nature of the variation without more long-term rainfall data. Variation in rainfall is common, both on a
short and long-term scale. But this recent reduction in rainfall may be related to the suspected decrease in flood intensity and regularity.

4.1.4 Rainfall and Runoff

It is no secret that the floods of the Namibian ephemeral rivers result from heavy summer rains. In the investigation of the Omaruru we found a significant correlation between river flow and rainfall patterns (p value < 0.000005). While these results indicate that one variable is highly dependent on the other, there is not an exact correlation between the two. As evident in Figure 4.2, a certain percentage of the rain that falls does not directly lead to river flow.

![Omaruru rainfall and riverflow](image)

*Figure 4.2: Effect of rainfall on river flow during 1968 – 2003*

In years with high or low rainfall, there is a corresponding peak in the graph for runoff. However, this trend is not the case for every year, which suggests that other factors influence runoff.

As rain begins to fall, it infiltrates soil by filling in the spaces between soil particles. The rate of infiltration depends on the type of rain and the condition of soil. In general, runoff can only occur if the rate of rainfall is higher than the rate of infiltration. However, if rain falls hard and fast, the soil will only be able to take up a small amount of the quantity of water that flows over its surface. This scenario typically takes place during the
thunderstorms prevalent in the summer rainy season in the western catchments of Namibia. In case of soft rain, the soil can absorb rain much faster and there is less runoff.

Furthermore, the type and abundance of vegetation in the catchment upstream can affect the runoff of water down the basin gradient and has a significant effect on rates of infiltration. If the veld is in poor condition due to overgrazing and trampling, there will be an associated increase in runoff. Poor veld condition can also promote the processes of erosion, which will also increase runoff. Conversely, a veld with a full stock of healthy grasses and topsoil will have a much greater rate of infiltration. This also means that the relative amount of runoff in a year is related to the success of the previous year's vegetation. A year of good, soft rains will promote an increase in vegetation, making the veld better equipped to take in water the following year. Our results showed an average infiltration rate of 4 mm/s for the entire catchment. Attached to this figure however, was a high amount of variability suggesting that different farms and farming techniques locally alter the rate of infiltration.

Thus, while rainfall can be a good predictor of the amount of runoff that can be expected, there are certainly other factors to consider.

4.2 Discussion of interview results

4.2.1 A critical water situation

The municipality of Henties Bay and commercial livestock/game farmers in the upper catchment were the only groups of interviewees that said they did not have a problem with water. All the other groups of people had one or more problems.

It is important to distinguish a permanent critical water situation from one that becomes increasingly worse. During the field trip it became obvious that all areas further away from the main Omaruru River have always had problems both with the supply of water and its quality, while the areas along the Omaruru River have experienced a worsening water situation during the past years. It was also evident that people along the Omaruru River have different opinions on the causes of their water problems than the people living away from the river. People on the main river channel generally believed that upstream dams caused the water problems, while people living off the main channel believed that it was poor rainfall or type of rainfall that caused water shortages. While neither of these beliefs is altogether incorrect, it is important to address both beliefs when explaining water shortage.

4.2.2 Water shortage

Water shortage can be understood in several ways. Some of the irrigation farmers said that water shortages forced them to reduce production and one of them considered
switching over to less water-demanding plants, like prickly pears. However, all commercial farmers had enough water available for domestic purposes, and they did not experience any serious water quality problems. In the communal areas further downstream there are settlements and families that have to transport drinking water over long distances, because the nearest borehole is brackish.

The communal farmers said that they had water problems, but those were often related to drinking water and not to access for the livestock. Water shortage can be limiting for income-generating activities such as farming and industry, but at the same time there can be sufficient water for residents' domestic consumption. Water shortage can also imply that the domestic demand exceeds the water supply, which forces people to reduce domestic water consumption and to accept low quality water even for drinking purposes.

4.2.3 Supply problems
The results showed that all interviewed groups experience problems with water supply from time to time. There are different reasons for this lack. While commercial farmers are responsible for themselves, communal farmers rely on help from the DRWS. Residents in towns and urban centres rely on the municipalities and the village council.

4.2.3.1 Henties Bay and Swakopmund
In Henties Bay and Swakopmund supply problems are normally caused by pipe breaks on the stretch from Omdel dam to the towns. According to the town engineer in Swakopmund, these pipes are old and need to be replaced. Apart from the pipe breaks, the water supply is reliable and stable.

4.2.3.2 Omaruru
Omaruru municipality is responsible for pumping and distributing water. They do not have any major supply problems at the moment. Omaruru has experienced water shortage, and implemented a scaled tariff system as a measure to reduce the town's water consumption.

4.2.3.3 Other urban centres in the basin
Okombahe, Uis, Spitzkoppe and Kalkfeld all experience supply problems. Boreholes in the nearby Omaruru River supply Okombahe, but the boreholes run dry, and the water supply is reduced. In the 1980s, Okombahe was considered as an important growth point because of the ample water supply (Geohydrology, 1984a). Kalkfeld has boreholes that are recharged by an earth dam, but because of lack of recharge they run dry and the water supply is reduced. According to residents in Kalkfeld, there has never been a water supply problem before. Spitzkoppe has never had a reliable water supply, but some years ago a sterilising machine was installed in the boreholes in the river, which improved the situation. However, the sterilised water is intended to be for the

Comment: Previously it was said that the dams were part of the problem, not the solution as indicated here. What possibly caused the lack of recharge? Water withheld by other dams upstream?
school and not the whole community. There is no other source of drinking water in Spitzkoppe. It is worth noting that until a few years ago the population in Spitzkoppe collected water in Usakos, and so they feel that the water supply has improved over the past years because they no longer have to travel to get water. However, no one knows how long the residents in the village will be able to use the school’s water.

4.2.3.4 Settlements along the pipeline

There are five dams along the pipeline from Nei-Neis to Uis (Geohydrology, 1984b). There are settlements along the whole pipeline but only the settlements close to Uis have a supply problem. There is only water in the pipeline when the two reservoirs closest to Uis are being filled up. If they are full, there is no water in the pipes. According to people living in these settlements, the reservoirs need to be refilled quite often, and they have never experienced more than two days in a row without water in the pipeline. The settlements closer to Nei-Neis do not experience any supply problems, and the situation has been stable since 1969 when the pipeline was built.

4.2.3.5 Communal areas away from the Omaruru River

Most of the interviewees in the communal area would like to have diesel pumps for their boreholes. They consider a diesel pump to be more reliable than a windmill. Some claimed that there is not enough wind in the area for windmills. This shortage of wind has created a supply problem for some settlements. Very few have electric pumps and no one has solar pumps in the study area. A lot of the communities at some stage had diesel pumps, but when they broke down they were replaced with windmills. All interviewees said that they had no influence in this decision and that pumps had been installed without involving the local community.

4.2.3.6 Commercial farmers

Commercial farmers supply themselves with water. If water is insufficient the farmers try to improve the situation by for instance cleaning the pipes, building dams or drilling new boreholes. Some of the commercial farmers live in areas with limited groundwater resources. Farmers build dams close to the boreholes to improve the boreholes’ recharge. One farmer said that he had built a dam close to a dry borehole and after some years the borehole had water. On farms with adequate groundwater it is more common to drill new boreholes or deepen existing ones if the water supply is insufficient. Their financial situation often determines what farmers choose to do about water shortage.

It was difficult to get the exact number of boreholes, because farmers often did not count the ones that had run dry or the ones that never had water. On average, a farmer needs to drill four boreholes to get one borehole with water, which is a success rate of 25%.
A reduced water supply has implications for the farming activities, and some of the irrigation farmers had reduced their production or changed production because of lack of water. A change in irrigation systems can improve water use and makes it possible to irrigate the same area with less water. Drip irrigation is currently the most water efficient irrigation system used in the basin. One farmer claimed that a change from flood irrigation or old sprinklers to drip irrigation reduced his water consumption by up to 75%. This change made it possible for him to increase the irrigated area from 5 to 15ha without using more water.

Again we see that supply problems are generally related to inability to water livestock/crops at optimum rates. No interviewee suggested that there was a lack of water for domestic purposes, thus suggesting that water problems mainly affect the region on an economic level.

4.2.4 Dry boreholes

The capacity of boreholes varies tremendously, from less than 1m³/hour to 60m³/hour. Both communal and commercial farmers experience that their boreholes run dry and that they need to deepen or make new boreholes.

It is generally a misconception that boreholes run dry because they actually are blocked by lime or silt and just need cleaning. One farmer said that before he cleaned the pipes in the borehole, it took him a whole day to fill up the reservoir. After he cleaned the pipes it took only two hours.

4.2.5 Maintenance of boreholes

The communities have different problems related to water. One problem is that the pumps need repair and maintenance and that it takes a long time from breakdown until the problem is fixed. This bad maintenance is a common problem in the whole communal area. Commercial farmers are always responsible for repairing their own boreholes and generally have more equipment available on the farms compared to the communal farmers. Most commercial farmers said that if their pumps were broken they fixed them. Only the Omaruru municipality is responsible for their own boreholes and pumps. Overall, the only group seen to have significant problems with maintenance were the communal farmers, who complained about waiting up to three months before DRWS would respond to a request to fix a borehole. All groups noted the significant cost of borehole drilling and maintenance as a constant problem/concern.

4.2.6 Water quality

The quality of water required depends on the type of farming. Irrigation farmers, who use drip or sprinkler irrigation, need cleaner water with less particles and silt than livestock/game farmers. High lime content can be a problem for irrigation farmers whereas it is not considered a problem in livestock farming.
Commercial farmers have few problems with water quality from their boreholes. The water in dams is generally not used for human consumption but rather to recharge nearby boreholes.

Brackish water in boreholes is a common problem in communal areas. No commercial farmer expressed problems with brackish water in boreholes used for domestic purposes, although some farmers said that they had brackish water in some boreholes used for livestock and wildlife. When asked about water quality, commercial farmers normally mentioned high lime content in the water. No communal farmers mentioned problems with lime. Some irrigation farmers had installed machines to reduce the lime content before it was pumped into the irrigation system.

Omaruru municipality normally has no problems with water quality except during periods when the river is flooded when they add chlorine. Henties Bay and Swakopmund add chlorine to the water they purchase from NamWater. According to both municipalities they receive class B quality water, which is satisfactory to them. Class B quality water is hard and has a high lime content, but it is still suitable for human consumption. Uis and Okombahe village councils said that the water quality was good but that the supply was not satisfactory. Spitzkoppe has a sterilising machine in order to use the water from the boreholes close by, but still have a problem with brackish water.

4.2.7 Distance to water
In communal areas, brackish water forces people to travel to other water points to get drinking water. This is a time-consuming and expensive task. A few families have arrangements with each other to collectively pick up water, but most of the communal farmers interviewed do not. Communal farmers travel to water points to pick up water approximately twice a week. Some travel further than the nearest water point because they have family or friends that provide them with cheaper water further away.

Commercial farmers normally situate their houses close to a reliable water source and have taps in the house. Irrigation fields are also normally situated close to a good water source. Water points for livestock and wildlife can be placed further away from the water source and are supplied by pipelines from the source. It is common to have a network of smaller pipes that distribute water to different areas to be able to utilise grazing and browsing on the whole farm.

All municipalities have pipelines from the boreholes to the towns, and within the towns water is distributed through a network of pipelines. It is thus available close to the homes and no one has to travel far to get drinking water.
4.2.8 Water Point Committees

Many of the communal communities have Water Point Committees but for several reasons, they do not function well in most places visited.

In one settlement all the other families had left, and only one farmer stayed there. According to him, they had left the settlement because of the high water price and that they wanted to move to a place where they would have free water or only pay for diesel for the pump. The farmer was asked if the people that had left had moved to town to find jobs, but he denied this and said that they had just moved to places where the water was cheaper and continued to farm there. In the study area, migration to places with free or cheap water was more common from along the pipeline to elsewhere than in the rest of the communal area.

Another interviewee claimed that a lot of Water Point Committees suffer because of committee members’ illiteracy and lack of knowledge. According to him, committees should play a more active part in water management than they do at the moment. The knowledge and competence of the committees must be increased, and the DRWS should be responsible for the training.

A chairman of one Water Point Committee said that it is important to give more power to the committee, so that they can actually make decisions about the water point. At the moment the suggestions of the committee are not taken into consideration, and in the end government institutions always make the decisions.

One of the most important tasks of the Water Point Committee is to organise residents, assign tasks and discuss how, for example, diesel for the pump should be financed, breakdowns reported and smaller repairs initiated. Through interviews it became clear that it was difficult for some communities to agree on how much each household should pay per month for diesel or for water. Different attempts have been made to solve this problem. If it is a diesel pump then it is normal that people are responsible for their own diesel. Some settlements have decided that the diesel tank should always be full and that it should always be refilled after use. This arrangement works in some places but in others, the community complains that not everybody does so. Another method was to have a rotating system where each household was responsible for diesel for one week. Some people felt that this was unfair because they had much fewer animals than their neighbours did and should not pay as much. In order to account for the differences in livestock numbers and household members, the cost was split between households in accordance with their use but this system also proved to be difficult.

Overall, it appeared that there is the potential for these committees to play an important role in moderating and maintaining communal water use. However, the current lack of
organisation and education among committees and committee members prevents them from being effective in most cases.

4.2.9 The cost of water – payment problems

A problem specific to communities that live along pipelines, which therefore includes Nei-Neis and Uis, is the accumulation of debt to NamWater because they are unable to pay the monthly fees for water.

For commercial farmers, the cost of water varies according to how many boreholes they have drilled and how deep they are. Most of the farmers have had help from professionals to find suitable locations for the boreholes. According to the farmers there is never any guarantee of finding water, with pumping capacities varying greatly. Commercial farmers point out that they make an effort to conserve water because they immediately feel the effect of water waste. Overuse of boreholes was often sited as a cause of the boreholes drying up. The farmers would then be forced to drill new boreholes at their own expense.

All municipalities have to distribute water to their residents and collect payment for the services related to it. Generally, they just adjust the water price accordingly. Henties Bay, Swakopmund and Omaruru have a scaled tariff system, and Uis has a flat tariff. However, the price per cubic metre of water is not the actual cost of water but the costs to provide the necessary infrastructure and installations.

There are different ways to collect the payments. Residents that get water from communal taps pay for the water services with prepaid cards. Residents with private taps often pay their bills from the municipality once a month. Most of the communal farmers do not pay for water since the government does not supply them with diesel for which they have to pay. The DRWS has to pay the costs associated with the supply of water to the rural communities.

Water services are cheaper for people who live closer to boreholes than the people living along the pipeline. Settlements close to boreholes only need to supply diesel, and the money available determines how much diesel can be bought per month. Farmers along the pipeline get a monthly bill from NamWater. The taps along the pipeline always have water, compared to prepaid meters that only work as long as there is credit on the card. This makes it possible for the residents to use more water than they can afford. NamWater is threatening to cut the water supply to some of the settlements with the largest debt along the pipeline.

Paying for water services is a new concept for most Namibians, and some communities struggle to come to an agreement with each other on how to pay and to reduce their water consumption to a level that they can afford. Education regarding the cost of water
infrastructure must be increased to erase the idea that water should be supplied for free. Furthermore, scaled tariffs and prepaid water metre use should be increased to reduce the number of communities falling into water debt and to reduce water waste.

4.2.10 River flow

It is a general perception that the river used to flow more often and more regularly. Communal farmers and people downstream claim that they used to have more water. They claim that newly built dams in the upper catchment is the main reason that the river flows less than before. According to the upstream farmers, no new dams have been built in the past years, and the problem with less water downstream is more likely caused by increased demand because of population growth and changes in rainfall pattern. The municipalities in Omaruru and the village councils in Uis, Kalkfeld and Okombaha claim that upstream dams play an important role in the reduced river flow. Municipalities, which are supplied by the Ondel dam, do not mention the upstream dams at all perhaps due to their more stable water supply.

4.2.11 Invisible dams

Commercial farmers upstream in the catchment claim that there are no invisible dams. However, most communal farmers downstream believe otherwise. They had heard about them from sources that they consider reliable. None of the interviewed farmers had ever seen an invisible dam. It is possible that farmers consider hydrological weirs upstream as invisible dams. There are two weirs in the Omaruru, one at Omburo and one at Etemba and both are upstream of the interviewed farmers. The weir at Omburo is the closest and was built in the mid-80s and consists of a visible concrete wall spanning the length of the main river channel.

According to upstream farmers, the DWA and agricultural extension officers, there are no invisible dams in the upper catchment. The DWA suggested that invisible dams could refer to the natural compartments created in the bedrock. These natural ‘dam walls’ have always been in the river, and thus cannot play a role in declining river flow. Communal farmers and irrigation farmers close to Omaruru expressed similar views on the upstream farmers illegally containing too much water.

4.2.12 Resource management

Interviews with the different stakeholders raised key issues on inefficiency and losses in the water supply system. These problems include pipe bursts and leakage, illegal connections and the time it takes to repair breakdowns. Each authority and supplier deals with the problems in their own way to minimise losses.

The Government supports a new demand management system and emphasises water conservation. Demand management uses a range of regulatory, economic and technical measures to achieve its objectives of more efficient water utilisation. Effective
measures include tariff structures, metering and improved water efficient technology, particularly in irrigation. Awareness campaigns on water management and scarcity have also been initiated.

4.2.13 Livestock or game
Game farming is becoming increasingly popular, and in the catchment there are many guest and game farms that focus on wildlife rather than livestock. The farmers all said that they changed to game farming because they thought it was easier than keeping livestock. They added that cattle trample down much of the grasses and that the bushes were under-utilised.

For similar reasons, some farmers changed from cattle to small stock. Small stock both browse and graze, which means that they will utilise the bush more than cattle do. Many of the commercial farmers mentioned bush encroachment as a problem on their farms. Small stock, especially goats, has been used as a way to fight bush encroachment.

4.2.14 Poaching and theft
Some farmers expressed concern about the future of tourism in the country. Poaching and political conditions are mentioned as the main causes for concern. All farmers, both commercial and communal, had problems with stock theft. The game farmers had problems with people putting up snares on their farms. For livestock farmers, both commercial and communal, the theft of cattle was a bigger problem than theft of small stock. While the cattle walk around at night, the small stock are usually collected and kept in the kraal during the night. A head of cattle is worth far more than one goat or sheep, both in social and economic terms.

The farmers had different opinions on who is to blame for the thefts. Some thought that outsiders did it, while others claimed it was community members. Most commercial farmers in the upper catchment thought that the thieves and poachers came from the Omaruru area. Whereas commercial farmers often complained about poaching, the communal farmers are more concerned with theft. The result, however, is the same; animals disappear and the farmers lose important income and security.
Chapter 5. Conclusions/Recommendations

The 71 farm dams found in the catchment can have significant effects on the flow of tributaries in their local catchment areas, but inflow modelling showed that these dams do not significantly affect the flow of the Omaruru river under mean rainfall conditions.

Due to the high correlation between rainfall and runoff, it is most likely that the variable amount and intensity of rainfall events are the main causes of variable river flow. The general decrease of river flow over the past 50 years is inevitably due to the long-term decrease in rainfall.

- There is no system for enforcing dam permits in the basin. A system needs to be installed to ensure that new farm dams are within specified limits.

- Development should be encouraged where sufficient water resources are available, and be limited to practices that return maximal social and economical output for minimal water input.

- There is no water demand management in the catchment and perceptions about water problems and water use vary greatly within the catchment. A system of communication should be initiated to allow the various stakeholders in the basin a forum to discuss water-related issues and come up with water demand management guidelines. This system should also inform and teach people in the catchment about historical records of rainfall, river flow and their interrelationship.

- Some water point committees are more effective than others. This system needs to be strengthened through education related to water, borehole maintenance, and community organisation.

- The vast majority of people interviewed in the catchment do not have a good idea about how much water they use. Water metres should be installed on farms and in households to monitor water use, identify water leakage, and encourage water conservation practices.

- Poor land management practices in some regions of the catchment have produced erosion (upper catchment) and exhausted forage (lower catchment). This is due to overstocking of the land. Rotational grazing and destocking during dry periods can be instrumental in reducing land degradation.
Our modelling showed that rainfall and flow records are sparse and unreliable. There is a need for the installation of electronic recorders to increase climate data and enhance efficiency and availability of recent data.

Chapter 6: References

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