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LIST OF ABBREVIATIONS

BOS	Bureau of Statistics
IFR	Instream Flow Requirements
D/S	Downstream
U/P	Upstream
TOR	Terms of Reference
DRWS	Department of Rural Water Supply
WASA	Water and Sewerage Authority
VWCs	Village Water Committees
MOHSW	Ministry of Health and Social Welfare
LWRM	Lesotho Water Resources Management Study
LHWP	Lesotho Highlands Water Project
R	River
l/c/d	Litres per capita per day
m^3/s	Cubic meters per second
m^3/day	Cubic meters per day
lit/sec	Litres per second

PART 1: INTRODUCTION

1 INTRODUCTION

1.1 Background

It is understood that there has been no specific study of the water needs of users downstream of LHWP water users, and how these needs will be affected by the construction of scheme. In the context of the Instream Flow Requirements study presently being performed by Metsi Consultants (Report No 648-F-03), it is important that human and animal requirements are considered within the contract of this study.

To achieve the objectives specified in the Terms of Reference (TOR), the approved methodology for this component of the project is a desk study, combined with discussions with other experts and interviews with appropriate staff from organizations involved with the management of water in Lesotho. The desk study was based on the review of the available literature covering relevant materials to the TOR.

Water resources availability consists of the quantity of water available to the riparian community and its distribution. When water availability becomes limited due to changes in water quality (the chemical, physical or biological characteristics of the water), it becomes apparent that the water resource consists of both the quantity and the quality of the water. The environmental acceptability of water is based on the concept that the quality of the water is harmless to users and to the aquatic ecosystem. The justification for the harmless to users is obvious and clear-cut as water-borne diseases are the scourges of poor sanitation. The aquatic ecosystem is important in its own right, but in addition a healthy aquatic community plays a vital role in the removal of pollutants and the restoration of water quality (TAMS, 1996).

This study focuses on the community water demand in terms of quantity and quality of the available water resources in the riparian communities.

1.2 Terms of Reference

The Terms of Reference (TOR) of the study is set out in the Social Planning Meeting Working Document as follows:

- Describe the target area of the study as defined by the appropriate corridor width on either side of the Senqu and Senqunyane Rivers (as identified in the sociological study) downstream of the LHWP to the South African border.
- Identify the component of the population in the target area that relies directly on the Senqu or Senqunyane Rivers for their water supply (target population).
- Estimate the present and future water requirements of the target population, using the available Lesotho Water Resources Study by TAMS (1996).
- Determine the quantity and quality of water required to meet the water supply needs of the target population downstream of the LHWP.
- Estimate the capacity of alternative sources of water (e.g., hand pumps) to offset the reduction in water availability to the target population from the main river due to the LHWP.
- Recommend modifications to any component of the LHWP (e.g., riparian release policies) and/or the additional development of water resources required to ensure the water requirements of the target population are met.

1.3 Limitation of the study

This being a desk study, all the available reports from relevant previous studies were reviewed. The Lesotho Water Resources Management report prepared by TAMS (1996) was the primary source document for this component of the study.

Findings from these previous studies that pertain to, or impact on the water availability and needs of people downstream of the LHWP were summarised and related to the above TOR. Particular attention was paid to reporting the opinions of the target population of sociological study.

PART 2: WATER SUPPLY AND USE IN LESOTHO

2 WATER SUPPLY AND USE IN LESOTHO

Historically the availability of water has strongly influenced the pattern of settlement in Lesotho. The widespread availability of perennial springs, arising from the relatively high levels of rainfall and the mountainous terrain, contributed to a more dense pattern of settlement than that to be found in the more arid, low-lying regions to the West of the present border (TAMS, 1996). The availability of these springs, in the past certainly influenced the siting of new extensive use of surface water (rivers or dams) for household purposes, as there was no need for the digging of shallow wells. As a result almost all villages established before introduction of borehole technology have at least one spring which flows throughout the year. Boreholes, equipped primarily with hand pumps, made it possible for settlements to expand into more arid parts of the Western Lowlands, filling areas which, might not otherwise have been occupied.

The above situation, that of an essentially rural population with a plentiful supply of water is one that has changed markedly, and at an accelerating rate within the past twenty years. Two components have contributed to the change. The first is the rapid growth of the population and the second is the internal migration within Lesotho from the Maloti Mountains to the Lowlands. The result has been the need for increased government intervention in the supplying of water for the population, both in rural and urban areas. For the rural areas the instrument has been the Department of Rural Water Supply (DRWS), for the urban areas it has been the Lesotho Water and Sewerage Authority (WASA).

2.1 Urban and peri-urban

The sole provider of reticulated water in Lesotho is WASA, which was created in 1992 as a parastatal, having been a Government department before that date. WASA has responsibility for, amongst other things, the supply of water services in Maseru and fifteen other gazetted urban centers in Lesotho. In those areas that do not receive a WASA supply, DRWS provides water. DRWS, by default, supplies much of the peri-urban area of Maseru and many of the rapidly growing peri-urban areas of the lowlands as well as meeting their main task of supplying water to the rural population.

WASA currently provides water services to around 176000 inhabitants, or approximately 50% of the population, living within its designated area of responsibility. The Authority has approximately 17000 domestic water supply connections and an additional 3000 commercial and Government water supply connection. Of the latter, approximately 420 are public standpipes that provide free water to some 18000 urban households.

Tariffs at WASA remained unchanged from April 1993 until June 1996 and the Authority's revenue is insufficient to cover costs.

WASA has a long-standing policy commitment to 'expanding the customer base'; this is in accordance with a Government manifesto commitment of universal access to water. In 1992 WASA served about 24% of the population through house connections and an additional 35% were served by public standpipes; giving a total coverage of some 59%.

By 1995 house connection coverage had only increased to 26% of the population. This reflected the interaction of two variables, the relatively slow rate of new connections (some 7% per year) and rapid population growth in WASA market areas (some 5.4% per year). More seriously, WASA had started to close public standpipes in response to late and non-payment by Government of the water consumed from standpipes. The negative impact on coverage of the closure of standpipes has been greater than the positive impact on the increase in house connections, so that total coverage is currently reducing. Total coverage in WASA market areas was estimated at 55% in 1996.

2.2 Rural water supply

The majority of Lesotho's population lives in rural areas. Although there are clear indications that this will change as people move from the Maloti Mountains to the Lowland, a significant proportion will continue to live in relatively small villages scattered throughout the mountains. The Government of Lesotho, through the Department of Rural Water Supply (DRWS) of the Ministry of Natural Resources, is committed to improving the health of rural communities, regardless of their circumstances, through the provision of ample quantities of clean water (30 litres per capita per day) within easy reach (150 meters) of their homes.

The policy statement of DRWS (TAMS, 1996) reads as follows:
"The overall objective of the DRWS is to contribute, in a sustainable way, to improvements in the health status and well-being of the rural population of Lesotho through the provision of safe drinking water."
The question of sustainability is central to the policies and strategies of DRWS and has a direct impact on three key areas: community involvement, choice of technology and operation and maintenance.

2.2.1 Community participation

The existing policy aims to have communities involved from initial planning and design throughout construction to final operation and management of the water supply. While the demands of villagers in the planning and design stages are limited the construction stage has very significant demands on their time and resources.

Present policy is that the benefiting communities should provide all unskilled labor, as their contribution to the water system. While hand pump systems from ground water require very little community labor, gravity-fed and pumped systems from rivers require a substantial one. The task of mobilising community labor is the responsibility of the elected Village Water Committees (VWCs) that are to be found in 96% of villages served with an improved water supply. It is DRWS policy that these VWCs should develop constitutions governing a wide range of issues including villagers' contributions to labor.

As well as labor, villagers contribute financially to a village fund used for maintenance and minor repairs. While in many cases this is a one-off event, in the case of pumped systems that depend on diesel engines or electricity, the community is required to make regular financial contributions. Approximately 80% of villages (VWC) have an account with and average balance of M850. This amount is usually adequate to cover the cost of minor repairs and, in 1995, it was found that villagers had replaced, at their own expense, over 3000 worn out taps.

2.2.2 Choice of technology

It is DRWS policy that, wherever possible, spring fed gravity systems should be built due to their generally low O & M costs relative to initial capital costs as well as their appropriateness to local physical conditions. Where spring-fed gravity systems are not feasible, springs-below are utilised with the aid of a mechanical means (diesel, electric, hydram, solar, etc.). When springs are not available, ground water, using boreholes, is used. Priority is given to high-yielding boreholes equipped with a pumping device. When these are not available hand pumps are installed.

2.2.3 Levels of service

DRWS policy is to provide the same level of service in terms of quantity of safe drinking water provided and in terms of the distance to the water collection point regardless of the type of system installed. After the 1978 *Feacham* report (TAMS, 1996), which considered the health impact of clean water, the 30 litres per capita per day was adopted as the quantity standard.

Wherever possible, if the population of the village is more than 200 people a reticulation system is installed with standpipes sited to serve between 80 to 120 people per tap (maximum number of people is when there are less than 40 people a walking distance of 300 meters is acceptable).

Looking at l/c/d by district some very significant differences emerge. The Table 2.1 shows l/c/d broken into different categories by district.

Overall only 35% of projects are meeting the l/c/d standard of 30 litres. The sparsely populated mountain districts of Mokhotlong and Qacha's Nek have the highest percentage of projects delivering 30 l/c/d and above. All the lowland districts have over 20% of projects with either no water or less than 30 l/c/d. As population grows and spring yields decline, it can be predicted that this percentage will rise.

Table 2.1 Litres per capita categories by district.

DISTRICT	No Water	Below 7	7 to 30	Over 30
Butha-Buthe	2%	24%	42%	32%
Leribe	7%	23%	48%	22%
Berea	6%	19%	36%	39%
Maseru	4%	17%	44%	34%
Mafeteng	3%	28%	39%	30%
Mohale's Hoek	3%	23%	38%	36%
Quthing	1%	14%	57%	29%
Qacha's Nek	2%	2%	46%	51%
Mokhotlong	6%	9%	27%	58%
Thaba-Tseka	4%	35%	41%	20%
Overall	4%	19%	43%	35%

Source: DRWS, National Inspection Data, 1995 (TAMS, 1996)

2.2.4 Operation and maintenance

The objectives of DRWS Maintenance policy are stated to ensure the water supply systems installed by DRWS remain in serviceable condition and to ensure that water supply systems constructed by other organisations are kept serviceable providing that these adhere to DRWS standards and are approved by DRWS. In order to achieve its maintenance objectives DRWS has adopted the following policies:

- To share responsibility for maintenance between the villagers and DRWS;
- to optimise village level operation and maintenance for the various types of water supply systems;
- to carry out repairs to water supply systems at the request of the village;
- to subsidise the cost of maintenance activities;
- to recover a percentage of maintenance costs from the villagers;
- to specify an affordable maximum charge, based on the population served, which villagers should pay.
- to provide an initial guarantee period when the water supply system is handed over to the villages;
- to inspect the system at the end of this guarantee period and to carry out any necessary repairs at no cost to the village;
- to monitor the status of existing water supply systems.

2.2.5 Cost recovery

A draft cost recovery policy was drawn up in 1987. In 1991 it was approved and published as *the Policy and Implementation Plan for the Recovery of Systems Maintenance Costs (TAMS, 1996)*. The policy aimed at recovering 50% of direct costs.

The new policy placed certain obligations on the VWCs and others on DRWS:

The VWCs obligations included:

- to provide free labor to assist DRWS crews,
- pay a minimum service charge for each repair requested,
- pay for materials and labor up to a maximum cost M1.00 per person in village, or M300 for hand pump repair; and
- pay bills within 90 days of receipt of invoice.

DRWS obligations included:

- guaranteeing new systems for one year;
- employing technically trained personnel in sufficient numbers to respond adequately to requests for repairs;
- continuing to train village water minders;
- maintaining necessary tools, spares and transport to meet maintenance needs;
- paying for all transport, administrative and overhead costs; and
- maintaining a comprehensive and updated system inventory of the status of all water supply systems.

2.2.6 System functioning

The national inspection of Rural Water Supply examined the extent to which the collection points inspected are functioning. Functioning was defined as whether or not there was a flow at the time of inspection or, in the case of hand pumps whether or not there was any yield within 60 turns. Table 2.2 shows the number and percentage of the main types of collection points with a flow according to age and project type.

Table 2.2 shows that age is significant factor with the most recently constructed projects significantly more likely have a flow than those built in earlier periods. In projects that are over 10 years old; one third of the collection points have no flow, compared to less than one quarter in the newer projects. These data give an indication of the growing rehabilitation task in the years ahead; clearly as the water systems age the proportion of functioning collection points will continue to drop if the systems are not rehabilitated. The impact of rehabilitation of old systems on the on-going effort to extend coverage is discussed later.

The most significant factor, however, to influence flow or yield is project type. The Table 2.2 also shows that simple water points (no reticulation beyond a tank) are most likely to have a flow (84%). The influence of project type is clearly seen when looking at standpipes: in gravity-fed projects 78% of standpipes have a flow while in pumped projects only 40% do, suggesting that very careful consideration will have to be given to the installation, operation and maintenance of different pumped technologies in the future. The percentage of hand pumps that work (i.e. yield water) is relatively higher than the percentage of taps that work.

2.2.7 Distance from collection points

It is DRWS policy that all households in a project area are within 150 meters of the nearest collection point. Results from the national inspection indicate that in half of villages with an improved water supply all households are within 150 meters. The remaining 50% are beyond the 150m zone as summarised in Table 2.3.

What is apparent from the table are the differences between geographic zone and project type. The Lowlands have the lowest percentage of villages with all households within the standard. This result is influenced by the extensive use of hand pumps in this zone. Because hand pumps cannot be situated just anywhere, they are often some distance from the village. Only 37% of villages that are served exclusively with hand pumps have all the homes within 150 meters of the pump.

Table 2.2 Number and percentage of collection points with flow/yield by age and project type.

	Type of Collection Point		
	Standpipe	Water Point	Hand-pump
By Age:	%	%	%
Pre-1986	65	82	69
1986-1990	70	82	73
1991-1995	78	91	78
By Project Type:	%	%	%
Gravity	78	88	N/A
Hand-pumps	N/A	N/A	75
Pumped	40	89	66
Overall	71%	84%	74%

Source: DRWS, National Inspection Data, 1995 (TAMS, 1996)

Table 2.3 Villages with households over 150 meters from nearest collection point.

% of Household situated over 150 m from the collection point					
	150m	150m-190m	190m-225m	525m-260m	260m-300m
By Zone:					
Lowlands	45%	31%	16%	5%	3%
Foothills	61%	26%	6%	4%	3%
Mountains	53%	33%	8%	4%	2%
Senqu Valley	57%	29%	10%	2%	3%
By Type:					
Gravity	60%	27%	7%	2%	2%
Hand pumps	37%	30%	22%	8%	6%
Mixed	44%	33%	17%	6%	1%
Pumped	52%	32%	9%	3%	5%
Overall	51%	30%	13%	4%	3%

Source: DRWS, National Inspection Data, 1995 (TAMS, 1996)

2.3 Coverage

The International Drinking Water and Sanitation Decade (TAMS, 1996) enable Lesotho to attract significant funds from a wide variety of donors and this, combined with the strategies developed in the Fourth Phase, resulted in rapid coverage. Table 2.4 shows the water supply coverage by district.

Although the mandate of DRWS is to serve rural areas the organisation has water systems in what, today, are legally defined urban areas as well as many peri-urban areas in the lowlands. This situation has occurred primarily as result of the shifts in urban boundaries. Settlements on the edge of towns, which 10 years ago where considered to be rural villages, have now been incorporated in to the fast growing peri-urban areas.

The data presented on coverage (TAMS, 1996) has, so far, not taken into consideration level of service. In other words the figures given include the total populations of villagers where there is an improved water supply regardless of the extent to which the system is functioning or meeting the standards set by DRWS.

2.4 Health, sanitation and water use

It is widely recognized that access to clean water is essential for good health. According to the World Health Organisation (WHO, 1996b), a third of the world's population suffer from diseases derived from contaminated drinking water. The DRWS and a number of non-government organisations (NGOs) working in the water sector aim to improve the health of the rural population in Lesotho through the provision of clean water and adequate means of sanitation.

Lesotho is fortunate in being free from many water-related diseases found in other African countries. It is the only country in Africa that does not have malaria, trypanosomiasis, sleeping sickness or filariasis. However, poor hygiene and sanitation practices and the use of low quantities of water have been recognized as contributing to a high prevalence of water-borne and water-washed diseases.

While the relationship between clean water and health is recognized, very little formal monitoring of the health impact of water supply has been undertaken in Lesotho.

2.4.1 Health center data

According to the 1993 Health Profile, which was based on data collected between 1988 and 1991, potentially water-related diseases ranked near the top of all diseases reported by outpatients.

The health study performed as part of the LWRM Study (TAMS, 1996) indicated that skin diseases, digestive diseases, diarrhoea with and without dehydration, and intestinal parasites were highest among children between 0-4 years, next among children 5-14 years, and least among adults for outpatient attendees. The pattern for in-patients was broadly similar: intestinal infections and skin diseases were near the top of the list for children between

0-4 years old, and near the middle of the list for children 5-14 years old. Such diseases were far less common among adults as a reason for admission to hospital.

Table 2.4 Rural water supply coverage by district.

District	1995 Population Served	% Served
Butha-Buthe	70,056	55%
Leribe	144,288	45%
Berea	126,757	70%
Maseru	159,713	86%
Mafeteng	134,151	56%
Mohale's Hoek	129,156	56%
Quthing	63,972	44%
Qacha's Nek	30,613	37%
Mokhotlong	23,789	24%
Thaba-Tseka	29,541	22%
National	912,045	56%

Source: TAMS, 1996

The incidence of typhoid was relatively low in relation to other water-related diseases over the four year period (41st on the list, at 0.8 per 1 000 attendees). However, recent data suggest that the incidence of typhoid can fluctuate dramatically from one year to another: in 1994 a total of 353 cases of typhoid were reported by the Ministry of Health and Social Welfare (MOHSW) while 1 327 cases were reported in 1995. It is not known what proportion of these were in rural areas. Outbreaks of typhoid also fluctuate between seasons with most cases occurring during the summer months of December, January and February. A similar pattern has been identified for diarrhoeal disease. Of the people interviewed during the above study, 2 300 were asked to recall what water-related illnesses members of their households had suffered from during the previous six months. Table 2.5 presents the result broken down according to type of water supply used by the household.

The overall incidence of water-related diseases was generally low. Comparing this with the health center data it was found that incidents of diarrhoeal disease were significantly higher than skin problems, the opposite of what the health center-based data suggested. Clearly treatment is not sought at health centers (if at all) for the bulk of diarrhoeal disease cases.

The differences between the different types of improved sources were generally insignificant. However, the much higher incidence of all disease types and symptoms among spring users was significant, suggesting that improved water systems, of whatever type, do have a positive health impact

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Table 2.5 Water-related diseases by source of water.

Source	Diarrhea	Stomach Ache	Vomiting	Worms	Skin Problems
Stand Pipe	5.0	7.3	2.5	0.2	1.0
Hand Pump	4.9	7.3	1.5	0.0	1.0
Priv. System	5.1	7.4	1.9	0.0	1.6
Spring	9.4	14.1	3.9	2.1	1.3
Priv. Connect	5.3	5.3	1.9	0.5	0.9

Source: LWRM Social Survey, Annex N (TAMS, 1996)

PART 3: WATER SUPPLY AND DEMAND ALONG THE SENQU AND SENQUNYANE RIVERS

3 WATER SUPPLY AND DEMAND ALONG SENQU AND SENQUNYANE RIVERS

This section summarises the procedure developed by the Consultants to estimate the water demand in the study area between 1999 and 2020. The study area was demarcated during the Phase 2 socio-economic (August 1999) component of the IFR Study as the “corridor of the river usage”. The water demand in this study integrates the dynamic of the population, its changing needs and habits related to water consumption to determine an overall domestic demand. The animals (livestock) consumption is added based on estimates calculated from present consumption. System losses in water conveyance system are set based on recommendations of the LWRM study (TAMS, 1996).

The methodology used in this study to estimate the water demand is appropriate as a first attempt using the available data. However the results will need to be updated as new and better data on population census and income growth becomes available in the future

3.1 Source of domestic water supply

Findings of LWRM Study (TAMS, 1996) indicated that theoretically 56% of the rural population are ‘covered’ in the sense that there is a water system somewhere in the village where they live. However, during the same study it was found that at present the mountains are poorly served (22%) compared to the Lowlands (78%).

During the Phase 1 Social Pilot Study (January 1999) it was found that ‘People drink water from the river everywhere’. The visited reaches differed in whether or not the river is the primary source of drinking water and water for household consumption. However, most of the villages visited have reliable water supply systems, which make them more independent from the river as a source of drinking water. Table 3.1 shows the degree of water supply on the visited villages in the study area. This table shows that a few of the villages visited relied to a very high degree on the river as the source of water for household consumption. A larger number of the villages do so only during droughts when the village water supply systems goes dry.

The river water use for household purposes is largely determined by the availability of other sources. Table 3.1 shows the nature and the reliability of the village water supply system as well as the presence and strength of a nearby tributary. It is true that there are springs where there are settlements. However, some of the unprotected springs are not strong or reliable enough to supply the village with water for household consumption for the whole year. In addition to that, it should be noted that the lowland areas rely more on river water for household consumption than the mountain areas.

Similarly Table 3.2 shows the main water supply system for domestic purposes. These data are the result of the Phase 2 socio-economic survey carried out by Metsi Consultants as part of the social component of the IFR study (Report No 648-F-08). This table also shows the river usage for water supply during all year, dry season and drought period.

Table 3.3 shows the survey results of livestock watering from the main river within the 5-km river corridor. This table illustrates for example on the Matsoku River between Matsoku diversion weir and the Malibamatso confl. 64.1 % uses the river for animal watering during the dry season and 80.8% during the drought period.

3.2 Population estimates and projections

The actual population estimates of the riparian communities in the Malibamatso, Senqunyane, Matsoku, and Senqu valleys downstream of the Katse and Mohale Dams and Matsoku Diversion Weir were compiled during this study in September 1999 using the 1996 Lesotho Population Census.

Table 3.1 Water supply system and its reliability.

	Villages in the IFR study area	Water supply system	Reliability	Tributary quality	River water used for household
M	Ha Soai	Gravity taps	High	Medium	Rarely
M	Koma Koma	Gravity taps	High	Medium	Rarely
M	Sanguela	Gravity taps	High	-	Rarely
M	Ha Noha	Unprotected spring	Medium	Excellent	Very rarely
M	Ha Noha Ext	Unprotected spring	Medium	None	Dry Season
M	Marakabei	Gravity taps	High	Strong	Rarely
M	Mapoho	Unprotected spring	Medium	Excellent	Never
M	Motenalapi	Unprotected spring	Medium	Medium	Rarely
M	Auplass	Gravity taps	Unreliable	Medium	Never
M	Maphuto	Unprotected Spring	-	Weak	Rarely
M	Sekake	Gravity taps	Very unreliable	Poor	Dry season
M	Pathela	Gravity taps	High	Medium	Never
M	Pathlong	Gravity taps	Medium	Medium	During drought
M	Ha Koali	Gravity taps	High	Excellent (far)	Never
L	Seleitara	Gravity taps	Medium	-	During draught
L	Phamong	Gravity taps	High	Good	During droughts
L	Ramatlalla	Borehole	Unreliable	Very weak	Dry season
L	Pathlalla	Borehole	Medium	Very weak	Dry season
L	Seaka	Borehole	Unreliable	Very weak	Dry season

Source: Report No 648-F-08

M = *Mountain areas*, L = *Lowlands*

Table 3.2 Main water supply systems for domestic use (%).

IFR Reach No (1)	Water from taps all year (2)	Water from covered spring all year (3)	Water from uncovered spring all year (4)	Water from river all year (5)	Water from river during dry season (6)	Water from river during drought (7)
1	30.6	27.8	30.6	2.8	12.2	4.9
2	24.2	18.6	40.0	0.5	2.3	14.0
3	25.6	24.2	31.6	0.5	0.0	0.5
4	41.6	9.3	35.4	0.4	1.3	1.3
5	53.0	2.3	33.5	0.0	0.5	2.8
6	51.3	6.4	12.7	0.4	11.9	33.1
7	0.0	29.5	42.9	9.2	8.3	23.5
8	2.4	18.9	61.7	0.6	2.9	8.7
Average	28.6	17.1	36.1	1.8	4.9	11.1

The Bureau of Statistics (BOS) has recognised that there was underenumeration of the population in 1996. For this reason census results were adjusted by a factor of 5% according to guidelines provided by BOS.

The actual *de jure* population for each village was obtained by totaling persons present and persons absent, whether absent in Lesotho or outside Lesotho (migrant workers).

Table 3.4 summarises the population estimates within 5-km river corridor in the study area. The assumed population growth rate is based on figures developed in the LWRM Study for different parts of Lesotho (TAMS, 1996).

Table 3.3 Percentage of animals drinking water from the rivers (%).

IFR Reach No	% Households owning animals	Dependent on river during dry season	Dependent on river during drought season
1	79.6	64.1	80.8
2	67.0	23.8	55.8
3	47.9	48.4	59.5
4	58.4	44.7	64.6
5	57.7	22.8	59.1
6	66.5	20.8	53.8
7	73.3	41.5	65.5
8	62.1	27.7	55.3
Average	62.5	31.5	56.0

Table 3.4 Population estimates within 5 km of the rivers in the study area.

IFR River Section No	River section	Total pop (1996)	Adjustment BOS figures (1)	Growth rate (%) (2)	1999 population
1	Matsoku R between Weir and Malibamatso confl.	6,801.00	1.05	1.48	7,462
2	Malibamatso R Between Katse Dam Matsoku confl.	2,624.00	1.05	1.48	2,879
3	Malibamatso R between Matsoku confl. and Senqu R	14,005.00	1.05	1.48	15,367
4	Senqu R between Malibamatso confl. and Tsoelike confl.	24,351.00	1.05	1.48	26,719
5	Senqu R between Tsoelike confl. and Senqunyane confl.	25,290.00	1.05	1.48	27,749
6	Senqu R between Senqunyane confl. and RSA border	54,777.00	1.05	1.48	60,104
7	Senqunyane R between Mohale Dam and Lesobeng R confl.	9,860.00	1.05	1.48	10,819
8	Senqunyane R between Lesobeng confl. and Senqu confl.	3,179.00	1.05	1.48	3,488
TOTAL		140,887.00			154,588

1 - The BOS has recognised that there was underenumeration of the population in 1996. For this reason census results have been adjusted by a factor 5% according to guidelines provided by BOS.

2 - The growth rate is based on the mean growth rates of all the 1986 constituencies through which the LHWP affected rivers pass (TAMS, 1996). This is below the national average due to out migration from these areas.

Table 3.5 Population projection in the study area within 5 km river corridor.

IFR No	River section	Population		
		2000	2010	2020
1	Matsoku River between Weir and Malibamatso confl.	7,573	8,769	10,155
2	Malibamatso River Between Katse Dam Matsoku confl.	2,922	3,383	3,918
3	Malibamatso River between Matsoku confl. and Senqu River	15,594	18,058	20,912
4	Senqu River between Malibamatso confl. and Tsoelike confl.	27,114	31,399	36,361
5	Senqu River between Tsoelike confl. and Senqunyane confl.	28,160	32,610	37,763
6	Senqu River between Senqunyane confl. and RSA border	60,992	70,631	81,792
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	10,979	12,714	14,723
8	Senqunyane River between Lesobeng confl. and Senqu confl.	3,540	4,099	4,747
	GRAND TOTAL	156,873	181,663	210,371

The population projection were estimated using the mean growth rates of all the 1986 constituencies through which the LHWP affected rivers pass (TAMS, 1996). This is below the national average due to migration out from these areas. Figure 3.1 shows the growth rates for Lesotho and Table 3.5 shows the population projections every ten years to 2020. APPENDIX 1 shows the population estimates, including inhabitants and livestock in the study area.

3.3 Domestic water demand estimates

3.3.1 General

The same procedure developed by TAMS in the LWRM Study (1996) was used to estimate the need in water of the population along the study area between the years 1999 and 2020. The LWRM Study integrated the dynamic of the population together with its changing needs and habits related to water consumption to determine an overall demand.

During the LWRM Study the domestic water demand for Lesotho was estimated based on the 1976 and 1986 population census data and projected between the years 1995 to 2025 using population growth rates and the average actual water consumption, litres per capita per day (l/c/d).

3.3.2 Data sources

The analysis was performed using the detailed population survey carried out during the Phase 2 socio-economic study (September 1998) along the Malibamatso/Senqu, Matsoku and Senqunyane rivers within 5 km of river corridor. The population distribution and its projection until 2020 were produced using the growth rates of the 1976, 1986 and 1996 census data (TAMS, 1996, Bureau of Statistics, 1997).

3.3.3 Assumptions to estimate the household water demand in the study area

To estimate the household water demand in the study area the following assumptions were applied:

- **Distance** - The maximum distance that people and livestock would go to the river for water is within 5 km river corridor as determined during the Phase 1 & 2 of Socio-economic Survey (January and September 1999).

- **Population Projections** – The projections were based on estimates given in Section 3.2 (Tables 3.4 and 3.5).

- **Consumption** – In rural areas, it is assumed that the consumption will increase from its present average of 11.78 l/c/d to 30 l/c/d in 2020. This increase will be gradual, as the quality of the distribution increases. For this study 30 l/c/d was used, as this is standard water consumption in rural areas and will also give more conservative results.

- **Losses** – System losses was assumed to be 16% or 5 l/c/d (TAMS, 1996).

3.3.4 Results

The total household water demand estimates in the study area are shown in Table 3.6 for the 5-km river corridor. These estimates are the total water demand for the whole household population living within the 5-km river corridor.

In fact, according to the Phase 2 socio-economic survey (September 1999) it was found that on average only approximately 1.8% of the total household population uses the river all year around. While in the dry season and drought period approximately 4.9% and 11.1% of the household population uses the river as the primary water supply system, respectively. Table 3.7 shows the household population water demand, which uses the river as the main water supply system on the basis of the social report (Report No 648-F-08).

In conclusion, Table 3.7 shows the household actual water demand from the main river in the study area.

Table 3.6 Household population total water demand estimates in m³/day within 5 km river corridor from all sources.

IFR No	River Section	1999	2010	2020
1	Matsoku River between Weir and Malibamatso confl.	261	307	355
2	Malibamatso River Between Katse Dam Matsoku confl.	101	118	137
3	Malibamatso River between Matsoku confl. and Senqu River	538	632	732
4	Senqu River between Malibamatso confl. and Tsoelike confl.	935	1099	1273
5	Senqu River between Tsoelike confl. and Senqunyane confl.	971	1141	1322
6	Senqu River between Senqunyane confl. and RSA border	2104	2472	2863
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	379	445	515
8	Senqunyane River between Lesobeng confl. and Senqu confl.	122	143	166
TOTAL		5411	6358	7363

Table 3.7 Household water demand estimates from the main river (m³/day).

IFR REACH		Water from river all year around		Water from river during dry season		Water from river during drought period	
No	NAME	1999	2020	1999	2020	1999	2020
1	Matsoku River between Weir and Malibamatso confl.	7	10	32	43	13	17
2	Malibamatso River Between Katse Dam Matsoku confl.	1	1	2	3	14	19
3	Malibamatso River between Matsoku confl. and Senqu River	3	4	0	0	3	4
4	Senqu River between Malibamatso confl. and Tsoelike confl.	4	5	12	17	12	17
5	Senqu River between Tsoelike confl. and Senqunyane confl.	0	0	5	7	27	37
6	Senqu River between Senqunyane confl. and RSA border	8	11	250	341	696	948
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	35	47	31	43	89	121
8	Senqunyane River between Lesobeng confl. And Senqu confl.	1	1	4	5	11	14
TOTAL		59	79	336	459	865	1177

3.4 Livestock water demand estimate

3.4.1 General

In the rural areas of Lesotho, the possession of livestock still continues to convey social status in proportion to the numbers of animals owned.

The annual drinking water requirements of livestock obviously depend on:

- the type and size of the animals,
- the climate and weather conditions which the animals experience at particular times of the year,
- the water content of fodder at different seasons,
- the amounts of energy expended during grazing or during drought or transport work, etc.

Table 3.8 shows the total indicative annual use of water by agricultural livestock estimated in the LWRM Study (TAMS, 1996). If the unit requirements for each type of animal are applied to the present numbers of animals estimated by the Bureau of Statistics (Bureau of Statistics 1997); the total annual use of water by agricultural livestock in Lesotho is indicatively 11.5 MCM per year (0.36 m^3/s). With little overall change in livestock numbers at present foreseen, this volume is, therefore, the indicative future requirement of water for livestock in the country.

3.4.2 Agricultural livestock water demand estimates

The water demand estimates made here for the agricultural livestock in the study area are based on the Phase 1 & 2 Social-economic survey study carried out in January and September 1999. During these studies the total number of animals within the 5 km river corridor and the average number of total livestock per household which included the number of cattle, small animals and equines were estimated as shown in Table 3.9. APPENDIX 1 shows the details of these estimates.

Number of people per household – Similarly the number of people per household was estimated during the Phase 1 & 2 Socio-economic survey (January, August 1999; Report No 648-F-08). In this study it was estimated an average of 4.7 people per household in the mountains and 4.73 people per household in the lowlands. The lowlands geographically start at Ha Moorosi to the border with RSA.

Table 3.8 Total indicative annual use of water by agricultural livestock in Lesotho.

Types of Animal	Number	Unit consumption (litres per day)	Total consumption $10^3m^3year^{-1}$
Dairy Cows (>2yrs old)*	45000	66	1084
Other Cattle (>2yrs old)	402205	25	3670
Cattle 1-2yrs old	67590	26	641
Cattle <1yr old	65435	20	478
Sheep >1yr old	904860	4	1318
Sheep <1yr old	225890	2	165
Goats >1yr old*	617215	4	901
Goats <1yr old	131920	2	96
Horses/Mules >2yrs old**	84375	48	1478
Horses/Mules <2yrs old**	15895	45	261
Donkeys >2yrs old**	123205	22	989
Donkeys <2yrs old	22760	20	166
Swine	65935	13	313
TOTAL	2772285	285	11560

Source LWRM Study Table 4 (TAMS, 1996).

* It was assumed that the number of dairy cattle is 45 000 out of the total cattle population of 580230, that the unit water consumption rates for goats are equivalent to those given and averaged for sheep, and that those for mules are the same as those for horses.

** Additional unit water consumption rates were taken after discussions with the Department of Livestock Services, Maseru.

Distance – The reasonable distance that animals would travel to drink water was concluded to be within the 5-km river corridor (Report No 648-F-08).

Table 3.10 shows the water demand estimates for the livestock in the study area within 5 km river corridor. This table shows that the total livestock water demand in the entire study area including the villages downstream of the Seaka Bridge (IFR 6) is 6344 m³/day or 0.073 m³/sec for the year 2020. In 1999 the animal water demand was estimated as 4663 m³/day or 0.054 m³/sec within "the corridor of river usage" which is 5 km either side of the river. APPENDIX 1 shows the livestock water demand estimates in greater detail.

Table 3.9 Number of livestock per household in the riverine areas.

IFR No	River Section	Cattle	Sheep	Goats	Pigs	Equines
1	Matsoku River between Weir and Malibamatso confl.	3.80	2.90	2.70	0.10	1.30
2	Malibamatso River Between Katse Dam Matsoku confl.	2.43	4.80	2.31	0.04	1.05
3	Malibamatso River between Matsoku confl. and Senqu River	1.76	2.50	1.34	0.01	0.51
4	Senqu River between Malibamatso confl. and Tsoelike confl.	1.85	3.10	2.45	0.01	0.83
5	Senqu River between Tsoelike confl. and Senqunyane confl.	1.51	1.91	3.55	0.09	0.60
6	Senqu River between Senqunyane confl. and RSA border	2.09	1.42	5.38	0.26	0.59
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	3.56	6.20	6.12	0.11	1.32
8	Senqunyane River between Lesobeng confl. and Senqu confl.	1.62	1.55	5.58	0.13	1.05
	Average animals per household	2.33	3.05	3.68	0.09	0.91

Table 3.10 Livestock water demand estimates in the study area in m³/day within 5 km river corridor

IFR No	River Section	1999	2010	2020
1	Matsoku River between Weir and Malibamatso confl.	376	442	512
2	Malibamatso River Between Katse Dam Matsoku confl.	104	122	142
3	Malibamatso River between Matsoku confl. and Senqu River	358	421	487
4	Senqu River between Malibamatso confl. and Tsoelike confl.	743	873	1011
5	Senqu River between Tsoelike confl. and Senqunyane confl.	634	744	862
6	Senqu River between Senqunyane confl. and RSA border	1778	2089	2419
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	569	668	774
8	Senqunyane River between Lesobeng confl. and Senqu confl.	100	118	137
TOTAL		4663	5479	6344

3.5 Irrigation water demand estimates

A comprehensive study on water use for irrigated agriculture for Lesotho was carried out during the LWRM Study (TAMS, 1996). The study estimated that to develop the potential irrigation areas of the entire Senqu catchment approximately 11.5 MCM per year of water is needed. This translates to flow rate is equivalent to 0.36 m^3/s in the lower reaches of the Senqu River. The socio-economic study found that the potential areas for irrigation were mainly in the lowlands and along the IFR Reach 6.

The quantity of water available at IFR Reach 6 for the scenario with Treaty releases and Mashai in place is expected to be approximately 25 m^3/s. The irrigation water demand of 0.36 m^3/s is approximately 1.5% of the amount of water, which will be available at IFR Reach 6 for the minimum release associated with the Treaty Scenario.

It is worth mentioning that of the four scenarios considered in the IFR Study, the Treaty Scenario provides minimum releases from the Phase 1 and 2 dams. It is thus results the lowest amount of water, being available at Site 6. This quantity available (25 m^3/s) is much larger than the amount needed (0.36 m^3/s) if the potential irrigation areas are fully developed. It is thus concluded that there will be enough water available to irrigate the potential irrigation areas in the Senqu and Senqunyane catchments.

PART 4: TOTAL DEMAND AT IFR REACHES

4 TOTAL WATER DEMAND AT IFR REACHES

4.1 Water demand

The household population and livestock water demands at IFR Reaches were estimated taking into account the following assumptions:

- The total water demands at IFR Reaches is defined as the water demand of all villages between the river sections (IFR Reaches) defined on the Phase 2 socio-economic study (August, 1999).
- The population growth rate estimated with the census 1976 – 1996 by LWRM study (TAMS, 1996) was applied.
- The number of people per household of 4.7 in the mountain area and 4.73 in the lowlands was applied. The lowlands were considered from Ha Moorosi down to RSA border.
- The average number of livestock per household shown in Table 3.9 was used.
- The population water consumption of 35 l/c/d was applied. This includes the standard per capita water consumption and losses in the system.
- The livestock water consumption applied was:

ANIMAL WATER CONSUMPTION l/c/d			
Cattle	Sheep/Goat	Equines	Pigs
45	3	38	13

- The maximum distance that animals and people could go to the river was considered to be 5 km either side of the river

Table 4.1 shows the total water demand within the study area at the IFR reaches. APPENDIX 1 shows the disaggregated water demand estimates at IFR reaches. Similarly Table 4.2 shows the total water demands in cubic meters per second to facilitate the comparison between the river flows and the water demands.

If the total amount of water demand at IFR Reaches is converted into litres/second, for example, the water demand at IFR Site No 3 is 14.11 lit/sec by the year 2020 (APPENDIX 1), which is equivalent to 0.014 m^3/s. The total water demand for the entire study area is 0.159 m^3/s. APPENDIX 1 shows the desegregated water demand estimates in m^3/day, lit/sec and in m^3/s in order to facilitate the comparison with the river flows at each IFR Reaches.

Table 4.1 Total Water Demand at IFR Reaches in m^3/day within 5 km river corridor.

IFR Site No	NAME	Total Water Demand in $m^3 day^{-1}$					
		1999			2020		
		Household	Livestock	Total	Household	Livestock	Total
1	Matsoku at Seshote	261	376	637	355	512	867
2	Malibamatso at D/S Katese Bridge	101	104	205	137	142	279
3	Malibamatso at Paray	538	358	896	732	487	1219
4	Senqu at Sehonghong	935	743	1678	1273	1011	2284
5	Senqu at Sekake	971	634	1605	1322	862	2184
6	Senqu at Seaka Bridge	2104	1778	3881	2863	2419	5282
7	Senqunyane at U/S Marakabei	379	569	948	515	774	1289
8	Senqunyane at Nkaus	122	100	222	166	137	303

	TOTAL	5411	4663	10073	7363	6344	13707

4.2 Comparison of the total water demand for the study area with LWRM water demand estimates for the Senqu River basin (TAMS, 1996)

The above estimates could be compared with the estimates done by TAMS during the LWRM Study (1996) for the entire Senqu River catchment as indicated in Table 4.3.

Table 4.3 shows clearly that the total demand for the Senqu River basin is far less than the water resources that is potentially available for each basin.

4.3 Comparison of total water demand and the Treaty releases at IFR reaches

The amount of water required to meet the total water demand was compared with the Treaty Scenario, which provides the lowest release of all four scenarios at each site. The comparison was made with dry season flows to provide a conservative estimate.

Table 4.2 Total water demand at IFR reaches in m^3s^{-1} within 5 km river corridor.

IFR Reach No	NAME	Total water demand in m^3s^{-1}					
		1999			2020		
		Household	Livestock	Total	Household	Livestock	Total
1	Matsoku at Seshote	0.003	0.004	0.007	0.004	0.006	0.010
2	Malibamatso at D/S Katese Bridge	0.001	0.001	0.002	0.002	0.002	0.003
3	Malibamatso at Paray	0.006	0.004	0.010	0.008	0.006	0.014
4	Senqu at Sehonghong	0.011	0.009	0.019	0.015	0.012	0.026
5	Senqu at Sekake	0.011	0.007	0.019	0.015	0.010	0.025
6	Senqu at Seaka Bridge	0.024	0.021	0.045	0.033	0.028	0.061
7	Senqunyane at U/S Marakabei	0.004	0.007	0.011	0.006	0.009	0.015
8	Senqunyane at Nkaus	0.001	0.001	0.003	0.002	0.002	0.004
	TOTAL	0.063	0.054	0.117	0.085	0.073	0.159

Table 4.3 Total water requirements and water resources for Senqu River basin in 1995 and 2025 (m^3s^{-1}).

Basin	1995		2025		Resources availability present conditions	
	Rural	Urban	Rural	Urban	Surface water	Ground water
Upper Senqu	0.02	0.00	0.06	0.00	52.00	2.49
Senqunyane	0.02	0.00	0.03	0.00	24.42	1.11
Middle Senqu	0.02	0.00	0.05	0.02	18.90	1.09
Maletsunyane, Qhoali, Katene and Lower Senqu	0.04	0.03	0.08	0.07	10.18	1.83
Total	0.10	0.03	0.22	0.09	105.5	6.52

Source: TAMS (1996)

Table 4.4 shows the comparison of the total water demand at IFR Reaches as a fraction of the water available from the treaty scenario releases during the dry season and a drought period. This table shows the total water demand (population + livestock) within the 5 km river corridor, assuming that the household and animals use the main river for water supply.

In conclusion Table 4.4 shows that the total water demand at IFR Reaches is far less than the Treaty Scenario IFR releases. The highest demand is at the IFR Reach 1 which, is approximately 9 % of the Treaty releases scenario by the year 2020.

Table 4.4 Comparison of water demand at IFR Reaches and Treaty Scenario releases.

IFR Reach No	Water demand m^3s^{-1} [1]		Treaty releases Dry season [2]	Water demand as % of treaty releases Dry season [3]	
	1999	2020	(m3/s)	1999	2020
1	0.0029	0.0039	0.05	6.32%	8.59%
2	0.0003	0.0004	0.51	0.06%	0.08%
3	0.0020	0.0028	0.75	0.27%	0.37%
4	0.0039	0.0053	1.80	0.22%	0.29%
5	0.0017	0.0023	4.49	0.04%	0.05%
6	0.0044	0.0060	15.49	0.03%	0.04%
7	0.0031	0.0043	0.43	0.74%	1.00%
8	0.0003	0.0004	0.67	0.05%	0.07%
Average				0.96%	1.31%
TOTAL	0.0186	0.0253			

PART 5: SENSITIVITY ANALYSIS

5 SENSITIVITY ANALYSIS

5.1 General

Computation of domestic water needs for drinking and watering animals assumes all villages which fall within a five-kilometer distance from the main river, could potentially use the river as primary source. This is clearly a very conservative estimate for the highland regions as the Phase 1 & 2 socio-economic study clearly shows that in the highlands, dependency on the main river is minimal.

This conservative estimate thus should be used as a guide, which gives us the magnitude of water needs in relation to availability. The following four cases are presented here to provide us with a sense of water demand and supply in the study area.

5.2 Cases

The socio-economic survey study estimated the water supply from the main river (see Table 3.2) to meet water demand:

- all year around
- during the dry season
- during the drought period

The sensitivity of water demand estimates using the above three cases is described below. In addition to the three cases given here, sensitivity of the entire population using the main river for domestic supply was also considered.

5.2.1 Case 1 – All year around demand

For Case 1 it was assumed that part of the population and livestock uses the river for water supply all year around within the 5-km river corridor as indicated in the Phase 2 socio-economic survey. This is a realistic case scenario, where the actual water demand for the household population and livestock is supplied from the river based on average all year around demands. This is based on the assumption that a certain percentage (given in Table 3.2 Column 5) of the population gets their supply from the main river.

Table 4.4 shows the water demand and supply for this case. This table indicates that the real water demand for the household population and livestock is 0.96% and 1.31% of the treaty scenario releases (column [2]) for 1999 and 2020, respectively.

5.2.2 Case 2 – Dry season demand

For this case it was assumed that the river use for supplying the water demand for household and livestock is according to the Phase 2 socio-economic survey of river use during the **dry season**. Table 5.1 shows the total water demand at IFR reaches in 1999 and 2020.

The number of people using the main river during the **dry season** is more than the number of people using the river all year around; therefore the water demand from the river increases accordingly.

5.2.3 Case 3 – Drought period water demand

Case 3 assumes that the river use for meeting the water demand of livestock and household is according to the Phase 2 socio-economic survey of river use during the **drought period**. Table 5.2 shows the total water demand at each IFR site, including the water demand, as a percentage of the Treaty releases (column [2]) during the dry season.

Similarly in this case the number of people using the river during the **drought period** is greater than the number of people using the river during the dry year.

5.2.4 Case 4 – All water needs are met by the river

For the case 4 it was assumed that the household and livestock uses the river for water supply from the entire 5-km river corridor. This is the worse case scenario, which is the upper limit of the household and livestock water demand in the study area. Table 5.3 shows the water demand and supply for this scenario.

Table 5.1 Total water demand for Case 2 – Dry season.

IFR Reach No	Water demand m^3s^{-1} [1]		Treaty releases Dry season [2]	Water demand as % of treaty releases Dry season [3]	
	1999	2020	(m^3s^{-1})	1999	2020
1	0.003	0.004	0.05	6.94%	9.44%
2	0.000	0.000	0.51	0.06%	0.08%
3	0.002	0.003	0.75	0.27%	0.36%
4	0.004	0.005	1.80	0.22%	0.30%
5	0.002	0.002	4.49	0.04%	0.05%
6	0.007	0.010	15.49	0.05%	0.06%
7	0.003	0.004	0.43	0.73%	0.99%
8	0.000	0.000	0.67	0.05%	0.07%
Average				1.04%	1.42%
TOTAL	0.022	0.030			

Table 5.2 Total water demand for Case 3 – Drought period

IFR Reach No	Water demand m^3s^{-1} [1]		Treaty releases Dry season [2]	Water demand as % of treaty releases Dry season [3]	
	1999	2020	(m3/s)	1999	2020
1	0.004	0.005	0.05	8.05%	10.96%
2	0.001	0.001	0.51	0.16%	0.19%
3	0.002	0.003	0.75	0.33%	0.45%
4	0.006	0.008	1.80	0.32%	0.43%
5	0.005	0.006	4.49	0.10%	0.13%
6	0.019	0.019	15.49	0.12%	0.12%
7	0.005	0.006	0.43	1.26%	1.50%
8	0.001	0.001	0.67	0.11%	0.14%
Average				1.31%	1.74%
TOTAL	0.043	0.049			

Table 5.3 Total water demand for Case 4 – All water needs are met by the river

IFR Reach No	Water demand m3/s		Treaty releases Dry season	Water demand as % of treaty releases Dry season	
	1999	2020	(m^3s^{-1})	1999	2020
1	0.007	0.010	0.05	16.2%	22.0%
2	0.002	0.003	0.51	0.5%	0.6%
3	0.010	0.014	0.75	1.4%	1.9%
4	0.019	0.026	1.80	1.1%	1.5%
5	0.019	0.025	4.49	0.4%	0.6%
6	0.045	0.061	15.49	0.3%	0.4%
7	0.011	0.015	0.43	2.6%	3.5%
8	0.003	0.004	0.67	0.4%	0.5%
Average				2.9%	3.9%
TOTAL	0.117	0.159			

PART 6: WATER QUALITY ASPECTS

6 WATER QUALITY ASPECTS

6.1 Present water quality

6.1.1 Microbiology

Water samples were collected at the IFR sites from January 1999 to June 1999 and analysed for the presence of coliforms and the protozoan parasites, *Giardia lamblia* and *Entamoeba coli* for the Public Health component of IFR Study.

The risk of being infected by microbial pathogens correlate with the level of contamination of the water and the amount of contaminated water consumed. Higher concentrations of coliforms in water will indicate a higher risk of contracting waterborne diseases, even if small amounts of water are consumed (Payment *et al.*, 1991).

Measuring total coliforms offers a good margin of safety for the detection of most bacterial pathogens, but cannot detect certain disease causing bacteria, viruses and protozoan parasites. For example, the deadly *E Coli* 0157 may be present even if faecal coliform measurements show negative.

A. Total Coliforms

The results of the field testing of 100 ml water samples from the river showed that the river was not contaminated during the high flow months of January to April. Isolated positive findings were in range where negligible risk of microbial infection exists. Only during April at IFR Site 8 (Lower Senqunyane), levels of total coliforms indicate a risk of contracting diarrhoeal disease with continuous human exposure.

During May low coliform counts were found at IFR 3 (Malibamatso River at Paray), IFR Site 7 (Senqunyane River at Marakabei) and IFR Site 8 (Lower Senqunyane), indicating negligible disease risk. During June low counts were also found at IFR Site 5 (Senqu River at Whitehill), IFR Site 6 (Senqu River at Seaka), IFR Site 7 and IFR Site 8.

During June three of the 5 samples taken at IFR Site 4 (Senqu River at Sehonghong) showed counts that increases the risk of infectious disease transmission if the water is consumed continuously. The risk is low with occasional exposure.

It is important that contamination of the river from human faeces be minimised. Communities along the river should be educated about hygiene practices to further reduce the risk of river contamination and human infection following the consumption of contaminated water.

B. *Giardia* and *Entamoeba coli*

Giardia lamblia has been identified as one of the most common causes of waterborne disease outbreaks in South Africa in recent studies (Rose *et al.* 1991). The infective dose for these parasites is extremely low. Theoretically, one cyst or oocyte is sufficient to cause infection, and an infective dose of 10 Giardia cysts has been demonstrated

Results of the *Giardia lamblia* parasite analysis on water samples of each IFR site revealed that IFR site 1 at Matsoku was contaminated throughout the sampling period indicating human faecal contamination from a source close to the river. At Marakabei, infective doses of *Giardia lamblia* were found during the wet season (Jan to April). The highest concentration of cysts was found in the samples collected at Seaka from January to March. The samples taken at Katse dam were contaminated during the February and June sampling times only indicating isolated faecal contamination or possible post collection contamination. IFR site 3 at Paray, IFR site 4 at Sehonghong and IFR site 5 at Whitehills showed no contamination throughout the period of investigation. Table 6.1 shows the results of water sample analysis at IFR sites for *Giardia lamblia* and *Entamoeba coli* as part of the Public Health component of the study.

Table 6.1 Water quality analysis – Microbiology.

IFR No	February 1999		March 1999		April 1999		May 1999		June 1999	
	Giardia	Entamo.	Giardia	Entamo	Giardia	Entamo.	Giardia	Entamo	Giardia	Entamo
1	40	ND	25	ND	70	ND	ND	ND	40	ND
2	80	800	ND	ND	ND	ND	ND	ND	100	ND
3	ND	ND	ND	ND	ND	600	ND	ND	ND	ND
4	ND	ND+	ND	ND	ND	ND	ND	ND	ND	ND
5	ND	ND+	ND	ND	ND	ND	ND	ND	ND	ND
6	340 (14 *l*)	ND+	ND	ND	180	ND	ND	ND	ND	ND
7	40	ND	90	ND	ND	ND	ND	ND	ND	ND
8	-	-	ND	ND	-	-	ND	ND	ND	ND

**Entamoeba Cysts/100 lit, Giardia Cysts/100 lit, ND+ = Not detected – too much mud, ND = No detected*

The concentration of cysts found in the samples indicate a high risk of contracting diarrhea disease from drinking the river water where the cysts were consistently found. The risk is high even if a small amount of water is consumed.

Except for isolated elevated cyst concentrations found at Katse Dam (February and June) and Paray (April), *Entamoeba coli* was absent from the water samples collected. The isolated levels found were very high indicating either post collection contamination or the presence of an isolated infective focus close to the sampling points.

Public health measures and education focussing on personal hygiene is recommended as protozoan infection is spread through a faecal-oral transmission. Public health measures would include the use of latrines and the protection of water sources.

6.1.2 Chemistry

The comparison of the individual IFR sites revealed limited differences in water chemistry observations. Except for isolated elevated measures, e.g. elevated iron levels in November 1998 at Paray (IFR site 3), the chemical composition of the rivers indicated safe levels for human consumption (Report No 648-F-15) in accordance with the WHO Standards (WHO, 1983).

6.1.3 Turbidity

The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination do occur when infectious disease agents become adsorbed onto particulate matter (Department of Water Affairs and Forestry, 1996).

An evaluation of the turbidity data collected at the eight sites indicates that the waters in the river have a great potential for carrying microorganisms that can cause human disease. Parasites and viruses would most likely be the organisms most associated with the turbidity levels found (Report No 648-F-15.

6.2 Effects of reservoirs on water quality

When a river is impounded, the downstream flows are reduced through abstraction. This can have far reaching effects on the water quality. These include changes in sediment load and changes to the downstream temperature profiles.

Ward and Davis (1984) listed the following variables as being affected by impoundment:

- erosive capacity,
- turbidity,
- silt and sediment load,
- water temperature,
- dissolved oxygen,
- salinity,
- reduced compounds (Fe, Mn) and nutrients.

All of these variables effect in one way or another the instream environment and hence the habitat available for the aquatic biota. River flow low in suspended material has a scouring effect and causes change in both uptake and deposition of sediment that again affects the physical environment of the aquatic biota. The productivity of a river is dependent on the levels of nutrients, temperature and turbidity.

When concentration of water constituents increase to deleterious levels, water is described as polluted (Ashton *et al.*, 1995, Sweeting, 1996, Dobbs and Zabel, 1996). Pollution can be caused by increased nutrient concentrations and resulting increases in primary production, eutrophication and possible anoxia, or by increases in the concentrations of toxins (either inorganic such as metal ions or organic such as pesticides, Haslam 1990). The multivariate nature of water chemistry results in considerable complexity. Examples include the changes in pH which affect the bio-availability of toxic metal ions (Kerr 1995); and the effect of turbidity on light penetration and productivity; physical abrasion, and provision of a surface area for the adsorption of metal and other inorganic ions.

Of importance in this study is the downstream water quality. This is very much dependent on the draw-off-point. The levels of temperature, dissolved oxygen (DO), TSS (sediment load) and turbidity are particular important. The water quality of the upper levels (epilimnion) of a dam will have lower levels of TSS than the inflows. Impoundments have been found to reduce the sediment load downstream in excess of 95% (Leopold, Woolman and Miller, 1964). Accumulated sediment can also be flushed out of impoundments during periods of high flow (Moore *et al.*, 1991). On the Bighorn River in the USA, turbidity was reduced by more than 98% as a result of impoundment (Soltero *et al.,* 1973).

As part of the modeling component of LHDA Contract 1007, Alavian *et al.* (1997) made predictions on the likely water quality of releases from Mohale Dam. The levels of predicted water quality variables are compared in the epilimnion and beneath the thermocline of the dam, with the Senqunyane just upstream of where the dam is being constructed and at Marakabei (20 km downstream). These are shown below in Table 6.2.

The reservoir will act as a sink for iron, suspended solids, ammonia, TOC and organic nitrogen. The level of DO will also be affected and dependent on the release depth of the compensation water. Temperature can also be important with the significance of this being dependent on the amount of water released as well as the draw-off level.

The level of DO is also dependent on the draw-off point where the lower levels (epilimnion) may be anaerobic. The release of anoxic water from the hypolimnion has caused extensive fish mortalities below dams (Palmer *et al.*, 1990 and Moore *et al.*, 1991).

The temperature of the release water will differ from that of natural rivers as the temperature of the water in the dam will be determined by the limnology of the dam. This has the effect of changing the downstream thermal regime. In regulated Oregon Rivers in the USA these effects are felt on average 30 to 40 km downstream (Petts, 1984).

Surface release reservoirs act as nutrient traps and heat exporters, whilst deep reservoirs may export nutrients and provide a heat store (Petts, 1984).

The temperature of the release water from Mohale Dam is expected to be severely impacted (Alavian *et al.*, 1997). The natural range of water temperature in the Senqunyane at the site of the dam varies from near below

Table 6.2 Comparison of current water quality with expected water quality below Mohale Reservoir for data collected from July 1995 - May 1996 (Alavian *et al.*, 1997).

Parameter	Senqunyane River above Likalaneng	Marakabei Weir	Forebay epilimnion	Forebay below the thermocline
Tot -N, $\mu g\ 1^{-1}$	205	569	~ 0	~ 0
TSS,mg.1^{-1}	7	32	< 1	< 1
Turbidity, NTU	3.5	6.3	< 1	< 1
TOC, mg 1^{-1}	3.2	3.0	< 1	< 1
NH3 -N,μ g 1^{-1}	126	109	~ 0	~ 0
Organic Nitrogen, $\mu g\ 1^{-1}$	392	565	~ 70 - 140	~ 0 - 35
No_3-N, $\mu g\ 1^{-1}$	303	380	~ 200 - 250	~ 0 - 300

Tot -P, µg 1^{-1}	26	33	~ 0	~ 0
SRP, µg 1^{-1}	5	8	~ 0	~ 0

freezing in the winter to the middle twenties (0º) in the summer months. Depending on the levels of release the temperature of the water will vary between 12 and 20º C. This will result in either warmer or cooler water being released causing a significantly impacted seasonal temperature distribution. Based on the proposed limited releases from Mohale, the temperature would be expected to move to equilibrium with the atmosphere within 10 km below Mohale/Katse Dams.

6.3 Direct water consumption from rivers

Analysis of the total coliforms during the dry season showed low counts, indicating negligible disease risk. An exception was found at IFR Site 4, where the counts showed an increased likelihood of infectious disease transmission if the water is consumed from the river continuously.

Data on water quality analysis at IFR sites indicated that infective parasites, such as the *Giardia Lamblia* and *Entamoeba coli*, were found at sites 1, 2, 6 and 7. If the people drink water directly from the river at these sites they will be potentially at risk of being infected with these cysts.

Water chemistry analysis at IFR sites indicated except for isolated high concentrations of iron levels such as at Site 3 (Paray), the Chemical composition of the rivers are safe for human consumption (Report No 648-F-15).

PART 7: CONCLUSIONS

7 CONCLUSIONS

- On average, more than 80% of the household within the 5-km river corridor have their water supply from taps and covered and uncovered springs.
- From the total household living within the 5-km river corridor on average only 1.8% use the river as the main water supply source all year around.
- In addition a further, 5% and 11% of the household within the 5-km river corridor use the river as a main water supply source during the dry season and drought period, respectively.
- On average 32% and 62% of livestock within the 5-km river corridor uses the river for watering during the dry season and drought period, respectively.
- Table 7.1 shows the population and livestock total water demand as percentage of the IFRs for treaty scenario releases within the 5-km river corridor for 1999 and 2020.
- The only site with significant water demand during the dry and drought period is IFR Site 1. Provisions should be made for extra releases if the IFR releases are kept at the Treaty Scenario level of 0.05 m^3s^{-1} at this site.
- The water demand at the remaining reaches are significantly lower than the Treaty Scenario releases. Therefore additional releases cannot be justified due to its very low magnitudes. Table 7.2 summarises the overall water demands compared to the Treaty Scenario releases excluding the IFR Site 1.
- The irrigation potential only exists in the lowland areas and at the IFR Reach 6. The total water needed to meet the demand of irrigation potential in the entire Senqu and Senqunyane catchments is 0.36 m^3s^{-1}. This is approximately 1.5% of the amount of water, which will be available at Reach 6 for the minimum release associated with the Treaty Scenario.
- Total coliform analysis indicated negligible disease risk in the wet season. However, during the dry season the risk could increase slightly if no river protection against contamination is carried out.
- Infective parasites (*Giardia and Entamoeba coli*) at IFR sites 1, 2, 6 and 7 were found. If people drink water directly from the river at these locations they will be potentially at the risk of being infected.
- Water chemistry analysis at IFR sites indicated except for isolated high concentrations of iron levels such as at Site 3 (Paray), the Chemical composition of the rivers are safe for human consumption.

Table 7.1 Water demand as percentage of the IFR treaty scenario releases.

Year	People and livestock dependent on river for water supply all year around	People and livestock dependent on river during dry season	People and livestock dependent on river during drought period
1999	0.96%	1.04%	1.31%
2020	1.31%	1.42%	1.74%

Table 7.2 Overall water demand as percentage of the IFR treaty releases (from IFR Site 2 to IFR Site 8).

Year	All year around	Dry period	Drought period	5-km total
1999	0.19 %	0.20 %	0.35 %	1.00%
2020	0.27%	0.27 %	0.42 %	1.31 %

PART 8: REFERENCES

8 REFERENCES

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PART 9: APPENDICES
APPENDIX 1: TABLES OF HOUSEHOLD AND LIVESTOCK POPULATION ESTIMATES, WATER DEMANDS AND TREATY SCENARIO WATER SUPPLY WITHIN 5 KM RIVER CORRIDOR

Table A1.1 Household population census and livestock population estimates within 5 km river corridor.

IFR Site	River section	1999 Pop. estimates by Sechaba	Pop. growth rate	2010	2020	ANIMAL POPULATION ESTIMATES									
						1999					2020				
						Cattle	Sheep	Goats	Pigs	Equine	Cattle	Sheep	Goats	Pigs	Equine
1	Matsoku River between Weir and Malibamatso River confl.	7462	1.478	8769	10155	5996	4576	4261	158	2051	8156	6225	5796	215	2790
2	Malibamatso River between Katse Dam and Matsoku River confl.	2879	1.478	3383	3918	1481	2922	1404	25	640	2015	3975	1910	34	871
3	Malibamatso River between Matsoku and Senqu River confls.	15367	1.478	18058	20912	5720	8137	4361	32	1659	7781	11069	5932	44	2257
4	Senqu River between Malibamatso and Tsoelike River confls.	26719	1.478	31399	36361	10450	17525	13824	75	4684	14215	23839	18805	102	6372
5	Senqu River between Tsoelike and Senqunyane River confls.	27749	1.478	32609	37762	8839	11211	20825	524	3496	12029	15256	28340	713	4758
6	Senqu River between Senqunyane River confl. and RSA border	60104	1.478	70631	81792	26498	18089	68320	3264	7468	36060	24616	92973	4442	10163
7	Senqunyane River between Mohale Dam and Lesobeng River confl.	10819	1.478	12714	14723	8147	14197	13997	242	3014	11082	19312	19040	329	4100
8	Senqunyane River between Lesobeng and Senqu River confl.	3488	1.478	4099	4747	1197	1145	4116	95	777	1628	1558	5599	129	1057
	TOTAL	154587		181662	210370	68328	77802	131108	4415	23789	92966	105851	178396	6008	32366

IFR Site No	No of household	Average number of animals per household				
		1999				
		Cattle	Sheep	Goats	Pigs	Equines
1	1578	3.80	2.90	2.70	0.10	1.30
2	609	2.43	4.80	2.31	0.04	1.05
3	3250	1.76	2.50	1.34	0.01	0.51
4	5651	1.85	3.10	2.45	0.01	0.83
5	5867	1.51	1.91	3.55	0.09	0.60
6	12707	2.09	1.42	5.38	0.26	0.59
7	2288	3.56	6.20	6.12	0.11	1.32
8	738	1.62	1.55	5.58	0.13	1.05
	Average	2.33	3.05	3.68	0.09	0.91

Source: Report No 648-F-08

Table A1.2 Household population and livestock water demand within 5 km river corridor at IFR sites.

IFR Site	NAME	Population water demand			Animal water demand in m^3/day											
		1999	2010	2020	1999						2020					
		(m^3/day)			Cattle	Sheep	Goats	Pigs	Equines	Total	Cattle	Sheep	Goats	Pigs	Equines	Total
1	Matsoku at Seshote	261	307	355	270	14	13	2.1	78	376	367	19	17	2.8	106	512
2	Malibamatso at D/S Katese Bridge	101	118	137	67	9	4	0.3	24	104	91	12	6	0.4	33	142
3	Malibamatso at Paray	538	632	732	257	24	13	0.4	63	358	350	33	18	0.6	86	487
4	Senqu at Sehonghong	935	1099	1273	470	53	41	1.0	178	743	640	72	56	1.3	242	1011
5	Senqu at Sekake	971	1141	1322	398	34	62	6.8	133	634	541	46	85	9.3	181	862
6	Senqu at Seaka Bridge	2104	2472	2863	1192	54	205	42.4	284	1778	1623	74	279	57.7	386	2419
7	Senqunyane at U/S Marakabei	379	445	515	367	43	42	3.1	115	569	499	58	57	4.3	156	774
8	Senqunyane at Nkaus	122	143	166	54	3	12	1.2	30	100	73	5	17	1.7	40	137
	TOTAL	5411	6358	7363	3075	233	393	57	904	4663	4183	318	535	78	1230	6344

WATER CONSUMPTION l/c/d				
Household	Cattle	Sheep/Goat	Equines	Pigs
35	45	3	38	13

Source: Report No 648-F-08

Table A1.3 Total water demand at IFR sites within 5 km river corridor in different units.

IFR SITE	NAME	Total water demand in m^3/day								
		1999			2010			2020		
		Population	Livestock	Total	Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	261	376	637	307	442	749	355	512	867
2	Malibamatso at D/S Katese Bridge	101	104	205	118	122	241	137	142	279
3	Malibamatso at Paray	538	358	896	632	421	1053	732	487	1219
4	Senqu at Sehonghong	935	743	1678	1099	873	1972	1273	1011	2284
5	Senqu at Sekake	971	634	1605	1141	744	1886	1322	862	2184
6	Senqu at Seaka Bridge	2104	1778	3881	2472	2089	4561	2863	2419	5282
7	Senqunyane at U/S Marakabei	379	569	948	445	668	1113	515	774	1289
8	Senqunyane at Nkaus	122	100	222	143	118	261	166	137	303
	TOTAL	5411	4663	10073	6358	5479	11837	7363	6344	13707

IFR SITE	NAME	Total water demand in l/sec								
		1999			2010			2020		
		Population	Livestock	Total	Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	3.02	4.36	7.38	3.55	5.12	8.67	4.11	5.92	10.04
2	Malibamatso at D/S Katese Bridge	1.17	1.21	2.37	1.37	1.42	2.79	1.59	1.64	3.23
3	Malibamatso at Paray	6.23	4.15	10.37	7.32	4.87	12.19	8.47	5.64	14.11
4	Senqu at Sehonghong	10.82	8.60	19.43	12.72	10.11	22.82	14.73	11.70	26.43
5	Senqu at Sekake	11.24	7.33	18.57	13.21	8.62	21.83	15.30	9.98	25.28
6	Senqu at Seaka Bridge	24.35	20.58	44.92	28.61	24.18	52.79	33.13	28.00	61.14
7	Senqunyane at U/S Marakabei	4.38	6.58	10.97	5.15	7.73	12.88	5.96	8.96	14.92
8	Senqunyane at Nkaus	1.41	1.16	2.58	1.66	1.37	3.03	1.92	1.58	3.50

IFR SITE	NAME	Total water demand in m^3s^{-1}								
		1999			2010			2020		
		Population	Livestock	Total	Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.003	0.004	0.007	0.004	0.005	0.009	0.004	0.006	0.010
2	Malibamatso at D/S Katese Bridge	0.001	0.001	0.002	0.001	0.001	0.003	0.002	0.002	0.003
3	Malibamatso at Paray	0.006	0.004	0.010	0.007	0.005	0.012	0.008	0.006	0.014
4	Senqu at Sehonghong	0.011	0.009	0.019	0.013	0.010	0.023	0.015	0.012	0.026
5	Senqu at Sekake	0.011	0.007	0.019	0.013	0.009	0.022	0.015	0.010	0.025
6	Senqu at Seaka Bridge	0.024	0.021	0.045	0.029	0.024	0.053	0.033	0.028	0.061
7	Senqunyane at U/S Marakabei	0.004	0.007	0.011	0.005	0.008	0.013	0.006	0.009	0.015
8	Senqunyane at Nkaus	0.001	0.001	0.003	0.002	0.001	0.003	0.002	0.002	0.004
	TOTAL	0.063	0.054	0.117	0.074	0.063	0.137	0.085	0.073	0.159

Source: Report No 648-F-08

Table A1.4 Population water demand in the study area at IFR sites for 5 km river corridor.

IFR SITE NO	NAME	Water from river all year			Water from river during dry season			Water from river during drought period		
		1999	2010	2020	1999	2010	2020	1999	2010	2020
		(m^3/day)			(m^3/day)			(m^3/day)		
1	Matsoku at Seshote	7	9	10	32	37	43	13	15	17
2	Malibamatso at D/S Katese Bridge	1	1	1	2	3	3	14	17	19
3	Malibamatso at Paray	3	3	4	0	0	0	3	3	4
4	Senqu at Sehonghong	4	4	5	12	14	17	12	14	17
5	Senqu at Sekake	0	0	0	5	6	7	27	32	37
6	Senqu at Seaka Bridge	8	10	11	250	294	341	696	818	948
7	Senqunyane at U/S Marakabei	35	41	47	31	37	43	89	105	121
8	Senqunyane at Nkaus	1	1	1	4	4	5	11	12	14
	TOTAL	58	68	79	336	395	458	865	1016	1177

WATER CONSUMPTION				
Population	Cattle	Sheep/Goat	Equines	Pigs
35	45	3	38	13

Source: Report No 648-F-08

Table A1.5.1 Total water demand at IFR sites within 5 km river corridor in three different units all year around.

IFR SITE No	NAME	Total water demand in m³/day all year around					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	7	241	249	10	328	338
2	Malibamatso at D/S Katese Bridge	1	25	25	1	34	34
3	Malibamatso at Paray	3	173	176	4	236	240
4	Senqu at Sehonghong	4	332	336	5	452	457
5	Senqu at Sekake	0	144	144	0	197	197
6	Senqu at Seaka Bridge	8	370	378	11	503	515
7	Senqunyane at U/S Marakabei	35	236	271	47	321	369
8	Senqunyane at Nkaus	1	28	29	1	38	39
	TOTAL	58	1550	1608	79	2109	2188

IFR SITE No	NAME	Total water demand in l/sec					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.08	2.79	2.88	0.12	3.80	3.91
2	Malibamatso at D/S Katese Bridge	0.01	0.29	0.29	0.01	0.39	0.40
3	Malibamatso at Paray	0.03	2.01	2.04	0.04	2.73	2.77
4	Senqu at Sehonghong	0.04	3.85	3.89	0.06	5.23	5.29
5	Senqu at Sekake	0.00	1.67	1.67	0.00	2.28	2.28
6	Senqu at Seaka Bridge	0.10	4.28	4.38	0.13	5.82	5.96
7	Senqunyane at U/S Marakabei	0.40	2.73	3.14	0.55	3.72	4.27
8	Senqunyane at Nkaus	0.01	0.32	0.33	0.01	0.44	0.45

IFR SITE No	NAME	Total water demand in m^3s^{-1}					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.0001	0.0028	0.0029	0.0001	0.0038	0.0039
2	Malibamatso at D/S Katese Bridge	0.0000	0.0003	0.0003	0.0000	0.0004	0.0004
3	Malibamatso at Paray	0.0000	0.0020	0.0020	0.0000	0.0027	0.0028
4	Senqu at Sehonghong	0.0000	0.0038	0.0039	0.0001	0.0052	0.0053
5	Senqu at Sekake	0.0000	0.0017	0.0017	0.0000	0.0023	0.0023
6	Senqu at Seaka Bridge	0.0001	0.0043	0.0044	0.0001	0.0058	0.0060
7	Senqunyane at U/S Marakabei	0.0004	0.0027	0.0031	0.0005	0.0037	0.0043
8	Senqunyane at Nkaus	0.0000	0.0003	0.0003	0.0000	0.0004	0.0004
	TOTAL	0.0007	0.0179	0.019	0.001	0.024	0.025

Source: Report No 648-F-08

Table A1.5.2 Human and animal water demand in the study area at IFR sites for 5 km river corridor for the dry season.

IFR SITE No	NAME	Population water demand (m³/day)			Animal water demand in m³/day											
					1999						2020					
		1999	2010	2020	Cattle	Sheep	Goats	Pigs	Equines	Total	Cattle	Sheep	Goats	Pigs	Equines	Total
1	Matsoku at Seshote	32	37	43	173	9	8	1.3	50	241	235	12	11	1.8	68	328
2	Malibamatso at D/S Katese Bridge	2	3	3	16	2	1	0.1	6	25	22	3	1	0.1	8	34
3	Malibamatso at Paray	0	0	0	125	12	6	0.2	31	173	169	16	9	0.3	42	236
4	Senqu at Sehonghong	12	14	17	210	24	19	0.4	80	332	286	32	25	0.6	108	452
5	Senqu at Sekake	5	6	7	91	8	14	1.6	30	144	123	10	19	2.1	41	197
6	Senqu at Seaka Bridge	250	294	341	248	11	43	8.8	59	370	338	15	58	12.0	80	503
7	Senqunyane at U/S Marakabei	31	37	43	152	18	17	1.3	48	236	207	24	24	1.8	65	321
8	Senqunyane at Nkaus	4	4	5	15	1	3	0.3	8	28	20	1	5	0.5	11	38
	TOTAL	336	395	458	1029	84	112	14	311	1550	1400	114	152	19	423	2109

WATER CONSUMPTION l/c/d				
Population	Cattle	Sheep/Goat	Equines	Pigs
35	45	3	38	13

Main water supply systems for domestic purposes from the river				
	Human population		Livestock	
IFR Site	Dry season	Drought	Dry season	Drought
1	0.1220	0.0490	0.641	0.808
2	0.0230	0.1400	0.238	0.558
3	0.0000	0.0050	0.484	0.595
4	0.0130	0.0130	0.447	0.646
5	0.0050	0.0280	0.228	0.591
6	0.1190	0.3310	0.208	0.538
7	0.0830	0.2350	0.415	0.655
8	0.0290	0.0870	0.277	0.553

Source: Report No 648-F-08

Table A1.5.3 Total water demand at IFR sites within 5 km river corridor in three different units during the dry season.

IFR SITE No	NAME	Total water demand in m³/day					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	32	241	273	43	328	371
2	Malibamatso at D/S Katese Bridge	2	25	27	3	34	37
3	Malibamatso at Paray	0	173	173	0	236	236
4	Senqu at Sehonghong	12	332	344	17	452	468
5	Senqu at Sekake	5	144	149	7	197	203
6	Senqu at Seaka Bridge	250	370	620	341	503	844
7	Senqunyane at U/S Marakabei	31	236	268	43	321	364
8	Senqunyane at Nkaus	4	28	31	5	38	43
	TOTAL	336	1550	1886	458	2109	2566

IFR SITE No	NAME	Total water demand in l/sec					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.37	2.79	3.16	0.50	3.80	4.30
2	Malibamatso at D/S Katese Bridge	0.03	0.29	0.31	0.04	0.39	0.43
3	Malibamatso at Paray	0.00	2.01	2.01	0.00	2.73	2.73
4	Senqu at Sehonghong	0.14	3.85	3.99	0.19	5.23	5.42
5	Senqu at Sekake	0.06	1.67	1.73	0.08	2.28	2.35
6	Senqu at Seaka Bridge	2.90	4.28	7.18	3.94	5.82	9.77
7	Senqunyane at U/S Marakabei	0.36	2.73	3.10	0.50	3.72	4.21
8	Senqunyane at Nkaus	0.04	0.32	0.36	0.06	0.44	0.49

IFR SITE No	NAME	Total water demand in m^3s^{-1}					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.00037	0.00279	0.00316	0.001	0.004	0.004
2	Malibamatso at D/S Katese Bridge	0.00003	0.00029	0.00031	0.000	0.000	0.000
3	Malibamatso at Paray	0.00000	0.00201	0.00201	0.000	0.003	0.003
4	Senqu at Sehonghong	0.00014	0.00385	0.00399	0.000	0.005	0.005
5	Senqu at Sekake	0.00006	0.00167	0.00173	0.000	0.002	0.002
6	Senqu at Seaka Bridge	0.00290	0.00428	0.00718	0.004	0.006	0.010
7	Senqunyane at U/S Marakabei	0.00036	0.00273	0.00310	0.000	0.004	0.004
8	Senqunyane at Nkaus	0.00004	0.00032	0.00036	0.000	0.000	0.000
	TOTAL	0.004	0.018	0.022	0.005	0.024	0.030

Source: Report No 648-F-08

Table A1.5.5 Human and animal water demand in the study area at IFR sites for 5 km river corridor for the drought period

IFR SITE No	Population water demand			Animal water demand in m³/day											
	1999	2010	2020	1999						2020					
	(m³/day)			Cattle	Sheep	Goats	Pigs	Equines	Total	Cattle	Sheep	Goats	Pigs	Equines	Total
1	13	15	17	218	11	10	1.7	63	304	297	15	14	2.3	86	414
2	14	17	19	37	5	2	0.2	14	58	51	7	3	0.2	18	79
3	3	3	4	153	15	8	0.2	38	213	208	20	11	0.3	51	290
4	12	14	17	304	34	27	0.6	115	480	413	46	36	0.9	156	653
5	27	32	37	235	20	37	4.0	79	374	320	27	50	5.5	107	510
6	696	818	948	642	29	110	22.8	153	956	873	40	150	31.1	208	1302
7	89	105	121	240	28	28	2.1	75	373	327	38	37	2.8	102	507
8	11	12	14	30	2	7	0.7	16	56	41	3	9	0.9	22	76
TOTAL	865	1016	1177	1859	143	229	32	552	2815	2529	195	311	44	750	3830

WATER CONSUMPTION l/c/d				
Population	Cattle	Sheep/Goats	Equines	Pigs
35	45	3	38	13

Main Water Supply Systems for Domestic Purposes				
IFR Site No	Human population		Livestock	
	Dry Season	Drought	Dry Season	Drought
1	0.1220	0.0490	0.641	0.808
2	0.0230	0.1400	0.238	0.558
3	0.0000	0.0050	0.484	0.595
4	0.0130	0.0130	0.447	0.646
5	0.0050	0.0280	0.228	0.591
6	0.1190	0.3310	0.208	0.538
7	0.0830	0.2350	0.415	0.655
8	0.0290	0.0870	0.277	0.553

Source: Report No 648-F-08

Table A1.5.5 Total water demand at IFR sites within 5 km river corridor in three different units during the drought period

IFR SITE No	NAME	Total water demand in m^3/day					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	13	304	317	17	414	431
2	Malibamatso at D/S Katese Bridge	14	58	72	19	79	98
3	Malibamatso at Paray	3	213	216	4	290	294
4	Senqu at Sehonghong	12	480	492	17	653	670
5	Senqu at Sekake	27	374	402	37	510	547
6	Senqu at Seaka Bridge	696	956	1653	948	1302	2249
7	Senqunyane at U/S Marakabei	89	373	462	121	507	628
8	Senqunyane at Nkaus	11	56	66	14	76	90
	TOTAL	865	2815	3680	1177	3830	5006

IFR SITE No	NAME	Total water demand in l/sec					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.15	3.52	3.67	0.20	4.79	4.99
2	Malibamatso at D/S Katese Bridge	0.16	0.67	0.84	0.22	0.92	1.14
3	Malibamatso at Paray	0.03	2.47	2.50	0.04	3.36	3.40
4	Senqu at Sehonghong	0.14	5.56	5.70	0.19	7.56	7.75
5	Senqu at Sekake	0.31	4.33	4.65	0.43	5.90	6.33
6	Senqu at Seaka Bridge	8.06	11.07	19.13	10.97	15.07	26.03
7	Senqunyane at U/S Marakabei	1.03	4.31	5.34	1.40	5.87	7.27
8	Senqunyane at Nkaus	0.12	0.64	0.77	0.17	0.87	1.04

IFR SITE No	NAME	Total water demand in m^3s^{-1}					
		1999			2020		
		Population	Livestock	Total	Population	Livestock	Total
1	Matsoku at Seshote	0.00015	0.00352	0.00367	0.000	0.005	0.005
2	Malibamatso at D/S Katese Bridge	0.00016	0.00067	0.00084	0.000	0.001	0.001
3	Malibamatso at Paray	0.00003	0.00247	0.00250	0.000	0.003	0.003
4	Senqu at Sehonghong	0.00014	0.00556	0.00570	0.000	0.008	0.008
5	Senqu at Sekake	0.00031	0.00433	0.00465	0.000	0.006	0.006
6	Senqu at Seaka Bridge	0.00806	0.01107	0.01913	0.011	0.015	0.026
7	Senqunyane at U/S Marakabei	0.00103	0.00431	0.00534	0.001	0.006	0.007
8	Senqunyane at Nkaus	0.00012	0.00064	0.00077	0.000	0.001	0.001
	TOTAL	0.010	0.033	0.043	0.014	0.044	0.058

Source: Report No 648-F-08

Table A1.6.1 Water demand as a percentage of the treaty releases all year around.

IFR No	Water demand (m^3s^{-1})		Treaty releases (m^3s^{-1})	Water demand as % of treaty releases during the dry season	
	1999	2020	Dry Season	1999	2020
1	0.003	0.004	0.05	6.32%	8.59%
2	0.000	0.000	0.51	0.06%	0.08%
3	0.002	0.003	0.75	0.27%	0.37%
4	0.004	0.005	1.80	0.22%	0.29%
5	0.002	0.002	4.49	0.04%	0.05%
6	0.004	0.006	15.49	0.03%	0.04%
7	0.003	0.004	0.43	0.74%	1.00%
8	0.000	0.000	0.67	0.05%	0.07%
TOTAL	0.019	0.025		0.96%	1.31%

Source: Report No 648-F-08

Table A1.6.2 Water demand as a percentage of the treaty releases during the dry season.

IFR No	Water demand (m^3s^{-1})		Treaty releases (m^3s^{-1})	Water demand as % of treaty releases during the dry season	
	1999	2020	Dry Season	1999	2020
1	0.003	0.004	0.05	6.94%	9.44%
2	0.000	0.000	0.51	0.06%	0.08%
3	0.002	0.003	0.75	0.27%	0.36%
4	0.004	0.005	1.80	0.22%	0.30%
5	0.002	0.002	4.49	0.04%	0.05%
6	0.007	0.010	15.49	0.05%	0.06%
7	0.003	0.004	0.43	0.73%	0.99%
8	0.000	0.000	0.67	0.05%	0.07%
TOTAL	0.022	0.030		1.04%	1.42%

Source: Report No 648-F-08

Table A1.6.3 Water demand as a percentage of the treaty releases during the drought period.

IFR No	Water demand (m^3s^{-1})		Treaty releases (m^3s^{-1})	Water demand as % of treaty releases during the drought period	
	1999	2020	Dry Season	1999	2020
1	0.004	0.005	0.05	8.05%	10.96%
2	0.001	0.001	0.51	0.16%	0.19%
3	0.002	0.003	0.75	0.33%	0.45%
4	0.006	0.008	1.80	0.32%	0.43%
5	0.005	0.006	4.49	0.10%	0.13%
6	0.019	0.019	15.49	0.12%	0.12%
7	0.005	0.006	0.43	1.26%	1.50%
8	0.001	0.001	0.67	0.11%	0.14%
TOTAL	0.043	0.049	0.00	1.31%	1.74%

Source: Report No 648-F-08