LESOTHO HIGHLAND DEVELOPMENT AUTHORITY

IFR annual report - 2015 to 2016

ENVIRONMENT BRANCH

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EXECUTIVE SUMMARY

Construction of LHWP dams has inevitably resulted in modification of the flow pattern of downstream rivers and overall condition of the aquatic and riparian ecosystems. The In-stream Flow Requirement (IFR) procedures of the LHDA are implemented with the aim to minimize the impacts of reduced flow by striking a balance between the water resources development goals, ecosystem conservation and protection goals as well as social needs. The policy sets appropriate river condition targets and provides for water release programme to realize the predetermined conditions for riverine ecosystem downstream of the impoundments.

The river condition classification comprises a set of qualitative descriptions of the state of the riverine ecosystem. While the management objective is to target the highest river condition state that is feasible, the specific objective is not to transform or modify any given river reach by more than two states from its baseline state. To determine whether the desired river conditions set out in the IFR Policy are achieved, key biophysical parameters that are expected to change as a result of flow modification are set as indicators for the river ecological condition. Data is collected on these parameters to allow for assessment of changes at eight (8) IFR sites identified in rivers downstream of LHWP structures. The rivers of concern are Malibamatšo, Matsoku, Senqunyane and Senqu.

Table 4.1 of LHWP IFR Policy (2003) has set out the river conditions which should be determined by the biophysical monitoring at IFR sites as stated below:

State 1: Pristine

State 2: Near Natural

State 3: Moderately Modified

State 4: Slightly Modified

State 5: Severely Modified

Biophysical monitoring

The biophysical disciplines identified to determine the river conditions are listed below: The geomorphology was not undertaken due to capacity limitations within LHDA hence the report does not present any findings related to these discipline

- **Hydrology**
- **Water quality**
- **Macro – invertebrates**
- **Riparian vegetation**
- **Fish**
- **Geomorphology**

On the basis of analysis of 2015/2016 biophysical monitoring data and the guidance provided in *Table 4.1* of IFR Policy to determine river conditions, the following conclusions can be drawn for each of the parameters assessed:

Hydrology

In the 2015/16 hydrological year the total IFR Release at Katse dam site was 28.78MCM against a target of 36.12MCM this was 80% of the target. At the IFR site a total flow of 37.15 MCM was observed against a target of 54.65 MCM this constituted 67.97% of the target. In general, in 2015/16 the river classification was VERY DRY YEAR with forecast flows mostly under the 25 percentile of the MAR.

In the Mohale dam catchment a total IFR Release of 26.07MCM was made at dam site against a target of 29.97MCM this was 98.23% of the target. At the IFR site 7 a total flow of 32.66 MCM was recorded against a target of 78.28 MCM, Overall the river classification was AVERAGE for the 2015/16 hydrological year. The 48.05% compliance performance to IFR Releases at IFR site 7 located approximately 28Km downstream of the dam structure is clearly due to less than expected contribution from the intermediate catchment.

Riparian Vegetation

IFR Sites 1 and 6 show worse conditions, significantly and moderately modified respectively, when compared to the pre-dam and predicted conditions which are moderately modified and near natural whilst the remaining IFR sites meet the predicted river conditions as the general actual observations is that they are on targeted condition. The IFR policy had predicted that no flow modification induced changes in riparian vegetation will occur at IFR Sites 5 and 6 as they are distal sites and it was expected that the flow would have adjusted to the natural condition by the time it reaches the distal sites. The initial changes in IFR Sites 5 and 6 observed in October 2005 might be attributed to the systems' adjustment to new flow patterns before reaching a new stable condition. During the April 2016 assessment, there was a decrease in woody vegetation (trees form) at the proximal IFR Sites 1 and 2, whilst there was an increase in woody vegetation (trees form) at IFR Sites 5. *Salix mucronata* is declining at IFR Sites 3, 4, 7 and 9 whilst it is increasing at IFR Site 6. *Salix fragilis* is decreasing at IFR Sites 1, 2 and 3 whilst it is increasing at IFR Site 7 and 9. Conditions at IFR Site 6 favor establishment of the native *Salix mucronata* whist conditions at IFR Site 7 are favorable for invasion by the alien *Salix fragilis*.

Water Quality

The analysis of data indicated that the river conditions at IFR sites 2, 3 and 7 have attained a better river condition from significantly modified to near natural for IFR site 2 and 3, moderately modified for IFR site 7, while 5 and 6 are on targeted conditions as prescribed in *Table 3-1* which is near natural. IFR sites 1 and 4 were expected to be moderately modified and 9 (reference site) to be near natural condition, however, the current reporting data categorized them at the worse state or river condition.

Macro-invertebrates (SASS5)

On the basis of macro-invertebrates' analysis, IFR sites 2 and 7 had a better condition (near natural) than the one predicted which is a significant modification condition and this was consistent with information from water quality. IFR sites 5, 6 and 9 were predetermined to be at near natural condition (State 2) for the fact that Site 9 is a reference, 5 and 6 are distal site. However, they are significantly modified based on the current assessment as shown in *Table 4-26* which is deemed worse than the predicted condition.

IFR sites 2 and 7 condition were better than the conditions predicted for macro-invertebrates' information mainly due to the presence of *Perlidae (neoperla spio)* with score of 12, *Tricorythidae* with a score of 9 and *Oligoneuriidae* with 15 which falls within the most sensitive benthos to degradation of biotopes and poor quality of water. More than two species of the families *Hydropsychidae* and *Baetidae* were found which is indicative of recruitment of highly sensitive benthos in this sites.

Fish

Fish species diversity at IFR sites show a general decline as some of the species have decreased in numbers or disappeared from the sites. The low diversity may be attributed to the limitation in catch methods that were applied. There are only two sites which have met targeted conditions (signification modification), these are IFR 3 and 7. The rest of the sites are in the worse state. Although it is prescribed in the IFR procedures that several methods can be used to maximize the catch, due to the limitations catch methods used and the time, there was relatively low catch across the IFR sites.

The river condition classes as determined by Water Quality, Macro-invertebrates and Riparian Vegetation at IFR sites in 2015 to 2016.

			Water Quality			Riparian Vegetation			Macro invertebrates		
IFR Site	Pre-dam condition	Predicted condition	River condition	State	Actual relative to prediction	River condition	State/class	Actual relative to target	River condition	State/class	Actual relative to Prediction
IFR 1	2	3	5	Severely modified	worse	4	Significantly modified	Worse	4	Significantly modified	worse
IFR 2	2	4	2	Near natural	Better	4	Significantly modified	On target	2	Near natural (Improved)	Better
IFR 3	2	4	2	Near natural	Better	4	Significantly modified	On target	4	Significantly modified	On target
IFR 4	2	3	5	Severely modified	Worse	3	Moderately modified	On target	4	Significantly modified	worse
IFR 5	2	2	2	Near natural	On target	2	Near natural	On target	4	Significantly modified	Worse
IFR 6	2	2	2	Near natural	On target	3	Moderately modified	Worse	4	Significantly modified	Worse
IFR 7	2	4	3	Moderately modified	Better	4	Significantly modified	On target	2	Near natural	better
IFR 9	2	2	3	Moderately modified	Worse	2	Near natural	On target	4	Significantly modified	worse

Water Quality: IFR sites 1, 4 and 9 are in worse conditions while IFR sites 2, 3 and 7 are in better than the predicted conditions.

Riparian Vegetation: Assessment of the river condition at each of the IFR sites, in terms of riparian vegetation, indicates that IFR sites 1 and 6 are worse than the predicted conditions, while all other sites are on target.

Macro-Invertebrates: IFR sites 1 4, 5, 6 and 9 are worse that the expected condition, IFR 3 is on target and 7 is better. IFR site 1 has shown remarkable improvement

The river condition classes as determined by Fish at IFR sites in 2015 to 2016.

IFR Site	Pre-dam Condition	Predicted Condition	River condition	State	Actual relative to prediction
IFR 1	2	3	5	Severely modified	Worse
IFR 2	2	4	5	Severely modified	Worse
IFR 3	2	4	4	Significantly Modified	On target
IFR 4	2	3	5	Severely modified	Worse
IFR 5	2	2	4	Significantly modified	Worse
IFR 6	2	2	5	Severely modified	Worse
IFR 7	2	4	4	Severely modified	On target
IFR 9	2	2	5	Severely modified	Worse

Fish: All the IFR sites are either significantly modified (State 4) or severely modified (state 5)

RECOMMENDATIONS

- The releases management has all along been implementing the quarterly scheduling method. However, it was realized that the flow variation downstream of the LHDA structures is minimized. Therefore, the daily releases scheduling was put into implementation beginning of 2016 and the positive changes observed at IFR sites 2 and 7 in relation to macroinvertebrates are highly attributed to this change. Notwithstanding, some of the variables/disciplines may indicate observable changes over relatively longer period, as a result, it is recommended that the daily releases be maintained.

- There is a need for awareness to communities on the importance of conservation of the woody vegetation along the river banks to prevent erosion of river banks.

- To improve on the accuracy of sampling so as to adequately address the limitation which could be caused by flow modification at the downstream, the sampling methods should be aligned with the one prescribed in the IFR Policy and Procedures

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1 INTRODUCTION

1.1 The Goals and objectives of IFR Biophysical Monitoring

The goals of the Instream Flow Requirements (IFR) monitoring are to assess the efficacy of the recommended IFR allocated for the lower Senqunyane, Malibamatšo, Matsoku and Senqu rivers. The releases downstream are meant to maintain the river conditions as per the conditions stipulated in the IFR Policy and Procedures. The specific objectives of IFR biophysical monitoring are to:

- establish whether or not the agreed flows are being released,
- determine whether the objectives linked to different components of the flow regime are being achieved,
- verify that the overall environmental objective, targeted river conditions, are being achieved,
- augment river condition data with incidental information that would assist with recognizing potential problems in the Study Rivers,
- assess the standard of living of the population at risk such that changes in livelihoods and welfare which are directly linked to flow modifications can be detected, and
- use this information to guide management interventions as necessary.

The general objective of this report is to present to the decision makers the analyses of the data and the discussion of the findings of the IFR biophysical monitoring downstream of the LHWP dams for the assessment undertaken from 2015 to 2016. The assessment was broadly undertaken to determine the efficacy of the flow releases, the river conditions attained and the socio-economic status of the communities living downstream of the LHWP dams.

1.2 Background

The In-Stream Flow Requirements (IFR) biophysical monitoring is implemented in accordance with the IFR policy and procedures developed to guide allocation and management of IFR flow releases and the monitoring of the downstream response to flow alterations as a result of Lesotho Highlands Water Project (LHWP) structures. The policy focuses on determination of the required flow releases to maintain pre-determined river conditions at pre-determined IFR sites and monitoring of the downstream response to the altered flows. The policy and procedures has determined eight (8) IFR sites in Malibamatšo, Matsoku, Senqunyane and Senqu rivers and on bi-annual basis seven (7) parameters which include hydrology, water quality, macro-invertebrates, fish, riparian vegetation, geomorphology and socio-economic status and public health are monitored. A brief explanation of these parameters is included in section 1.4 of this report.

The bio-physical monitoring undertaken in 2015 to 2016 hydrological year excluded assessment of geomorphology due to lack of internal capacity to undertake its assessment. Contrary to previous reports, fish monitoring was undertaken from 2015 and related information will now form part of the annual report as positions that were previously vacant were filled. Socio-economic aspects of monitoring programme were however not undertaken following an internal resolution to discontinue their monitoring. This report therefore presents the analysis of the bio-physical monitoring data collected during the 2015/16 hydrological year and recommendations on the way forward for implementation of the IFR policy and procedures.

1.3 Scope of IFR Monitoring

The monitoring program is undertaken in accordance with provisions of the LHDA IFR Policy Procedures (2003) and is made up of two major components which are biophysical and socio economic monitoring. A suitable monitoring regime has been determined for each parameter as follows: hydrology monitoring is continuous; water quality, micro-invertebrates and fish monitoring is done twice a year in autumn and spring; whilst riparian vegetation monitoring is done once a year in autumn. IFR Sites are located on four rivers downstream of LHWP structures as follows: Senqu, Senqunyane, Matsoku and Malibamatšo. Envisaged high impact sites are located close to LHWP structures and are classified as proximal sites, whilst low impact sites are located further from the LHWP structures and are classified as distal sites. Based on the understanding that there are natural fluctuations within any ecosystem, the monitoring programme includes a reference site that is similar to IFR sites but is located outside the area of dam influence (LHWP IFR Policy Procedures, 2003). Monitoring is implemented as a long-term programme in order to distinguish long-term trends from inter-annual variability.

1.3.1 Biophysical Monitoring sites

Locations of the IFR biophysical monitoring sites are as follows:

IFR sites proximal to LHWP structures

IFR 1 Matsoku River near Seshote from Matsoku weir to Malibamatšo River
IFR 2 Malibamatšo River 3 km downstream from Katse Road Bridge
IFR 3 Malibamatšo River at Paray
IFR 7 Senqunyane River at Marakabei
IFR 8 Following contract 1237 IFR 8 was removed from the routine biophysical monitoring

IFR sites distal to LHWP structures

IFR 4 Senqu River at Sehong-hong downstream of foot bridge
IFR 5 Senqu River at Whitehill
IFR 6 Senqu River at Seaka

A reference site

IFR 9 Matsoku River upstream of Matsoku Weir.

1.3.2 Bio-physical Monitoring

Biophysical monitoring has six (6) components which are hydrology, geomorphology or habitat, water quality, macro-invertebrates, riparian vegetation and fish. A brief description of the components that formed part of the current study will be provided under **Section 4,** whilst a brief description of the geomorphological monitoring is provided below.

Geomorphology: geomorphology helps to determine the structure of rivers at IFR sites. The flow changes determine the morphology of the rivers; therefore, it is very important to vary flows downstream of dams so that the river morphology is maintained as natural as possible. The presence of habitats such as sand, mud, gravel, pools, stones and boulders are largely determined by geomorphology and the changes that occur over time in these habitats. These are important for growth of aquatic vegetation and benthos.

1.3.3 Socio-Economic Monitoring

In accordance with the provisions of the LHWP IFR Policy Procedures, 2003, Socio-economic monitoring covers the assessment of the public health status of the population living along the river reaches downstream of the LHWP Phase 1 dams. The population has been subdivided geographically and epidemiologically into three areas: Area A corresponding to reaches 1, 2 and 3, Area B corresponding to reaches 7 and 8 and Area C corresponding to the lower reaches of the Senqu River, IFR reaches 4,5 and 6 combined, where the population are expected to be negligibly affected (LHWP IFR Policy Procedures, 2003).

Parameters measured to establish the socio-economic status of affected communities and in control populations are as follows: production activities and livelihood resources, livelihood strategies (Agricultural intensification, Livelihoods diversification, migration, and consumption activities) as well as coping strategies and their outcomes. In addition, the following parameters have been selected to establish the health status of affected communities and in control populations: the incidence and prevalence of diarrhoeal disease in children under five years old (U5Y); the incidence and prevalence of low weight for age (global malnutrition) in U5Y, the prevalence of low weight for height (wasting) and of low height for age (stunting) in U5Y, the prevalence of low body mass index (BMI, a measure of thinness) in adults; the incidence and prevalence of dermatitis and conjunctivitis in children and adults; and the level of irritation caused by black flies. Nepid Consultants (2014) recommended that there is no more need to compensate downstream communities, therefore an internal decision was made to discontinue monitoring of socio-economic activities under IFR monitoring.

2 Guiding principles for IFR implementation in the LHWP

2.1 Water Allocation Principle

Under good climatic conditions the IFR policy dictates that allocation of water from the LHWP dams should be done in such a way that the three categories would be satisfied which are Treaty water delivery, IFR maintenance flow releases and generation of hydropower. In situations when the climatic conditions are adverse, the policy prioritizes the three categories as follows:

- The first priority is given to IFR maintenance flow releases, this further reiterates that protection and conservation of the environment is very important to the management of the project.
- The second priority goes to Treaty water delivery being the core objective of the existence of the project.
- The last one goes to generation of hydropower.

2.2 IFR maintenance flows

The released flows are the driving force behind the river conditions downstream of LHWP dams. This implies that releases play an important role in the maintenance of all the riverine resources from which communities can benefit. It is of utmost importance that management of flows in terms of volumes as far as practically possible mimics natural flows. To respond to changing weather conditions, the policy has provided for development of quarterly schedules which predicts how releases and variation should be done in order to meet the demands downstream within a given quarter based on general contribution of the inflows. This is done to avoid releasing one constant volume throughout the year. *Table 2.1* as extracted from LHWP IFR Policy Procedures (2003) is one of the provisions of the Policy which enables development of the releases schedule which allows for variability in the flows to achieve the desired river conditions at IFR sites.

Table 2-1 Bulk allocations to IFR as percentages of Mean Annual Runoff (MAR)

Structure/ IFR Site	Initial bulk IFR at IFR site		Dam release		Treaty Minimum Dam Releases	
	(%MAR)	(MCM)	(%MAR)	(MCM)	(%MAR)	(MCM)
Matsoku/ 1	40.0	34.8	39.7 1*	34.4	Not stipulated *	Not stipulated *
Katse/ 2	15.3	88.1	12.1**	66.9	2.8	15.7
Mohale/ 7	22.0	78.1	10.3***	31.9	3.1	9.5
‘Muela/11	100	4.8	100****	4.8	100	4.8

1* Although the Treaty did not stipulate a release from Matsoku, the feasibility study base flow of 50 litres per second (1.8% MAR) may be interpreted as equivalent to a Treaty minimum, for comparative purposes.

** Flood releases subject to the results of test releases from low-level outlets. The difference between 15.3% at the IFR Site and the 12.1% dam release is supplied by the intervening catchment.

*** IFR 7 is 28 km downstream of the Mohale Dam wall; the difference between 22% and 10.3% is made up by the catchment over that distance.

****’Muela was not included in the IFR study, as the Treaty (article 7(10)) specified 100% MAR to be released downstream. The amount to be released downstream (4.8MCM) is the mean annual flow in the Nqoe River (LHDA Operations and Maintenance Group (2002) Flow Releases Downstream of Katse and Muela Reservoirs. LHDA Report, Maseru, April 2002).

2.3 Predicted River Conditions at IFR Sites

It is envisaged that when constructing large dams in rivers, there will be some level of impact realized downstream and such rivers will never be the same as before impoundment. In view of this, the LHDA developed and implemented IFR policy and procedures in which predicted river conditions are embedded. The framework for the releases is centered around attaining the desired river conditions as extracted from the LHWP IFR Policy Procedures (2003) and presented in Table *2.3* below. The disciplines described in this report are used as ecological descriptors which are monitored to observe the performance of flow releases management with time. *Table 2.2* below as extracted from LHWP IFR Policy Procedures (2003) shows how the key indicators/descriptors should be used in order to determine the river condition at IFR sites. The information collected during monitoring is used to inform decisions around the changes that need to be effected which are dictated by the trends of the key variables monitored from the descriptors.

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Table 2-2 Definitions of the River Condition Classes using key indicators/ descriptors

Indicator	State 1 Pristine	State 2 Near natural	State 3 Moderately modified	State 4 Significantly modified	State 5 Severely modified
GEOMORPHOLOGY/HYDRAULICS					
Instream Habitat Diversity	Full natural diversity	5-15% loss in diversity	15-40% loss in diversity	40-70% loss in diversity	>70% loss in diversity
Pool depth	Natural	5-15% loss in depth	15-40% loss in depth	40-70% loss in depth	>70% loss in depth
Bank erosion or collapse	<5% of bank area	5-10% of bank area	10-20% of bank area	20-40% of bank area	>40% of bank area
WATER QUALITY					
Mean monthly temperature[1]	Natural	< 3^{O}C	< 4^{O}C	< 5^{O}C	< 6^{O}C
pH annual range* change	Natural	< 0.5 pH units	< 1.0 pH units	< 1.5 pH units	< 2 pH units
Rapid Biological Assessment Score	Total Score: Unknown	Total Score: ≥ 95	Total Score: 94-70	Total Score: 69-45	Total Score: < 45
VEGETATION					
Zone definition[2]	All present and distinct	All present and distinct	Loss of ≤ 2 zones and/or zone definition less distinct	Loss of ≤ 3 zones and/or zone definition indistinct	No definition
Species composition of riparian vegetation	Full complement	Change in ratios of indigenous species	Dominated by hardy indigenous species and/or exotic species	Dominated by exotics and/or weedy indigenous species	Dominated by one or two species, often > 80% exotics OR no plants
Structure	Full array of growth forms	5-10% reduction in growth forms	11-25% reduction in growth forms	26-50% reduction in growth forms	> 50% reduction in growth forms
FISH					
Community composition	Full complement of indigenous species in natural proportions. No exotic species.	Full complement of indigenous species, plus very low numbers of exotic species	Noticeable shifts in natural community structure, moderate numbers of exotic species	Very few natural fish and/or exotic fish dominate	Very few fish dominated by exotic species

[1]After South African DWAF Guidelines (1999); values given represent degrees Centigrade *change* from the natural mean monthly temperature

[2] Zones include: Aquatic Zone, Lower Wetbank Zone, Upper Wetbank Zone, Lower Dynamic Zone, Tree/Shrub Zone, Back Dynamic Zone (Report LHDA 648-F-16)

* pH Annual Range refers to the change in pH units, not levels.

Table 2-3 Target River Condition Classes for river reaches affected by LHWP

Reach	Description	Present[†] river condition class	Targeted river condition class
Reach 1	Matsoku River, from Matsoku Weir to confluence with Malibamatšo River (30 km)	2	3
Reach 2	Malibamatšo River, from Katse Dam to confluence with Matsoku River (18 km)	2	4
Reach 3	Malibamatšo River, from confluence with Matsoku River to confluence with Senqu River (35 km)	2	4
Reach 4	Senqu River between confluences with Malibamatšo and Tsoelike rivers (115 km)	2	3
Reach 5	Senqu River between confluences with Tsoelike and Senqunyane rivers (90 km)	2	2
Reach 6	Senqu River, from confluence with Senqunyane River to South African border (150 km)	2	2
Reach 7	Senqunyane River from Mohale Dam to confluence with Lesobeng River (90 km)	2	4
Reach 8	Senqunyane River, from confluence with Lesobeng River to confluence with Senqu River (40 km).	2	3
Reach 11	Nqoe and Hololo Rivers, from Muela Tailpond to confluence with the Caledon River (13 km)	2[‡]	2

3 IFR Monitoring Results

In the absence of adequate baseline studies or data, it was decided that data of LHDA Contract 83 undertaken in 1991 and1992 and data from LHDA Contract 648 collected in 1998 and 1999 should be used concurrently as a benchmark to determine trends in the performance of the release management with regard to the river conditions downstream. For the sites where information from the aforementioned contracts and/or studies is not available, data collected from LHDA Contract 1237 in 2005 and 2006 is used. The 2015 to 2016 monitoring results are therefore referenced against these data sets for the disciplines where data is available and presented below.

[†] The 'present' river condition (PRC) class represents the pre-impoundment condition of the rivers. At the time of the IFR field studies, Katse Dam was already operational and the Malibamatšo River condition was judged to have declined to a class 3 river ("moderately modified"). However, in view of the fact that all other (then unaffected by LHWP) river reaches were assessed as class 2 rivers [not class 1 ("pristine") rivers], because they were slightly affected by land use practices, the pre-impoundment state of the Malibamatšo River is also likely to have been class

[‡] Not formally assessed, assumed to be in a similar state to other Lesotho rivers. (The average river reach distance based on the actual length of river, not as a crow flies)

3.1 Hydrology

3.1.1 Introduction

Hydrology is integral to holistic management of environmental flows. It manages the distribution of water within the hydrological year be it floods, freshets and compensation releases and assists in the management of all the releases occurring from the dams. Furthermore, it monitors the level of flows at key IFR stations to determine the discharges as a result of input from the releases and from the tributaries of the rivers in question. To get the correct flows at the IFR station, it uses the readings from the gauge height and the recorders installed in the hydrometric stations constructed at these IFR sites. The volume of water to be released from dams which is envisaged to meet the requirements of the downstream users and the variations in flows are determined by the hydrology discipline, it goes further to monitor the implementation of the predicted releases to determine if the releases were made according to the plan.

The objective of hydrological monitoring is to obtain accurate hydrological data that will allow for the characterization for both natural occurring and IFR release flood events in terms of discharge, stage height and duration at each IFR, inform on low flow discharge and verify that the stipulated IFR has been released from each structure and received at each Site (LHWP IFR Policy Procedures, 2003).

3.1.2 Methodology

The operators of LHWP dam structures released water as guided by the LHDA Policy and Procedures: Instream Flow Requirements 2003, this determined volumes and flows were meant to maintain the river health to acceptable levels after the construction of the dams. When the procedures were developed there were assumptions made particularly relating to the contributions made by the catchment between the dam site and the IFR sites. In application of the policy and procedures, observations were made that contrary to predictions, the catchment between the Mohale dam and IFR site 7 was not contributing as much as anticipated, it was noted that despite increasing the releases at dam site, the flow at IFR site 7 could not meet the target. Also, Katse dam posed structural limitations in that the compensation valve could deliver a maximum flow of 1.5cumecs and the Low Level Outlet could deliver a minimum flow of 15cumecs. Additionally, Mohale dam experienced vibrations which were deemed to compromise the structural integrity of the dam when delivering some floods as dictated by the policy and procedures.

The LHDA considered all these and in line with the Adaptive Management System provided for in the LHDA Policy and Procedures 2003 revised the flows at dam sites and IFR site 7 accordingly as presented in table 3-1below. Also in order to meet the objective of mimicking the natural flow patterns of the rivers, during Oct - Mar 2015/16 the IFR release scheduling was undertaken using the quarterly IFR releases and this was revised to the daily IFR Release scheduling during the latter part (Apr – Sep) of the year. The revision introduced variability in the flow patterns thereby mimicking the natural river flow pattern more closely than the quarterly scheduling.

Table 3-1 Contributions to long-term IFR flows at proximal sites as a result of IFR releases from LHWP Phase 1 control structures and runoff from incremental catchments

IFR site No.	Associated control structure	At IFR site		From control structure			From incremental catchment		
		MAR(1) (million m^3/a)	Total annual IFR (as % runoff)	MAR (million m^3/a)	Annual IFR release (as % inflow)	Annual IFR release (as % runoff at IFR site)	MAR (million m^3/a)	Annual IFR contribution (as % runoff)	Annual IFR contribution (as % runoff at IFR site)
2	Katse Dam	576.0	15.3	554.8	**12.1**	11.6	21.2	100.0(2)	3.7
7	Mohale Dam(4)	355.0	13.5	339.0	**20.1**	17.5	16.0	100.0(3)	4.5
-	'Muela Tailpond	5.0	25.0	5.0	**25.0**	25.0	0.0	-	-

Notes: (1) Mean annual runoff.

(2) IFR Site 2 (Katse Bridge, Malibamatšo River) is located downstream of the Khohlo-ntšo River tributary and it is assumed that 100 % of runoff from this catchment contributes to the IFR. This assumption, however, requires verification and IFR releases from Katse Dam adjusted if necessary.

(3) IFR Site 7 (Marakabei, Senqunyane River) is located 28 km downstream of the Mohale Dam and it is assumed that 100 % of runoff from this catchment contributes to the IFR.

(4) The contribution to the IFR from Mohale Dam releases has been increased subsequent to Edition 2 of the IFR Procedures (LHDA, 2007a) as the contribution from the incremental catchment was found to be lower than initially estimated.

3.1.3 Flow releases management and flood definition

IFR Releases from the dams are categorized into two categories, namely low flow releases through low capacity compensation valves and flood releases made through low level outlets. Low flow releases are made at all times as a percentage of daily inflow to the maximum capacity of the of the compensation valves.

Flood (excess volume of water) above the capacity of the compensation valves is accumulated and released when the volume is enough to be released over twenty-four hours at the minimum capacity of the low level outlet. All flood releases are made after five days' notice to the downstream communities only when wet weather conditions are forecasted.

The criteria for ideal flood conditions is when there is at least three days of Lesotho Meteorological Services forecast of rainfall of 30% chance or more on each of the three days. The releases from the Katse dam during the report period are presented in table 3-2 below.

Table 3-2 IFR releases downstream of Katse dam

Date	IFR at dam site			Aliwal North Drought Relief	Actual IFR Releases Excluding Drought Relief(MCM)	Variance to Set IFR Target at Dam site (MCM)	IFR at site			Variance (MCM)
	Target Release Volume (MCM)	Classification	Actual Releases (MCM)				Target Volume @IFR Site (MCM)	Actual @ IFR Site (MCM)	Actual @ IFR Site Excluding Drought Relief(MCM)	
Oct-15	2.9	A	2.95		2.95	0.05	5.02	3.38	3.38	-1.64
Nov-15	12.1	A	3.11		3.11	-8.99	14.32	3.21	3.21	-11.11
Dec-15	3.2	A	8.4	3.942	4.458	1.258	5.15	8.03	4.088	2.88
Jan-16	2.7	-2	20.49	15.79	4.7	2	4.14	18.36	2.57	14.22
Feb-16	2.3	-2	2.38		2.38	0.08	3.72	3.46	3.46	-0.26
Mar-16	2.4	-2	2.26		2.26	-0.14	3.96	4.38	4.38	0.42
Apr-16	3.49	-2	2.47		2.47	-1.02	7.7	3.06	3.06	-4.64
May-16	3.35	-2	2.53		2.53	-0.82	2.85	3.06	3.06	0.21
Jun-16	1.46	-2	2.42		2.42	0.96	2.06	3.46	3.46	1.4
Jul-16	0.82	-2	0.94		0.94	0.12	1.75	3.49	3.49	1.74
Aug-16	2.44	-2	2.19		2.19	-0.25	6.15	3.32	3.32	-2.83
Sep-16	1.86	-2	1.32		1.32	-0.54	2.85	3.05	3.05	0.2
Grand Totals	**36.12**		**48.51**	**19.73**	**28.78**		**54.65**	**56.88**	**37.15**	

3.1.4 Discussions

In the 2015/16 hydrological year the total IFR Release at dam site was 28.78MCM against a target of 36.12MCM this was 80% of the target. At the IFR site a total flow of 37.15 MCM was observed against a target of 54.65 MCM this constituted 67.97% of the target. In general, in 2015/16 the river classification was VERY DRY YEAR with forecast flows mostly under the 25 percentile of the MAR.

The 80% compliance performance to IFR Releases at dam site was largely attributed to the revision of percentage of MAR to be released from 20.1% to 17.5%. The 68% compliance performance to IFR Releases at IFR site 2 was largely caused by the unrevised percentage of MAR 15.3% to be released at dam site even though the figure was revised down at dam site.

As determined under the flood definition the flood accumulation in the 2015/16 was 6.87 MCM even though it could be released since not all determinants were fulfilled to release a flood.

The relationship between the water level and the flow at IFR site 2 has not been established yet instead a nearby flow station's flow data approximately 900m has been used for determining compliance to IFR releases at IFR site 2. Need mention that between the two stations there is a contributing stream namely Khohlontso inevitably its flow has not been accounted for.

In December 2015 - January 2016 the severe drought experienced in both Lesotho and South Africa necessitated release of water from Katse dam to relief the drought situation downstream of the structures. A total water release of 19.73MCM was released from Katse dam. For purposes of monitoring IFR Releases compliance the flow was recorded separately as reflected on the table above.

Table 3-3 IFR releases downstream of Mohale dam

Date	IFR at dam site				Allocation for Drought Relief (MCM)	Excess to Set IFR Target (MCM)	IFR at IFR 7		
	Target Volume (MCM)	Class	Flood (MCM)	Actual IFR Releases (MCM)			Targets @IFR Site (MCM)	Actual @ IFR Site (MCM)	Variance (MCM)
Oct-15	2.00	A		1.57		-0.43	6.88	1.27	-5.61
Nov-15	3.28	A		3.27		-0.01	11.26	3.21	-8.05
Dec-15	1.44	A		2.54	1.00	2.10	4.95	3.31	-1.64
Jan-16	1.12	-2		2.18	0.77	1.83	2.82	3.37	0.55
Feb-16	5.35	-2	3.90	1.46		-3.89	8.68	2.44	-6.24
Mar-16	1.55	-2		6.80		5.25	5.07	6.08	1.01
Apr-16	2.28	A		1.98		-0.30	8.24	1.64	-6.60
May-16	1.52	A		1.50		-0.02	3.70	1.67	-2.03
Jun-16	1.04	A		0.95		-0.09	1.68	0.83	-0.85
Jul-16	1.07	+2		1.18		0.11	12.23	1.99	-10.24
Aug-16	4.35	+2		2.96		-1.39	7.46	5.44	-2.02
Sep-16	1.07	+2		1.28		0.21	5.28	1.40	-3.88
Grand Totals	**26.07**		**3.90**	**29.44**	**1.77**		**78.25**	**32.66**	

3.1.5 Discussions

A total IFR Release of 26.07MCM was made at dam site against a target of 29.97MCM this was 98.23% of the target. At the IFR site 7 a total flow of 32.66 MCM was recorded against a target of 78.28 MCM, Overall the river classification was AVERAGE for the 2015/16 hydrological year. The 48.05% compliance performance to IFR Releases at IFR site 7 located approximately 28Km downstream of the dam structure is clearly due to less than expected contribution from the intermediate catchment. To relief the drought situation experienced downstream of Mohale dam in December 2015 – January 2016 water releases totaling 1.77MCM. For purposes of monitoring IFR Releases compliance the flow was recorded separately as reflected on the table above.

3.2 Riparian Vegetation

3.2.1 Introduction

Riparian vegetation refers to vegetation which grows along river channels (Nepid, 2014) and the riparian vegetation communities mainly comprises woody vegetation due to the moist conditions. Riparian vegetation responds to different flow regimes in different ways and the responses tend to be species and site specific, however some general inferences can be made (Nepid, 2014). If river banks are altered by the flows or deposition shifts from one part of the river to another or there is no flow variation, the diversity of vegetation changes as well. If there is prolonged decrease of water in the river channel, vegetation may encroach towards the area of the river where there is enough water or diversity will be reduced. This means that riparian vegetation communities can visibly show if there has been a prolonged decrease in flows. Therefore, it is important to monitor riparian vegetation communities to see decrease or increase of native plants and recruitment of alien species. In Lesotho, terrestrial species such as *A. afra* and *R. rubiginosa* tend to colonise upper riparian zones following impoundment, whilst species such as *G. virgatum* and *S. mucronata* tend to decline in abundance or shift their distribution towards a shrinking active channel (Nepid, 2014). Riparian monitoring therefore considers diversity of vegetation communities and their abundance per IFR site.

This report relates the status of riparian vegetation as per information collected in April 2016. Information observed in October 2005 will be used as a base year due to limitation in the information of LHDA Contract 684 for riparian vegetation, and where possible available data of 2006 and 1998 is added to determine trends. The riparian vegetation data is collected to obtain information on the riparian communities that will determine the condition and recruitment success of key species – and provide an early-warning mechanism for changes occurring in the riparian communities. The analysis of this information is done to verify that the environmental objectives and targeted river condition for riparian vegetation are being achieved.

The objectives of the vegetation assessment were to obtain data on the riparian communities that will:

- allow assessment of changes in vertical and longitudinal distributions associated with changes in the flow regime
- detect long-term trends in the riparian community

3.2.2 Methodology

Riparian vegetation sampling was done on permanent monitoring transects that are assessed annually by LHDA IFR in-house riparian vegetation monitoring team. Transect sizes vary based on local conditions at each IFR Site. The width of the transect is maximally 10m, while the individual zone width determines the length of each transect, with the largest transect being 100m. Where conditions allow, transects are located on both banks and two to three transects are set at each location.

Assessments are based on recording of precise species density or stem counts and the height of each plant. The contribution by each species toward the vegetation community present in the sample in each zone was assessed using the Braun-Blanquet abundance scale. Additional environmental data was recorded at each site and it included: aspect, slope and substratum type to assist with data interpretation. Species height data collected allow for assessment of recruitment success of key species and provide an early-warning of changes occurring in the vegetation community. Assessment of the riparian habitat condition and recruitment success are based on the following suggested key species: *Gomphostigma virgatum*; *Cyperus marginatus*; *Chenopodium ambrosoides; Salix fragilis* and *Salix mucronata*. Also any *Acacia* spp. (specifically *A. dealbata*).

The field studies adopted the Braun-Blanquet data collection method as stipulated in the LHWP IFR Policy Procedures (2003) and as applied by LHDA in earlier assessments done since 2003. Sampling was done in 8 IFR sampling sites indicated in Section 1.3.1 of this report. In applying Braun-Blanquet assessment method the following were undertaken:

- Visual assessment of species composition and abundance through head counting all shrubs and trees of importance to the communities within each demarcated area (Transect). The heights of trees were estimated while actual height measurements were taken for shrubs.
- Some observations were also made along transects regarding river conditions.
- Both dry bank and wet bank including cobble beds were monitored for the effects of floods. Flooding was also recorded as evidenced by signs on the trees.
- Any new growths were recorded, including cut and dead trees.
- Results of the current study were compared with results of previous studies to track changes in species composition, abundance and overall river condition.

In 2014, LHDA engaged in collection of supplementary biophysical monitoring assessment of IFR implementation through Nepid (2014). In addition to re-survey of woody vegetation plots which entailed counting of plants and measuring their height, the assessments employed other methods for monitoring that included: Point-Centered-Quarter method and fixed point photographs, as a result more comparisons were made under that study.

3.2.3 Data Analysis

The results of species count per IFR Site in different years were as follows:

Table 3-4 Summary of changes in key woody vegetation at IFR Site 1

Key taxa (Predicted change)	Recorded October 1998	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra ↑(10%)	Very numerous	76	20	117	199	↑	Notable increase
Gomphostigma virgatum ↓(25-50%)	Numerous in wet bank	588	582	231	427	↓	Notable recovery from 2015 but decrease from baseline.
Salix fragilis ↓(20-40%)	rare	324	91	73	99	↓	Very high decline from 2006

Gomphostigma virgatum and *Salix fragilis* showed a decline of 27% in accordance with prediction, while Artemisia *afra* has increased beyond the predicted 10%. New recruitment of *Rhus divaricate*, *Salix babylonica* and *Rosa rubiginosa* was observed.

Table 3-5 Summary of changes in key woody vegetation at IFR Site 2

Key taxa (Predicted change)	Recorded October 1998	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra ↓(40-60%)	numerous	10	20	1	4	↓	Decrease in numbers
Gomphostigma virgatum ↓ (40-60%)	numerous	635	594	111	182	↓	Very high decrease (more than 60%)
Populus canescens ↓ (0-10%)	present	8	0	3	1	↓	Significant decline
Rosa rubiginosa (No prediction)	Not recorded	10	11	2	6	↓	Notable decline in the species
Salix babylonica (No change)	Rare	1	1	0	1	↓	The species remains rare on this site
Salix fragilis ↓ (20-50%)	Rare	401	111	26	96	↓	Very high decrease
Salix mucronata ↓ (20-50%))	Present in west bank	15	10	10	11	↓	

Gomphostigma virgatum and *Salix fragilis* dominate the site while the other species largely remain rare.

Table 3-6 Summary of changes of key woody vegetation at IFR Site 3

Key taxa (Predicted change)	Recorded October 1998	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra ↓ (30-60%)	Rare in riparian zone	1	Not recorded	2	13	↑	Rare on this Site
Gomphostigma virgatum ↓ (30-60%)	Numerous	226	1305	697	693	↑	Increase in the species abundance
Rhus divaricata ↓ (30-60%)	Scattered in drier regions	10	30	0	95	↑	Increase in the species abundance
Salix fragilis ↓ (30-60%)	Numerous	228	87	36	88	↓	Decline by more than the predicted 60%
Salix mucronata ↓ (30-60%)	Numerous	50	35	14	25	↓	The 50% level of decline is within predicted range.

Gomphostigma virgatum and *Rhus divaricate* have shown a significant increase (67%). (There is new recruitment of *Diospyros austro-africana*.

Table 3-7 Summary of changes of key woody vegetation at IFR Site 4

Key taxa (Predicted change)	Recorded October 2005	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra (No prediction)		Not recorded	3	4	7	↑	The species remain rare on the site.
Gomphostigma virgatum ↓ (5-20%)	111	227	1	17	105	↓	Small decline from 2005 baseline
Rhus divaricata ↓(40-80%)	20	19	1239	53	63	↑	Significant increase.
Salix fragilis ↓ (20-40%)	6	7	188	40	12	↑	Slight increase
Salix mucronata ↓(20-40%)	325	335	335	451	34	↓	A high decrease on the seedlings.

The results show a high decline (90%) in *Salix mucronata* than was otherwise predicted. Significant increase (68%) in *Rhus divaricata* contrary to predicted decline of up to 80%.

Table 3-8 Summary of changes of key woody vegetation at IFR Site 5

Key taxa (Predicted change)	Recorded Oct. 1998	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Gomphostigma virgatum ↓ (5-10%)		132	98	62	122	↓	Slight decline from 2006 baseline
Salix fragilis ↓ (5-10%)		2	0 (2 cut)	40	0	↓	Species has remained rare on the site
Salix mucronata (No prediction)		7	43	451	17	↑	A higher number of seedlings recorded on the left bank

Salix mucronata has increased (59%) and there is new recruitment of *Artemisia afra* and *Acacia dealbata.*

Table 3-9 Summary of changes of key woody vegetation at IFR Site 6

Key taxa (Predicted change)	Recorded October 2005	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Acacia dealbata ↓ (10-20%)	38	10	9	125	39	↓	Very small change from 2005 baseline
Gomphostigma virgatum ↓ (5-10%)	61	52	17	1	0	↓	The species continued to decline down to 0
Salix fragilis (No prediction)	19	18	17	0	0	↓	The species continued to decline down to 0
Salix mucronata ↓ (10-20%)	2	3	2 (cut)	165	62	↑	Increase in the number of seedlings.
Rhus divaricate ↓ (10-30%)	2	3	Not recorded	Not recorded	17	↑	Increase in the number of seedlings.

Gomphostigma virgatum and *Salix fragilis* have shown a progressive decline over the years to a zero record in 2016 whilst *Salix mucronata* has increased contrary to the prediction of (10-20%) decline.

Table 3-10 Summary of changes of woody vegetation at IFR Site 7

Key taxa (Predicted change)	Recorded October 2005	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra ↓ (30-50%)	101	31	2	8	7	↓	The level of decline is much higher than the predicted 50%
Gomphostigma virgatum ↓ (20-40%)	61	19	Not recorded	2	3	↓	The level of decline is much higher than predicted 40%
Rhus divaricata ↓ (40-80%)	2	12	Not recorded	11	19	↑	There is an increase in the number of seedlings.
Phygelius capensis ↓ (None)	1	0	Not recorded	Not recorded	Not recorded	↓	Species not recorded over the last four assessments
Salix fragilis ↓ (20-40%)	24	40	96	103	99	↑	The species has increased contrary to the predicted decline of up to 40%
Salix mucronata ↓ (20-40%)	190	128	68	30	54	↓	Higher level of decline than predicted

Salix fragilis has increased by 76% contrary to the predicted decline of up 40% and *Salix mucronata* has much higher level of decline than predicted (72%).

Table 3-11 Summary of changes of key woody vegetation at IFR Site 9

Key taxa (No Predicted change)	Recorded October 2005	Sept 2006	April 2014	April 2015	April 2016	Change	Comments
Artemisia afra (No prediction)	422	396	275	351	514	↑	There is an increase in the number of seedlings compared to 2005 baseline.
Gomphostigma virgatum (No prediction)	133	243	96	8	54	↓	There was a significant decline in abundance
Salix babylonica (No prediction)	9	9	20	9	8	↓	Very small decline
Salix fragilis (No prediction)	17	50	17	39	142	↑	There was a significant increase in the species
Salix mucronata (No prediction)	7	15	0	0	0	↓	Not recorded since 2014

No predictions were made for IFR Site 9

3.2.4 River Condition

Table 3.12 below presents the river condition as per analysis of riparian vegetation data of 2016. The determination of the conditions is guided by *Table 2.2* as extracted from IFR Policy and Procedures, 2003.

Table 3-12 The assessed river condition (Riparian Vegetation) for each of the IFR sites.

IFR Site	Pre-dam condition	Predicted condition	April 2016	River Condition	Actual relative to target
IFR Site 1	2	3	4	Significantly modified	Worse
IFR Site 2	2	4	4	Significantly modified	On target
IFR Site 3	2	4	4	Significantly modified	On target
IFR Site 4	2	3	4	Significantly modified	Worse
IFR Site 5	2	2	2	Near natural	On target
IFR Site 6	2	2	3	Moderately modified	Worse
IFR Site 7	2	4	4	Significantly modified	On target
IFR Site 9	2	2	3	Moderately modified	Worse

3.2.5 Conclusion

In comparison with the previous years, there is a progressive decline in all the species at IFR Site 2. IFR Sites 1, 4, 6 and 9 show worse conditions when compared to the pre-dam and predicted conditions whilst the remaining IFR sites meet the predicted river conditions as the general actual observations is that they are on targeted condition. The IFR policy had predicted that no flow modification induced changes in riparian vegetation will occur at IFR Sites 5 and 6 as they are distal sites and it was expected that the flow would have adjusted to the natural condition by the time it reaches the distal sites. During the April 2016 assessment, there was a decrease in woody vegetation (trees form) at the proximal IFR Sites 1 and 2, whilst there was an increase in woody vegetation (trees form) at IFR Sites 5. *Salix mucronata* is declining at IFR Sites 3 (50%), 4 (90%), 7 (72%) and 9 (100%) whilst it is increasing at IFR Sites 5 (59%) and 6 (62%). *Salix fragilis* is decreasing at IFR Sites 1 (72%), 2 (76%), 3 (61%) and 6 (100%) whilst it is increasing at IFR Site 7 (76%) and 9. Conditions at IFR Site 6 favor establishment of the native *Salix mucronata* whist conditions at IFR Site 7 are favorable for invasion by the alien *Salix fragilis*.

3.3 Water Quality

3.3.1 Introduction

Water quality discipline helps to characterize the quality of water at IFR sites and to assess the impacts associated with modifications in river flow conditions. Among the descriptors of water quality, pH and temperature have been selected to determine the impacts of the releases in the rivers because they do not change abruptly when water is released. All organisms living in a given system have preference with regard to quality of water, therefore maintaining the quality of water at IFR sites to near natural condition or to the levels prescribed in IFR policy is important.

The objective of water quality monitoring is to obtain accurate water quality data that will detect long-term trends in water quality (LHWP IFR Policy Procedures (2003)).

3.3.2 Methodology

Prior to water sampling, sampling bottles were cleaned and preserved with mercuric chloride and hydrochloric acid for analysis of nutrients and metals respectively. Water samples were collected in the main channel of the river for analysis of total suspended solids (TSS), nutrients and metals. All the sample bottles were properly labelled to indicate site reference, site number and date of sampling. Following collection of samples, the *insitu* variables were measured with hand held meters which have been cleaned and calibrated before the measurements could be taken. The *insitu* variables include temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO). All the readings were recorded in the field data book. Following the field monitoring, water samples were delivered to laboratories in RSA for analysis of nutrients and metals.

3.3.3 Data Analysis

Analysis of water quality data in this report leads to classification of river conditions which is guided by *Tables 4.1* and *4.2* of this report and as extracted from the LHDA Policy and Procedure, 2003*. Tables 3.13* to *3.19* present data at IFR sites from 1991 to 2016. In comparison with data from the monitoring undertaken in the past, there is little increase of *sodium* at IFR9, otherwise it is below the benchmarking values at all IFR sites while potassium has increased at IFR sites 4 and 5, calcium and magnesium have increased at IFR sites 6 and 7. Nitrate levels indicated an increase at IFR sites 2 and 9 only. This is an improvement when compared to the concentration level in the previous reporting period where nitrate was above the benchmarking values at all sites.

The lower dissolved oxygen at IFR sites 1 and 4 can be related to the elevated temperatures during the report period. Other variables fall below the benchmarking data at both proximal and distal reaches. It should be noted that variables which have deviated from the referenced data are highlighted in red.

Table 3-13 Summary data for a range of water quality variables at IFR 1 for 1991/92 (LHDA 83), 1998/1999 (LHDA 648) and 2015/2016

WQ variables	Temp ◦C	DO mg\l	pH $[H^+]$	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	NO3-N mg/l	TSS mg/l	Tot-P ug\l	PO4 ug\l
LHDA 83 Range	6 - 27	n/a	7.3 – 8.9	11.1-28.5	2 - 4	0.5 - 2	11 - 29	4 -13	n/a	0.5 - 20	49-207	12 - 63
LHDA 648												
25th per	11.0	9.1	8.2	11.8	1.9	0.1	10.6	4.5	0.2	2.0	8.0	0.6
75th per.	16.0	9.7	8.4	21.3	4.9	0.8	22.5	8.2	0.4	41.0	123.0	11.6
Median	14.0	9.4	8.3	16.8	4.1	0.7	17.5	6.8	0.3	40.0	65.0	8
Oct 2015 – Sept 2016	**22.9**	**7.4**	**8.1**	**15.9**	**4.14**	**1.93**	**20.5**	**7.5**	**0.27**	**14.4**	**28.5**	**6.6**

Table 3-14 Summary data for IFR 9 (Upstream of Matsoku Weir) between 2003 to 2006 and for 2015/2016

WQ variables	Temp °C	DO mg\l	pH $[H^+]$	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	NO3-N mg/l	TSS mg/l	Tot-P ug\l	PO4 ug\l
2003-2006												
25th per	9	7.6	7.2	11.8	2.2	0.4	13.5	5.2	0.1	0.0	7.5	4.3
75th per.	17.5	8.8	7.8	17.4	3.1	0.7	21.0	7.8	0.6	8.4	48.7	12.4
Median	14	8.4	7.5	14.2	2.7	0.6	16.8	6.3	0.3	0.0	21.5	6.7
Oct 2015 – Sept 2016	**16.1**	**9.6**	**8.8**	**11.0**	**3.7**	**1.21**	**17.6**	**6.1**	**1.95**	**1.4**	**3.13**	**0.69**

NB: IFR 9 was not part of the study area for LHDA Contracts 83 and 648; hence the absence of information from these contracts in this table.

Table 3-15 Summary data for a range of water quality variables at IFR 2 for 1991/92 (LHDA 83), 1998/1999 (LHDA 648) and 2015/2016

WQ variables	Temp °C	DO mg\l	pH $[H^+]$	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	NO3-N mg/l	TSS mg/l	Tot-P ug\l	PO4 ug\l
LHDA 83 Range	6 - 22	n/a	6.8 - 8	7.9 – 20.5	2 - 4	0.5 - 2	6 - 22	2 - 6	n/a	0.5 - 104	62 - 163	12-98
LHDA 648												
25th per	11	8.6	8.2	9.6	2.7	0.3	9.7	3.8	0.1	3	18.0	5.2
75th per.	16	10.2	8.7	12.7	3.9	0.9	14.7	5.4	0.2	12	32.0	15.2
Median	13	9.5	8.5	11.1	3.5	0.9	12.6	4.9	0.2	6	45.0	9
Oct 2015 – Sept 2016	**15.2**	**8.2**	**8.4**	**7.0**	**3.1**	**1.8**	**13.4**	**4.5**	**1.7**	**3.4**	**11.6**	**3.9**

Table 3-16 Summary data for a range of water quality variables at IFR 3 for 1991/92 (LHDA 83), 1998/1999 (LHDA 648) and 2015/2016

WQ variables	Temp °C	DO mg\l	pH $[H^+]$	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	NO3-N mg/l	TSS mg/l	Tot-P ug\l	PO4 ug\l
LHDA 83 Range	9-24	n/a	6.4–7.8	n/a	2-4	0.5-1	8-25	3-9	n/a	0.5-73	49-528	
LHDA 648												
25th per	13.0	8.3	8.1	12.2	2.7	0.5	12.3	6.2	0.2	8.0	15.0	3.8
75th per.	19.0	10.7	8.6	21.6	5.7	0.8	18.2	7.7	0.6	86.0	53.0	21.5
Median	16.0	9.5	8.4	16.5	4.5	1.2	15.4	7.0	0.4	91.0	110.0	9
Oct 2015 – Sept 2016	**18.0**	**8.9**	**8.2**	**9.9**	**3.6**	**1.0**	**17.0**	**6.6**	**4.3**	**22.3**	**22.6**	**5.1**

Table 3-17 Summary data for a range of water quality variables at IFR 4 for 1998/1999 (LHDA 648) and 2015/2016

WQ variables	Temp °C	DO mg\l	pH $[H^+]$	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	NO3-N mg/l	TSS mg/l	Tot-P ug\l	PO4 ug\l
LHDA 648												
25th per	11	8.3	8.2	15.9	3.4	0.4	11.9	6.3	0.3	2.0	17.0	9.5
75th per.	19	10.9	8.5	24.3	5.9	0.7	20.2	9.5	0.5	60.0	158.0	21.5
Median	15	9.3	8.3	19.9	4.4	0.6	17.4	8.1	0.5	30.0	105.0	15
Oct 2015 – Sept 2016	**25.1**	**6.4**	**8.4**	**19.2**	**5.0**	**1.3**	**25.2**	**9.8**	**0.5**	**19.1**	**45.4**	**18.0**

Table 3-18 Summary data for a range of water quality variables at IFR 5 for 1998/1999 (LHDA 648) and 2015/2016

WQ variables	**Temp** ◦C	**DO** mg\l	**pH** [H+]	**EC** mS/m	**Na** mg/l	**K** mg/l	**Ca** mg/l	**Mg** mg/l	**NO3-N** mg/l	**TSS** mg/l	**Tot-P** ug\l	**PO4** ug\l
LHDA 648												
25th per	13	7.6	8.2	16	4.4	0.5	15.4	6.8	0.2	4	8	5.0
75th per.	21	10.2	8.5	22.3	5.6	0.9	27.8	10.2	0.5	213	131	29.5
Median	20	8.1	8.4	20	4.6	0.6	25.9	9.2	0.4	81	55	8
Oct 2015 – Sept 2016	**19.7**	**9.7**	**8.3**	**14.9**	**5.4**	**2.3**	**26.6**	**9.7**	**0.3**	**39.4**	**2.2**	**0.7**

Table 3-19 Summary data for a range of water quality variables at IFR 6 for 1998/1999 (LHDA 648) and 2015/2016

WQ variables	**Temp** ◦C	**DO** mg\l	**pH** [H+]	**EC** mS/m	**Na** mg/l	**K** mg/l	**Ca** mg/l	**Mg** mg/l	**NO3-N** mg/l	**TSS** mg/l	**Tot-P** ug\l	**PO4** ug\l
LHDA 648												
25th per	15.0	7.3	8.1	13.8	3.8	0.7	14.0	5.6	0.3	9.0	19.0	11.6
75th per.	22.0	10.2	8.4	18.8	5.8	2.0	21.0	8.0	0.5	879.0	248.0	26.4
Median	18.0	8.7	8.2	17.3	4.7	1.4	17.3	6.7	0.5	500.0	238.0	16
Oct 2015 – Sept 2016	**23.7**	**8.7**	**8.2**	**19.5**	**5.7**	**1.2**	**26.3**	**9.2**	**0.1**	**6.4**	**11.8**	**3.7**

Table 3-20 Summary data for a range of water quality variables at IFR 7 for 1998/1999 (LHDA 648) and 2015/2016

WQ variables	**Temp** ◦C	**DO** mg\l	**pH** [H+]	**EC** mS/m	**Na** mg/l	**K** mg/l	**Ca** mg/l	**Mg** mg/l	**NO3-N** mg/l	**TSS** mg/l	**Tot-P** ug\l	**PO4** ug\l
LHDA 648												
25th per	12	8.2	8.0	9.2	2.2	0.4	9.0	3.0	0.1	1.0	18.0	4.0
75th per.	19	9.9	8.2	10.2	4.8	0.8	11.7	4.0	0.2	8.0	51.0	8.0
Median	15	9.2	8.0	9.8	3.6	0.6	11.2	3.9	0.2	17.0	40.0	5
Oct 2015 – Sept 2016	**21.7**	**9**	**8.8**	**11.0**	**3.6**	**0.7**	**14.7**	**5.0**	**0.4**	**1.1**	**1.9**	**1.3**

3.3.4 River condition

The data analysis is made to enable determination of river conditions at IFR sites. The conditions are set based on the changes in pH and temperature. These two variables have been identified as the ones which will quickly impact negatively on organisms in rivers if they change remarkably. *Table 3.21* below shows river conditions relative to targeted conditions of each IFR site with reference to pH and temperature between 2015 and 2016. The text highlighted in red indicates the sites which have been modified by more than two states from their baseline state.

Table 3-21 The assessed river condition for 2015/2016 IFR sites, accounting only for water quality.

IFR site	Pre-dam condition	Targeted condition	2015 to 2016		River Condition 2015 to 2016	River condition	Actual relative to target
			Temp	pH			
1	2	3	4	5	5	Severely modified	Worse
2	2	4	2	2	2	Near natural	Better (improve
3	2	4	2	2	2	Near natural	Better
4	2	3	5	2	5	Severely modified	Worse
5	2	2	2	2	2	Near natural	On target
6	2	2	2	2	2	Near natural	On target
7	2	4	2	3	3	Moderately modified	Better
9	2	2	2	3	3	Moderately modified	Worse

3.3.5 Conclusion

The analysis of data indicated that the river conditions at IFR sites 2, 3 and 7 have attained a better river condition from significantly modified to near natural for IFR site 2 and 3, moderately modified for IFR site 7, while 5 and 6 are on targeted conditions as prescribed in *Table 3-1* which is near natural. IFR sites 1 and 4 were expected to be moderately modified and 9 (reference site) to be near natural condition, however, the current reporting data categorized them at the worse state or river condition.

3.4 Macro-invertebrates

3.4.1 Introduction

Macro invertebrates help to determine the health of the river. The integrity and availability of the biotopes is of utmost importance to benthic macro-invertebrates. The benthos which are sensitive are specific about the quality of water and the habitats, this is why they are related to river morphology, and if the flows get rid of the habits preferred and the water quality changes drastically some of them will completely disappear from such a site. Some of them are disease vectors and pests (*Simullidae and snails)* so it is very important to monitor them to keep abreast of their availability and trends.

Generally, where habitat diversity (biotopes) is poor, there will be less biotic diversity and hence lower SASS score. If a few present macro-organisms have appropriate sensitivity, the ASPT will be less affected. The ASPT will be lower if the present macro-organisms are adaptable and tolerant to pollution or biotope degradation and scarcity.

The benthic macro-invertebrates have varying sensitivity which is denoted by numbers ranging from 1 to 15. The most resistant organisms are given 1 and the most sensitive ones are denoted by 15. Macro-invertebrates react to change in flow, habitat and quality of water. The SASS5 protocol is used to sample the macro-invertebrates where the SASS score, Number of Taxa (NOT) and the Average Score Per Taxon (ASPT) are determined. The benthic macro-invertebrates are used to confirm the quality of water in water bodies, to a greater extent, they are used to indicate the health of the river because of their sensitivity to the changes in quality of water, the status and availability of the biotopes.

The objective of micro-invertebrates monitoring are early warning indicators of increases in the populations of potential pest species (simuliids, snails) (LHDA IFR Policy Procedures, 2003).

3.4.2 Methodology

Prior to sampling, each IFR site was assessed for available biotopes and then the white tray was filled with water and placed at the river bank. Then, the sampler went into the river and agitated the water by kicking the stones in current and stones out of current for about 2 minutes and I minute respectively facing the flow of the current and then swept over the kicked area but below the surface with a SASS5 net to collect the escaped invertebrates. The collected sample was washed and emptied into the white tray containing water and got analyzed for available macro-invertebrates. The net was cleaned prior to taking another sample. The sample from stones was returned into the river and the tray was cleaned and filled with water for the next sample. The marginal vegetation of about 2 meters and the square meter of the aquatic vegetation were sampled. Then the contents of the net were washed and emptied into a tray with clean water for analysis. The net was cleaned, the vegetation sample was returned back to the river, the tray was cleaned and filled with water for the next sample. Lastly, gravel, sand and mud were sampled together for about 1 minute. The contents of the net were washed and emptied into the tray containing water for analysis. All the families observed in the samples were recorded in a SASS5 scoring sheet (Dickens et al, 2002). Immediately after sampling, the number of taxa (NOT) observed, site score and average score per taxon (ASPT) were calculated and recorded in the SASS5 score sheet. Following field monitoring, the samples from rapids collected from each IFR site are sent to laboratory for further analysis to determine if the disease carrying species such as *Physidae* and *Simullidae chutteri* are available.

3.4.3 Data Analysis

IFR Sites 1 and 9 – Matsoku River

The macro-invertebrates' information at Matsoku river observed in1998 was collected before Matsoku diversion weir was constructed, therefore it is proper to use it as reference data for both IFR Sites 1 and 9 as shown in Table 3-22.

In October 2015, IFR Site 9 had the SASS score of 100 and the NOT of 17 while IFR site 1 has score of 81 and NOT of 14. These are close to SASS Score of 112 and NOT of 14 as observed in October 1998. The high SASS scores at IFR sites 1 and 9 indicate high biotic diversity hence healthy reference river site. However, the ASPTs indicate that the level of sensitivity has deteriorated at both sites. A deterioration in biotic diversity is observed in April 2016 at IFR Sites 1 and 9 where the SASS score, NOT and ASPT are lower than the ones observed in May 1998 at 143, 22 and 6.5 respectively. The difference between the reference site and the impacted site is minimal in scores, NOT and ASPT as indicated in *Table 3.22* is minimal. Therefore, the inference made is that the changes in the communities in both sites is caused by general environmental impact and it is not related to management of the releases downstream of Matsoku wier.

Table 3-22 SASS data collected at IFR Sites 1 and 9 in 1998, Oct. 2015 and April 2016

IFR station	SASS Score	No. of Taxa (NOT)	ASPT
IFR1			
October 98	112	14	8.0
May 98	143	22	6.5
October 15			
IFR9	**100**	**17**	**5.9**
IFR1	**81**	**14**	**5.8**
April 16			
IFR9	**50**	**11**	**4.54**
IFR1	**47**	**11**	**4.3**

IFR 2 – Malibamatšo River below Katse bridge

The SASS score, NOT and ASPT at IFR 2 have been reduced in October 2015 in comparison with 1998 information (*Table 3.23*). A drastic increase in the score, NOT and ASPT are observed in April 2016 in comparison with the numbers observed in 1998. These are the highest values observed at IFR site 2 ever since the impoundment of Katse dam. IFR site 2 is nearest of all to the dam wall, therefore, it was characterized by constant flows with minimal to no variation during quarterly scheduling of releases. Since the beginning of January 2016 the management of releases downstream of Katse dam was changed from quarterly schedule to daily flows and this brought in an element of natural variation to some extent, this could be the main reason behind the recolonization at IFR site 2 by the sensitive species. Therefore, the flows at this site became conducive for recolonization, hence increase in the scores and the number of taxa. The ASPT value indicated that the site was recolonized by sensitive species (*Table 3.23)*.

Table 3-23 SASS data collected at IFR Sites 2 in April and Oct. 1998, Oct. 2015 and April 2016

IFR 2	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	**42**	**10**	**4.2**
October 2015	**25**	**7**	**3.6**
April			
April 98	**74**	**10**	**7.4**
April 2016	**130**	**20**	**6.5**

IFR 3 – Malibamatšo River at Paray

The score and ASPT at IFR site 3 are reduced both in October and April when compared to the readings observed in 1998, *Table 3-24.* However, the NOT remained constant indicating that biotopes have not been disturbed and there is still high biotic diversity. However, the current ASPTs are lower than the ones observed in 1998 indicating that the organisms remaining at this site are generally less sensitive to pollution. IFR 3 as well, is a proximal reach which is expected to reflect the effects of the manipulated flows.

Table 3-24 SASS data collected at IFR Sites 3 in April and Oct. 1998, Oct. 2015 and April 2016

IFR 3	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	**78**	**10**	**7.8**
October 2015	**58**	**12**	**4.8**
April			
April 98	**88**	**12**	**7.3**
April 2016	**67**	**12**	**5.6**

IFR 4 – Senqu River at Sehonghong

Although the NOTs are generally higher the ones observed in 1998 at IFR site 4, the ASPTs are lower and suggesting that the macroinvertebrates dwelling at IFR site 4 are less sensitive than the ones observed in 1998 (*Table 3-25*). The flow level at IFR 4 is beginning to become high because of inflowing tributaries. The high flows carry most of the sensitive organisms downstream and the less sensitive organisms are tolerant to the high flows and attach to rocks and sand in the biotope thereby reducing the SASS score. Also, it makes it impossible to reach all the biotopes available at this site, this could be the reason why the diversity is very low. However, the sensitivity of organisms has increased. With more distance away from the dam wall, the impact of the manipulated releases is minimised by the incoming flows of the tributaries which results in more natural flow.

Table 3-25 SASS data collected at IFR Sites 4, in April and Oct. 1998, Oct. 2015 and April 2016

IFR 4	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	77	9	8.6
October 2015	**84**	**14**	**6.0**
April			
April 98	60	8	**7.5**
April 2016	**56**	**10**	**5.6**

IFR 5 – Senqu River at Whitehill

There is general improvement in the NOTs in October and April and the score of April 2016. The ASPT of October 2015 is lower than ASPT of October 1998 indicating the presence of less sensitive organisms. However, the ASPT in April remained constant and higher indicating some improvement *(Table 3-26)*. Although it is expected that there could be natural variations at this site brought in by flow of tributaries, the river at this reach has very high flows, therefore, not all available biotopes are sampled. This factor could explain the low scores and NOT observed at this site.

Table 3-26 SASS data collected at IFR Sites 5, in April and Oct. 1998, Oct. 2015 and April 2016

IFR 5	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	86	9	9.6
October 2015	**76**	**13**	**5.9**
April			
April 98	35	5	7.0
April 2016	**55**	**8**	**6.9**

IFR 6 – Senqu River at Seaka bridge

On the basis of *Table 3-27,* IFR site 6 is showing an improvement in terms of score, NOT and ASPT in comparison with the values observed in 1998. At this site, the river is expected to have no impacts of manipulated releases because of the inflowing tributaries. Furthermore, one would expect that there are more natural variations resulting to high scores and NOT. However, the river at this reach has very high flows such that it is impossible to reach the representative biotopes such as gravel, sand, stones in and out of current where benthos with high scores dwell, hence relatively low ASPT in relation to other distal IFR reaches. Where habitat diversity is poor, there is less biotic diversity and in the long run the SASS scores are low.

Table 3-27 SASS data collected at IFR Sites 6 in April and Oct. 1998, Oct. 2015 and April 2016

IFR 6	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	**23**	**6**	**3.8**
October 2015	**64**	**11**	**5.8**
April			
April 98	**31**	**5**	**6.2**
April 2016	**64**	**11**	**5.8**

IFR 7 – Senqunyane River at Marakabei

The Score, NOT and ASPT observed in October 2015 are higher than those observed in 1998. This is indicating recovery in the communities. Although the ASPT is reduced, the more increase in the score and NOT is observed in April 2016 (*Table 3-28).* IFR site 7 is proximal to Mohale dam wall, therefore it is able to show the effects of the manipulated flows. The change from quarterly scheduling of the releases to daily releases is attributed to the increase in the scores and NOT because it increased variability in flows which is favoured by benthos.

Table 3-28 SASS data collected at IFR Sites 7 in April and Oct. 1998, Oct. 2015 and April 2016

IFR7	SASS Score	No. of Taxa (NOT)	ASPT
October			
October 98	**23**	**6**	**3.8**
October 2015	**110**	**18**	**6.11**
April			
April 98	**31**	**5**	**6.2**
April 2016	**120**	**23**	**5.2**

3.4.4 River condition

Table 3-29 presents the river condition at IFR sites. The determination of the condition of each site is based on the SASS5 scores of each site and be defined as per Table 2.2 of IFR policy. The actual river condition will be assessed in relation to the predicted condition to indicate whether the conditions are as per predictions or not. The text highlighted in red indicates the sites which have been modified by more than two states from their baseline state

Table 3-29 The assessed river condition for 2015/2016 every IFR site, accounting only for macroinvertebrates.

IFR Site	Pre-dam condition	Predicted condition	2014 to 2015	2015 to 2016	River condition	Actual relative to target
IFR 1	2	3	4	4	Significantly modified	Worse
IFR 2	2	4	5	2	Near natural	Better
IFR 3	2	4	4	4	Significantly modified	On target
IFR 4	2	3	5	4	Significantly modified	Worse
IFR 5	2	2	5	4	Significantly modified	Worse
IFR 6	2	2	4	4	Significantly modified	Worse
IFR 7	2	4	2	2	Near natural	better
IFR 9	2	2	4	4	Significantly modified	worse

3.4.5 Conclusion

On the basis of macro-invertebrates' analysis, IFR sites 2 and 7 had a better state than the one predicted (Tables 3-23 and 3-28) from significant modification to near natural condition and this was consistent with information from water quality. IFR sites 5, 6 and 9 were predetermined to be at near natural state (State 2) due to the fact that Site 9 is a reference site and sites 5 and 6 are distal sites. However, they are modified based on the current assessment as shown in Table 3-29 hence the modifications in these cannot be attributable to the modifications in the flow regimes of the river.

In IFR sites 2 and 7 the conditions were better than the conditions predicted for macro-invertebrates' due to the presence of *Perlidae (neoperla spio)* with score of 12, *Tricorythidae* with a score of 9 and *Oligoneuriidae* with 15 which falls within the most sensitive benthos to degradation of biotopes and poor quality of water. More than two species of the families *Hydropsychidae* and *Baetidae* were also found at the sites which is indicative of recruitment of highly sensitive benthos in these sites and therefore good quality water.

3.5 Fish

3.5.1 Introduction

Fish in IFR biophysical monitoring is considered as a resource for human consumption as well as being one of the biophysical parameters that are used to determine the impact of modified flows at IFR sites. Monitoring determines the increase or decrease in fish communities which could be related to the released flows. The information from monitoring of fish is used in conjunction with the one from monitoring of other resources to determine the impacts on the resources used by the downstream communities and hence it forms part of the resources used to determine compensation due to the downstream communities where such is indicated. Generally, monitoring of fish makes it possible to determine species diversity, abundance, size and sex at every IFR site. Phase 1 dams were predicted to reduce the abundance of fish in downstream reaches particularly in reaches 4 and 7 (Nepid, 2014).

The objectives of the fish assessment were to obtain data in the fish communities that will detect any long-term changes in fish community structure.

3.5.2 Methodology

Visual observation to detect presence of fish was conducted at all sites prior to gill net setting. The nets were set overnight at IFR sites to maximize the chances of catching as fish movement is at its highest at night. Three gillnets of the mesh sizes 20mm, 40mm and 60mm were set overnight at each IFR site to cater for sampling of different fish sizes. The 20 mm mesh nets were used to detect presence of fingerlings (recruitment), while the 40mm and 60 mm mesh nets were used to assess adult fish populations. Each catch was assessed for species identification, size (full length), abundance, sex and fishing effort was made and all the information was recorded in the data sheet. In April 2016 the nets were set for 4 hours at IFR sites 1, 2 and 9. Since there was no catch, a repeat of overnight setting of two nets per site was conducted for the said three sites. However, a repeat could not be set for IFR site 4 at which a single 60mm mesh size gill net was set for a period of five hours due to the sinking ground at this site.

According to the LHDA IFR Policy Procedures (2003) fish should be sampled using a wide variety of methods to maximize the chances of capturing individuals present at each IFR Site. The applicable methods consist of electro-fishing, seine netting, gill netting and angling. However, limited sampling methods were employed as only two catch methods of seine and gill netting were employed. The data collected during the current year surveys was then compared to the one obtained from the 1998/1999 surveys to determine changes in the composition and abundance of fish populations at each IFR site.

3.5.3 Data analysis

Table 3-30 Species Diversity and Sample Size at IFR1

Fish species	April 1998	January 1999	April 2016
A. sclateri	0	0	0
L. aeneus	0	0	0
L. kimberleyensis	0	0	0
P. quathlambae	18	6	0
L. capensis	0	0	0
O. mykiss	0	0	0

No fish were found at this site during the April 2016 surveys. All species which were previously recorded have now disappeared from this site. This site is therefore, worse than it was anticipated.

Table 3-31 Species Diversity and Sample Size at IFR Site 2

Fish species	April 1998	January 1999	April 2016
A. sclateri	0	1	0
L. aeneus	6	11	0
L. kimberleyensis	0	0	0
P. quathlambae	0	0	0
L. capensis	14	9	0
O. mykiss	7	12	0

The current survey portrays a decline in species diversity at this site, as only *Oncorhynchus mykiss* was sampled, according to the current study, this site consists of the exotic species only and the previously observed native species (*L. aeneus*) is no longer found.

Table 3-32 Species Diversity and Sample Size at IFR Site 3

Fish species	April 1998	January 1999	April 2016
A. sclateri	0	0	1
L. aeneus	0	0	3
L. kimberleyensis	0	0	0
P. quathlambae	0	0	0
L. capensis	12	0	0
O. mykiss	5	28	1

Fish populations at this site consists of two indigenous species (*A. sclateri* and *L. aeneus*) and one exotic species (*O. mykiss*); and is dominated by the natives. *A. sclateri* and *L. capensis* populations are totally absent in October 2016 sample.

Table 3-33 Species Diversity and Sample Size at IFR Site 4

Fish species	April 1998	January 1999	April 2016
A. sclateri	0	1	0
L. aeneus	7	214	0
L. capensis	4	9	0
O. mykiss	9	0	0

One *L. aeneus* and three *A. sclateri* were sampled at this site in April 2016 even though they were not found in the past.

Table 3-34 Species Diversity and Sample Size at IFR Site 5

Fish species	April 1998	January 1999	April 2016
A. sclateri	2	0	0
L. aeneus	3	153	4
L. kimberleyensis	0	1	2
L. capensis	4	1	2

The native species form the only component of fish assemblage at this site. However, all show a decline since April 2016.

Table 3-35 Species Diversity and Sample Size at IFR Site 6

Fish species	April 1998	January 1999	April 2016
A. sclateri	0	0	2
L. aeneus	19	306	3
L. kimberleyensis	0	8	3
L. capensis	5	122	0

The fish assemblage is made up purely of indigenous species even though the numbers of all species have declined in as compared to those sampled in the past.

Table 3-36 Species Diversity and Sample Size at IFR Site 7

Fish species	April 1998	January 1999	April 2016
A. sclateri	**0**	**1**	**7**
L. aeneus	**14**	**0**	**2**
O. mykiss	**-**	**-**	**2**

There is decline in the numbers of *A. sclateri* and *L. aeneus* over the period and a total disappearance of *L. capensis*.

Table 3-37 Species Diversity and Sample Size at IFR Site 9

Fish species	2005	2006	April 2016
L. aeneus	14	0	0
P. quathlambae	1	1	0

This site showed total absence of fish. A prior assessment of 2005-2006 indicated presence of *P. quathlambae* and *L. aeneus* which have also disappeared from the site. Even though there was no target shown for this site in the IFR policy, IFR 9 (Reference) has been severely modified. The site is not affected by flow modifications.

3.5.4 Relative Abundance (CPUE) and Average Length of Sampled Fish

A low average catch per unit effort of 0.27 fish per hour was obtained, which is far lower than the average CPUE of 25.81 fish/hour obtained in the 2013/14 study, indicating a current low relative abundance of fish at IFR sites.

Table 3-38 Relative abundance and Average Length of Sampled Fish

IFR Sites	Total No. sampled in April 2016	Total No sampled in October 2016	Total No sampled per site	Average Length	Fishing Effort (net hour)	CPUE (Fish No./Net/hr.)
IFR 1	0	0	0	0	32 net hrs.	0
IFR 2	3	4	7	23.73	32 net hrs.	0.22
IFR 3	5	1	6	24.95	32 net hrs.	0.19
IFR 4	0	1	1	55	32 net hrs.	0.03
IFR 5	8	4	12	30.83	32 net hrs.	0.38
IFR 6	8	2	10	12.96	32 net hrs.	0.31
IFR 7	11	5	16	21.53	32 net hrs.	0.50
IFR 9	0	0	0	0	32 net hrs.	0

4.5.4 Recruitment Success

A juvenile is defined as any fish that has not reached sexual maturity. During sampling, juveniles are characterized by a size of a finger or a length that is less than 20cm (Arthington et. al., 2003). All sites showed some recruitment except three (IFR 1, 4 and 9), two (IFR 1 and 9) of which had no fish at all. The most successful recruitment was observed at IFR 6 with a total of 10 juveniles and an average length of 13.85 cm.

Table 3-39 Number and length of samples juveniles

IFR Sites	April 2016	Length (cm)
IFR 1	0	0
IFR 2	3	16.67
IFR 3	3	6.5
IFR 4	0	0
IFR 5	2	8.00
IFR 6	8	13.85
IFR 7	5	8.3
IFR 9	0	0

4.5.5 River condition

Table 4-28 presents the river condition at IFR sites. The determination of the condition of each site is based on the fish complement at each site and be defined as per Table 4.1 of IFR policy. The actual river condition will be assessed in relation to the predicted condition to indicate whether the conditions are as per predictions or not. The text highlighted in red indicates the sites which have been modified by more than two states from their baseline state

Table 3-40 The river condition classes as determined by Fish at IFR sites in 2015 to 2016.

IFR Site	Pre-dam Condition	Predicted Condition	River condition	State	Actual relative to prediction
IFR 1	2	3	5	Severely modified	Worse
IFR 2	2	4	5	Severely modified	Worse
IFR 3	2	4	4	Significantly modified	On target
IFR 4	2	3	5	Severely modified	Worse
IFR 5	2	2	4	Significantly modified	Worse
IFR 6	2	2	5	Severely modified	Worse
IFR 7	2	4	4	Severely modified	On target
IFR 9	2	2	5	Severely modified	Worse

3.5.5 Discussion

Species Diversity at IFR sites

All sites except IFR 4 show a decline in species diversity and sample size. Some species either reduce in numbers or totally disappear from the sites. This is most evident at IFR I and 9 where the previously recorded fish species such as *L. aeneus, O. mykiss* and the red data listed *P. quathlambae* have disappeared (Nepid Consultants, 2014) leaving those site with no fish at all.

Relative Abundance of Fish at IFR Sites

A low relative abundance observed from the current study may be resulting from use of only one type of sampling equipment (the gill nets) which are only ideal for fish sampling in reservoirs not rivers.

Recruitment Success at IFR Sites

The recruitment May have been higher than observed, however, this could not be detected due to inefficiency of the sampling gear used. The use of a single type of sampling equipment (Gill net) in the current study also renders the data not comparable with the one from previous studies when it comes to sample size including recruitment (number of juveniles) at each site.

3.5.6 Recommendations

Flood releases that are in line with biological needs of Fish (spawning) are recommended for better recruitment and maintenance of species diversity down stream of LHWP reservoirs, including IFR sites. The procurement of relevant equipment is recommended to enable collection of representative samples and to make current data comparable with data observed in the past sampling efforts.

3.5.7 Conclusion

Fish species diversity at IFR sites show a general decline as some of the species have decreased in numbers or disappeared from the sites. The low diversity may be attributed to the limitation in catch methods that were applied. There are only two sites which have met targeted conditions (signification modification), these are IFR 3 and 7. The rest of the sites are in the worse state. Although it is prescribed in the IFR procedures that several methods can be used to maximize the catch, due to the limitations catch methods used and the time, there was relatively low catch across the IFR sites.

4 Analysis of Impact of hydrology on biophysical parameters

As per IFR procedures, the purpose of integrating hydrology with biophysical monitoring is to provide a basis on which biophysical responses to changes in flow can be measured. It is against this value that the effect of releases to the disciplines which have been presented in this report is assessed. Tables 4-1 to 4-4 of this report present the assessment of the expected conditions at IFR sites based on the current dam releases. IFR sites proximal to the dam are part of the assessment because they have target releases as per the IFR policy and assessment made was in relation to the daily releases and assessment is based on *Tables* 4-1 and 4-2 of IFR Policy. Therefore, expected conditions should improve from the IFR Policy target conditions for both sides. However, the assessment of fish at IFR site 2 shows deviation from the expectation. As per the discussion provided under fish, the observed deviation is attributed to inconsistency in applied sampling methods.

Table 4-1 The expected river condition at IFR sites based on releases , accounting only for water quality.

IFR site	Targeted conditions	Expected Condition with current release	2015 to 2016		2015 to 2016	Actual relative to Expected Condition with current release
			Temp	pH		
Malibamatšo River Below Katse dam (Proximal reaches)						
2	4	=<4	2	2	2	Consistent with releases
3	4	=<4	2	2	2	Consistent with releases
Senqunyane River Below Mohale dam (Proximal reach)						
7	4	=<4	2	3	3	Consistent with releases

Table 4-2 The expected river condition at IFR sites based on releases , accounting only for riparian vegetation.

IFR site	Targeted conditions	Expected Condition with current release	2015 to 2016	Actual relative to Expected Condition with current releases
Malibamatšo River Below Katse dam (Proximal reaches)				
2	4	=<4	4	Consistent with releases
3	4	=<4	4	Consistent with releases
Senqunyane River Below Mohale dam (Proximal reach)				
7	4	=<4	4	Consistent with releases

Table 4-3 The expected river condition at IFR sites based on releases , accounting only for macro-invertebrates.

IFR site	Targeted conditions	Expected Condition with current release	2015 to 2016	Actual relative to Expected Condition with current release
Malibamatšo River Below Katse dam (Proximal reaches)				
2	4	=<4	2	consistent with releases
3	4	=<4	4	Consistent with releases
Senqunyane River Below Mohale dam (Proximal reach)				
7	4	=<4	2	Consistent with releases

Table 4-4 The expected river condition at IFR sites based on releases , accounting only for fish

IFR site	Targeted conditions	Expected Condition with current release	2015 to 2016	Actual relative to Expected Condition with current release
Malibamatšo River Below Katse dam (Proximal reaches)				
2	4	=<4	5	inconsistent with releases
3	4	=<4	4	Consistent with releases
Senqunyane River Below Mohale dam (Proximal reach)				
7	4	=<4	4	Consistent with releases

5 Conclusions

The biophysical monitoring was implemented as scheduled for 2015 to 2016 by all disciplines except geomorphology. The monitoring was undertaken in accordance with the provisions of the policy and procedures for the implementation of the LHWP Phase 1 Instream Flow Requirements. Based on these assessments, the following conclusions can be drawn for each of the parameters assessed:

Hydrology

In the 2015/16 hydrological year the total IFR Release at Katse dam site was 28.78MCM against a target of 36.12MCM this was 80% of the target. At the IFR site a total flow of 37.15 MCM was observed against a target of 54.65 MCM this constituted 67.97% of the target. In general, in 2015/16 the river classification was VERY DRY YEAR with forecast flows mostly under the 25 percentile of the MAR.

In the Mohale dam catchment a total IFR Release of 26.07MCM was made at dam site against a target of 29.97MCM this was 98.23% of the target. At the IFR site 7 a total flow of 32.66 MCM was recorded against a target of 78.28 MCM, Overall the river classification was AVERAGE for the 2015/16 hydrological year. The 48.05% compliance performance to IFR Releases at IFR site 7 located approximately 28Km downstream of the dam structure is clearly due to less than expected contribution from the intermediate catchment.

Riparian Vegetation

IFR Sites 1 and 6 show worse conditions, significantly and moderately modified respectively, when compared to the pre-dam and predicted conditions which are moderately modified and near natural whilst the remaining IFR sites meet the predicted river conditions as the general actual observations is that they are on targeted condition. The IFR policy had predicted that no flow modification induced changes in riparian vegetation will occur at IFR Sites 5 and 6 as they are distal sites and it was expected that the flow would have adjusted to the natural condition by the time it reaches the distal sites. The initial changes in IFR Sites 5 and 6 observed in October 2005 might be attributed to the systems' adjustment to new flow patterns before reaching a new stable condition. During the April 2016 assessment, there was a decrease in woody vegetation (trees form) at the proximal IFR Sites 1 and 2, whilst there was an increase in woody vegetation (trees form) at IFR Sites 5. *Salix mucronata* is declining at IFR Sites 3, 4, 7 and 9 whilst it is increasing at IFR Site 6. *Salix fragilis* is decreasing at IFR Sites 1, 2 and 3 whilst it is increasing at IFR Site 7 and 9. Conditions at IFR Site 6 favor establishment of the native *Salix mucronata* whist conditions at IFR Site 7 are favorable for invasion by the alien *Salix fragilis*.

Water Quality

The analysis of data indicated that the river conditions at IFR sites 2, 3 and 7 have attained a better river condition from significantly modified to near natural for IFR site 2 and 3, moderately modified for IFR site 7, while 5 and 6 are on targeted conditions as prescribed in *Table 3-1* which is near natural. IFR sites 1 and 4 were expected to be moderately modified and 9 (reference site) to be near natural condition, however, the current reporting data categorized them at the worse state or river condition.

Macro-invertebrates (SASS5)

On the basis of macro-invertebrates' analysis, IFR sites 2 and 7 had a better condition (near natural) than the one predicted which is a significant modification condition and this was consistent with information from water quality. IFR sites 5, 6 and 9 were predetermined to be at near natural condition (State 2) for the fact that Site 9 is a reference, 5 and 6 are distal site. However, they are significantly modified based on the current assessment as shown in *Table 4-26* which is deemed worse than the predicted condition.

IFR sites 2 and 7 condition were better than the conditions predicted for macro-invertebrates' information mainly due to the presence of *Perlidae (neoperla spio)* with score of 12, *Tricorythidae* with a score of 9 and *Oligoneuriidae* with 15 which falls within the most sensitive benthos to degradation of biotopes and poor quality of water. More than two species of the families *Hydropsychidae* and *Baetidae* were found which is indicative of recruitment of highly sensitive benthos in this sites.

Fish

Fish species diversity at IFR sites show a general decline as some of the species have decreased in numbers or disappeared from the sites. The low diversity may be attributed to the limitation in catch methods that were applied. There are only two sites which have met targeted conditions (signification modification), these are IFR 3 and 7. The rest of the sites are in the worse state. Although it is prescribed in the IFR procedures that several methods can be used to maximize the catch, due to the limitations catch methods used and the time, there was relatively low catch across the IFR sites.

6 Discussions and Recommendations

The assessment of biota, largely the benthic macroinvertebrates, in rivers is a widely acknowledged way of determining the condition or health of rivers (Dickens et al, 2002). The user of SASS5 data can derive meaningful benefit from the data collected only if it is assessed together with other factors that may influence scores, diversity of the benthos and their sensitivity. These include the habitat quantity and diversity, hydrology (the level and variability of flow) of the river (Dallas et al, 1993). This implies that the benthic macro-invertebrates are sensitive to change in hydrology (the level and variability of flow), the status of habitat/biotope and the quality of water. They thrive in the natural variable moderate flows with high quality water and variety of healthy biotopes.

The communities at IFR sites 1, 3, 4, 5, 6 and 9 indicate some impacts due to combination of the above or one of them. In comparison with the river conditions observed in the previous reporting period, the reaches at IFR site 2, 4, 5, and 7 have shown improvement although IFR sites 4 and 5 are significantly modified. The reaches closest to the dam walls, IFR sites 2 immediately downstream of Katse dam and 7 downstream of at Mohale dam, have responded remarkably to the change in the flow management downstream of the dam walls. The increase of the score at IFR site 2 at 130 has never been observed since the impoundment of Katse dam, this is why it is related to the change in releases management. In the beginning of 2016 the management of the releases changed from quarterly scheduling of releases to daily releases. This method is bringing in an important factor of mimicking daily variability of flow in rivers resulting into increasing degree of the variability in the flow which has been lacking when the releases were scheduled quarterly. Although there is negligible intervention of flow from tributaries at IFR site 2 and 7, the increase of variability from the dam walls seems to be maintaining the reaches at near natural state.

The previous summer was characterized by hot temperatures and relatively dry conditions, therefore, the flows at IFR sites 2 and 7 were mainly the water released from the dams which could have reduced the flow level to the level preferred by the benthos, hence increase in scores, variability and ASPT at these sites. The relevant recommendation would be to maintain daily releases to see its effect to benthos and other IFR disciplines over long period given that some may need more time to show noticeable change.

The rivers at IFR site 4, 5 and 6 are wider and more often than not, the levels are elevated due to flows from the tributaries. Consequently, most of the biotopes are hidden or not easy to reach or access, as a result, very few biotopes are sampled leading to poor collection of benthos which is not representative of the reaches. However, the presence of benthos with high score indicate these reaches are healthy and the quality of water is good. For example, IFR site 4 has two species of *Betide,* and numerous (172) of *Tricorythidae.* IFR site 5 has many *Tricorythidae* and IFR site 6 has *Oligonueriidae,* the most sensitive macroinvertebrate with score of 15 and *Perlidae* which is among sensitive benthos with score of 12 and numerous (112) of *Tricorythidae.*

According to (Strydom et al, 1992) all rivers cannot be maintained in natural state mainly due to human pressures on water are increasing at a high rate. Dam impoundments and regulated releases are examples of human pressures on water driven behind by need to sustain socio-economic benefits from the freshwater systems. The main impacts on rivers are attributed to over-abstraction of water which can be caused by impoundments among others, dam impoundments, weirs and inappropriate land use practices and management (Strydom et al, 1992). To some extend impoundments deny rivers natural ability to dilute pollutants (Dallas et al, 1993). In the LHWP area, the IFR sites proximal to structures are exposed to a threat of reduced assimilative capacity for pollutants, however, the impact is minimized due to the fact that there are no socio-economic projects such as factories, farming with excessive use of pesticides and manure in the highlands which can release high level pollutants into the rivers and dams. The reaches distal to structures are not expected to indicate water quality change that could be related to dam releases.

7 REFERENCES

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