

# LESOTHO HIGHLANDS DEVELOPMENT AUTHORITY

## ANNUAL FLOW RELEASES INSTREAM FLOW REQUIREMENT (IFR) IMPLEMENTATION AND MONITORING



*(October 2005 to September 2006)*



*REPORT NO.7*

**OCTOBER 2007**

**STRATEGIC AND CORPORATE SERVICES DIVISION  
MONITORING AND EVALUATION BRANCH**

Aquatic Systems Section  
HYDROLOGY

## TABLE OF CONTENTS

	Page
<b>Executive Summary .....</b>	<b>iii</b>
<b>List of Figures .....</b>	<b>vi</b>
<b>List of Tables .....</b>	<b>vii</b>
<b>Introduction.....</b>	<b>1</b>
<b>1. Katse Dam .....</b>	<b>5</b>
Inflows.....	6
Hydrological Classes.....	6
Dam Releases.....	8
Discharges through the Low level Outlets.....	8
Fresnet Releases.....	8
Flood Releases.....	8
Spillage.....	9
Recorded flows at Katse Bridge Hydrometric Station.....	9
<b>2. Mohale Dam.....</b>	<b>12</b>
Inflows.....	12
Hydrological Classes.....	12
Dam Releases.....	13
Discharges through the Low level Outlets.....	15
Seepage.....	15
Flood Releases.....	15
Spillage.....	16
Recorded flows at IFR site 7 Reach.....	16

<b>3. 'Muela Dam.....</b>	<b>18</b>
Flow Releases.....	20
Discharges through the Low level Outlets.....	20
Spillage.....	20
Recorded flows at Hololo River Downstream of the 'Muela Dam.....	20
<b>4. Matsoku Diversion Weir and Tunnel.....</b>	<b>22</b>
Matsoku Weir Releases.....	22
Flows Recorded at Matsoku River Downstream of The Diversion Weir and Tunnel.....	24
Discharges through the Tunnel Outlet to Katse Dam.....	24
Spillage.....	24
<b>5. Conclusions.....</b>	<b>26</b>
<b>6. Recommendations.....</b>	<b>29</b>

## EXECUTIVE SUMMARY

This Report: “Annual Flow Releases for IFR Policy Implementation and Monitoring – October 2005 to September 2006” provides information on compliance with the IFR policy and procedures of the Lesotho Highlands Water Project (LHWP). The report covers the release of water for IFR purposes from Katse Dam, Mohale Dam, Muela Dam and the Matsoku diversion Weir. The report also covers the hydrological year classification and monitoring of inflows into these structures.

### Katse Reservoir

Generally the hydrological year 2005/2006 was characterized by wet climatic conditions. Table 1 below shows quarterly inflows into the Katse Reservoir and the associated hydrological year classes in which these inflow figures belong.

**Table 1: Katse Reservoir Inflows**

Quarter	Inflow into Katse (MCM <sup>1</sup> )	Actual Hydrological Year Class
Oct 2005 – Dec 2005	242.40	Plus 1
Jan 2006 – Mar 2006	832.10	Plus 2
Apr 2006 – Jun 2006	282.90	Plus 2
Jul 2006 - Sep 2006	322.61	Plus 2
<b>Total</b>	<b>1,680.01</b>	

The total recorded and/or calculated reservoir inflow for 2005/2006 hydrological year is 1,680.01 MCM. This is inclusive of the transfers of 51.85 MCM from Matsoku Diversion Weir and Tunnel<sup>2</sup> and 412.03 MCM from Mohale Dam. When these transfers are deducted, the net inflow from the Katse Catchment

<sup>1</sup> Million cubic metres of water

<sup>2</sup>The Matsoku data records do not include the records for October and November 2005, and June and July 2006. The data records for August and September 2006 do not include the Tunnel flows to Katse Dam. It has since been discovered that the meters at this structure were all malfunctional and the existing gaps are filled with the estimated flows from the Matsoku Hydrometric Station at Seshote. See Table 10 for details

was 1,216.13 MCM, which is above the 'very wet' (Plus 2) classification range for Katse reservoir.

An actual amount of 67.03 MCM was released downstream from the Katse Dam during period, which was lower than Target Flow amounts of 84.40 MCM specified by the IFR policy. The target releases were based on the calculated quantities required to supplement the Khohlontšo inflows to achieve the prescribed flow requirements at IFR site 2

The actual volume of flows recorded at the Katse Bridge Hydrometric Station, a reference point for the flows through IFR river reach 2, downstream of the Katse Dam amounted to 108.04 MCM against the target IFR volume for this IFR site 2 of 109.50 MCM. No spillage occurred at Katse Dam during reporting period.

### **Mohale Reservoir**

The Mohale reservoir also experienced 'Plus 2' hydrological year classification conditions based on the total inflow for the year. Actual quarterly hydrological classification conditions varied from Plus 1 to Plus 2, to Plus 1 and to Average with Plus 2 class dominating the months of January-March 2006 as indicated in Table 2, below.

**Table 2: Mohale Reservoir Inflows**

<b>Quarter</b>	<b>Inflow into Mohale (MCM)</b>	<b>Actual Hydrological Year Class</b>
Oct 2005 – Dec 2005	113.25	Plus 1
Jan 2006 – Mar 2006	393.82	Plus 2
Apr 2006 – Jun 2006	81.15	Plus 1
Jul 2006 - Sep 2006	38.73	Average
<b>Total</b>	<b>626.95</b>	

The total recorded dam inflow for 2005/2006 hydrological year was 625.93 MCM, which is within the very wet 'Plus 2' range for Mohale.

A total amount of 55.32 MCM was released from the dam, which was higher by 19.06 MCM from a target of 36.26 MCM. However this figure includes the effects of spill events during the period and seepage through the dam wall. Mohale Dam experienced its first spill on the 13<sup>th</sup> February 2006 since its impoundment in October 2002. Several spill events occurred subsequent to this, contributing 31.29 MCM of the amounts released downstream.

The flow volume recorded at IFR site 7 amounted to 97.86 MCM against target IFR flow volumes of 89.10 MCM. A surplus of 8.76 MCM (9.83%) therefore occurred at IFR Site 7 during reporting period.

#### **'Muela Dam**

'Muela Dam released 1.23 MCM which is approximately 24% of the long term Mean Annual Runoff (MAR) of 5.05 MCM for the Nqoe River. No spill occurred at 'Muela Dam.

#### **Matsoku Diversion Weir and Tunnel**

The actual flow recorded at Matsoku hydrometric station downstream of the Matsoku weir was 78.54 MCM. The estimated Matsoku weir inflows based on this figure amounted to 70.68 MCM for period. Actual inflow volumes could not be definitively established due to faulty recording equipment at the weir. Based on the design capacity of the weir, it is estimated that 18.83 MCM was released downstream while 51.85 MCM was transferred to Katse.

#### **Conclusion**

In general there was compliance with the IFR Policy and Procedures for 2005/2006 Hydrological Year as target flows at IFR sites were either met or exceeded. However lack of and/or faulty measuring equipment at key points raises questions of the accuracy of the records. Further the inclusion of spilled water in the IFR releases figures is debatable.

**List of Figures:**

- Figure 1: Hydrological Map showing the major rivers and the locations of all IFR sites.
- Figure 2: The Katse Dam and the IFR site 2 reach
- Figure 3: The Mohale Dam and the IFR site 7 reach
- Figure 4: The Monthly Flow Releases and the target IFR releases from the Katse Dam.
- Figure 5: The Monthly Flow Releases and the target IFR releases from the Mohale Dam.
- Figure 6: The Monthly Flow Releases and the target IFR releases from the 'Muela Dam.
- Figure 7: The Monthly Estimated Flow Releases and the target releases requirement from the Matsoku Diversion Weir and Tunnel.

**List of Tables:**

Table 1: Summary of Katse Reservoir Inflows

Table 2: Summary of Mohale Reservoir Inflows

Table 3: Rainfall Patterns within the Katse Catchment

Table 4: Inflows and Transfers into Katse Reservoir

Table 5: Monthly Flow Releases and Target IFR Flows from the Katse Dam

Table 6: Rainfall Patterns within the Mohale Catchment

Table 7: Inflows into Mohale Reservoir

Table 8: Monthly Flow Releases and Target IFR Flows from the Mohale Dam

Table 9: Monthly Flow Releases from the 'Muela Dam

Table 10: Monthly Flow Releases from Matsoku Diversion Weir

## **INTRODUCTION**

The Lesotho Highlands Development Authority (LHDA) is mandated to implement IFR Policy and Procedures approved in December 2002. The IFR Policy and Procedures prescribe the amounts of water that must be released from dam structures to meet target flows at designated IFR sites. The targeted flows are intended to sustain the environment by meeting river health conditions so as not to comprise the aquatic benthic communities and the riparian vegetative plants. These releases are also aimed at sustaining social economic activities downstream.

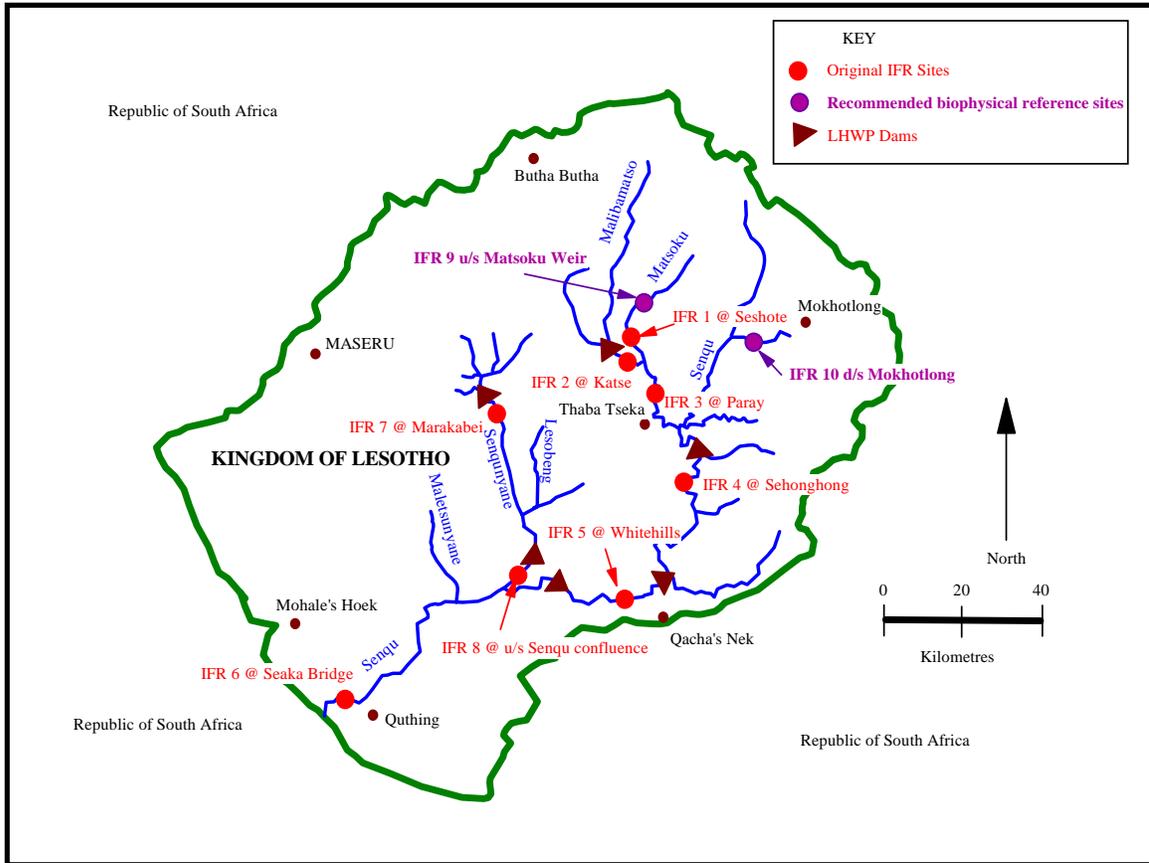
This report provides an account of compliance with the said IFR policy and procedures for flow releases downstream of the LHWP structures for the period October 2005 to September 2006. Compliance with the IFR Policy is measured at selected points along the rivers reaches downstream of the dam structures. These are designated as IFR sites where flow measurements are taken to verify this compliance.

All IFR sites are indicated on Figure 1, which shows the major river systems affected by the Lesotho Highlands Water Project (LHWP). Figure 2 shows the Katse Dam, the Downstream Hydrometric Station at Katse Bridge, the Khohlontšo Stream and the IFR site 2 reach. Figure 3 provides the locations along the Senqunyane River where IFR site 7 is situated 28 km downstream of the Mohale Dam wall.

Generally 2005/06 was a very wet year with snowfalls occurring more than two times in the Project area during winter months. The average snow depth measured 35 mm in May 2006, 43 mm in July 2006 and 38 mm in September 2006. Much rainfall also occurred in the Project area and throughout the entire Country during summer months. The average rainfall was 1,133.04 mm for Katse catchment and 1,248.60 mm for Mohale catchment during the hydrological year.

This report discusses in detail the events and variations experienced during the implementation of the IFR Policy and Procedures influenced by the prevailing weather conditions and other operational requirements for the 2005/2006 hydrological year.

**Figure 1: Hydrological map showing location of the original IFR sites and reference sites**



- IFR Site 1\* Matsoku near Seshote
- IFR Site 2\* Malibamatšo 3 km downstream from Katse road bridge
- IFR Site 3\* Malibamatšo at Paray
- IFR Site 4 Senqu at Sehong-hong
- IFR Site 5 Senqu at Whitehills
  
- IFR Site 6 Senqu at Seaka
- IFR Site 7\* Senqunyane at Marakabei
- IFR Site 8\* Senqunyane upstream of the Senqu confluence.

**Figure 2: Katse Dam and the IFR site 2 reach**

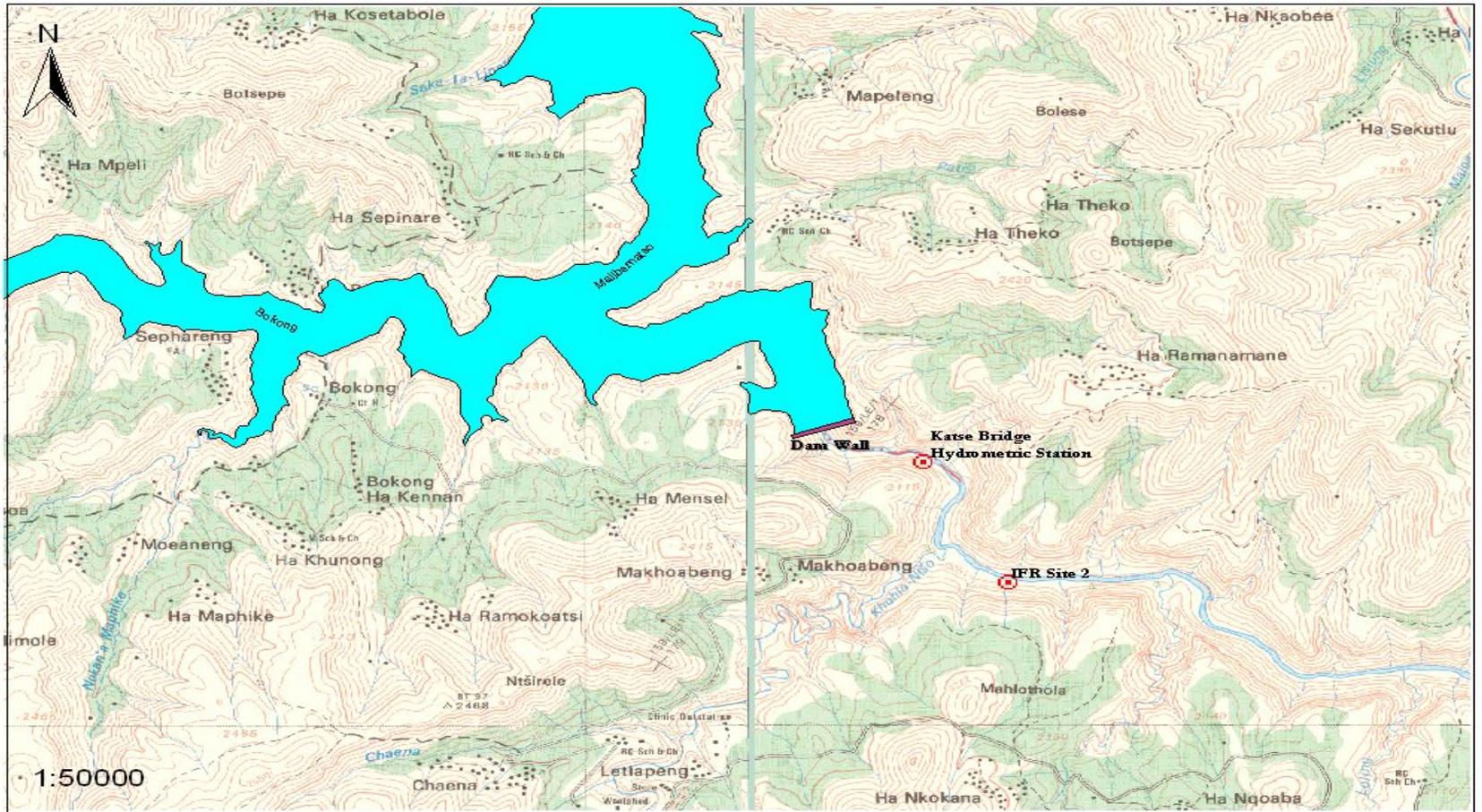
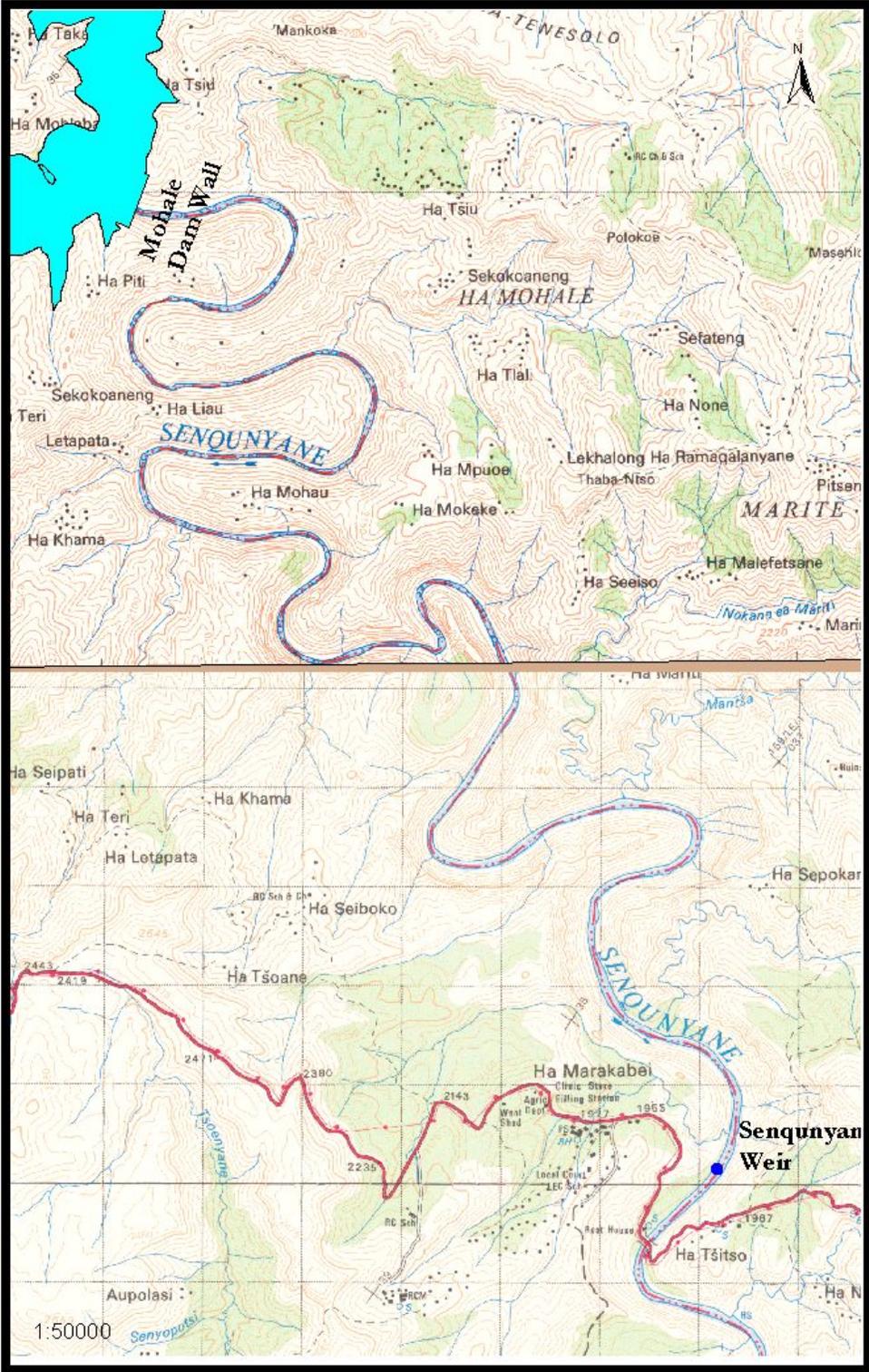


Figure 3: Mohale Dam and the IFR site 7 reach



## 1.KATSE DAM

**Figure 2** shows the location of key IFR areas downstream of the Katse dam, which are:

- a) Katse bridge hydrometric station at 1.06 km downstream
- b) Khohlontšo River, a tributary of Malibamatšo main channel River 2 km from the dam and providing additional flows to IFR Site 2
- c) IFR Site 2 at 3.06 km downstream of the dam.

Rainfall patterns within Katse catchment are illustrated in Table 3 below. Rainfall provides the necessary runoff to drive the implementation of IFRs. Likewise, snowfall occurred in Katse Catchment. Although snow replenishes moisture levels and provides the runoff when it is melted, This was experienced during period when Data collection was hampered by inaccessibility.

**Table 3**  
**Rainfall patterns within the Katse Catchment**

Month	Mphosong	Rampai	Ha-Poli	Makopela	Katse Village
05-Oct	284.30	183.00	120.80	141.70	114.60
05-Nov	272.30	136.50	126.20	162.40	105.10
05-Dec	79.20	38.80	43.70	18.70	21.30
06-Jan	399.10	222.00	141.60	194.60	174.40
06-Feb	424.70	208.50	174.30	154.80	160.80
06-Mar	251.60	74.50	81.10	98.80	101.80
06-Apr	178.10	65.50	48.80	44.80	51.70
06-May	37.90	45.00	17.10	20.00	16.00
06-Jun	24.00	0.00	1.80	1.80	0.00
06-Jul	23.30	0.00	2.00	0.30	0.00
06-Aug	0	118.00	68.70	75.90	56.50
06-Sep	12.30	8.00	7.30	11.20	18.00
<b>Total</b>	<b>1,986.80</b>	<b>1,099.80</b>	<b>833.40</b>	<b>925.00</b>	<b>820.20</b>

### Inflows

The Katse reservoir received a total inflow of 1,680.01 MCM for the 2005/2006 hydrological year. This amount of inflows into the Katse Dam is inclusive of the transfers of 412.03 MCM from Mohale Dam and 51.86 MCM estimated from the Matsoku Diversion Weir and Tunnel. The estimated net inflow into the Katse reservoir was therefore 1,216.12 MCM. Table 5, below, presents the monthly inflows and releases data for the Katse Reservoir.

### Hydrological Classes

The Plus 2 hydrological year class ranges from the minimum of 757.20 MCM to the maximum of 1,183.40 MCM as given in Table 2.2-A of the IFR Procedures. The net inflows into the Katse Dam during 2005/2006 hydrological year fall beyond this range. The Actual quarterly hydrological classification conditions varied from 'Plus 1 to Plus 2' hydrological year classification conditions, with Plus 2 class dominating the larger part of the year. Table 4 presents the quarterly flows and the actual Hydrological classifications.

**Table 4: Actual Quarterly inflows into Katse Reservoir (in MCM)**

Quarter	Total Inflow into Katse Dam	Less Transfers from Mohale Dam	Less Transfer from Matsoku	Add Incremental Catchment Flows	Net Actual Inflows at IFR Site 2	Actual Hydrological Class
Oct 2005 To Dec 2005	242.40	0.00	7.60	3.12	237.92	Plus 1
Jan 2006 To Mar 2006	832.10	119.07	71.29	19.23	660.97	Plus 2
Apr 2006 To Jun 2006	282.90	105.86	17.03	6.92	166.93	Plus 2
July 2006 To Sept 2006	322.62	187.09	0.00	11.74	148.48	Plus 2
<b>Total</b>	<b>1,680.02</b>	<b>412.02</b>	<b>95.92</b>	<b>41.01</b>	<b>1,214.30</b>	

**Table 5:**  
**Monthly Flow Releases and the Target IFR flows from the Katse Dam**

Month	Assumed Hydrological Categories	Inflows at Dam site	Target Dam Release MCM				Actual Dam Release MCM				IFR Site 2 Target Flow Volume	Katse Bridge Hydrometric Station Actual Volume	Actual Recorded at IFR Site 3 Reach (Malibamatšo at Paray Weir)	Actual Water Delivered to RSA
			MCM	Floods	Freshets	Low Flows	Total	Floods	Freshets	Low Flows				
Oct-05	Average	90.63	0.00	0.00	2.95	2.95	0.00	0.00	3.29	3.29	5.02	4.29	7.27	65.71
Nov-05	Average	89.72	9.00	0.00	3.11	12.11	0.00	0.00	3.20	3.20	14.32	4.35	8.74	58.11
Dec-05	Average	62.05	0.00	0.00	3.21	3.21	0.00	0.00	3.33	3.33	5.16	4.30	8.54	55.13
Jan-06	Plus 1	187.85	4.50	3.50	3.48	11.48	0.00	0.00	3.33	3.33	14.70	4.69	13.62	74.55
Feb-06	Plus 1	380.12	9.00	0.00	3.14	12.14	13.55	0.00	3.14	16.69	15.30	30.59	78.92	67.38
Mar-06	Plus 1	264.13	0.00	3.50	3.48	6.98	0.00	6.98	3.62	10.59	10.40	14.56	37.20	74.55
Apr-06	Plus 2	181.69	4.50	0.00	3.24	7.74	7.13	0.00	3.48	10.61	10.40	11.08	18.99	72.14
May-06	Plus 2	86.89	0.00	1.50	3.21	4.71	0.00	0.00	3.49	3.49	6.30	6.76	9.39	75.15
Jun-06	Plus 2	14.32	4.50	0.00	2.85	7.35	0.00	0.00	3.36	3.36	8.20	6.54	5.68	75.62
Jul-06	Plus 2	76.71	0.00	1.50	2.95	4.45	0.00	0.00	3.45	3.45	5.40	6.84	5.25	75.72
Aug-06	Plus 2	140.65	4.50	0.00	2.68	7.18	0.00	0.00	2.98	2.98	7.90	6.56	11.01	77.24
Sep-06	Plus 2	105.26	0.00	1.50	2.59	4.09	0.00	0.00	2.71	2.71	6.40	7.48	7.96	64.83
<b>Total</b>		<b>1,680.02</b>	<b>36.00</b>	<b>11.50</b>	<b>36.89</b>	<b>84.39</b>	<b>20.68</b>	<b>6.98</b>	<b>39.38</b>	<b>67.03</b>	<b>109.50</b>	<b>108.04</b>	<b>212.57</b>	<b>836.13</b>

\*\* There is no gauging station at IFR site 2, the designated point for demonstrating compliance with IFR Policy.

### **Dam Releases**

The actual total volume of water released from the Katse Dam Outlets during October 2005 to September 2006 is 67.03 MCM, which is 17.37 MCM (20.58%) lower than the targeted IFR release requirement of 84.40 MCM. This variance is attributed to the floods and freshets that were not released.

The other factor to note is that the discharge or flow volume released downstream of the Katse Dam is hydraulically driven by the reservoir level (the Head of water in the reservoir). When the reservoir level is high, more discharge will be released downstream, and when the reservoir level is low the discharge will be lower at the same percentage opening.

### **Discharges through the Low Level Outlets**

The volume of water released through the Low Level Outlets (LLOs) amounts to 20.68 MCM for this period. This amount is 15.32 MCM (43%) less than the target flood of 36.00 MCM.

### **Freshet Releases**

The total volume of 6.98 MCM that combines the Freshet volume of 3.50 MCM for January and March 2006 was released in March 2006. Freshets releases for May, July and September of 1.50 MCM each were however missed completely. In total the released volume was 4.52 MCM (39%) less than the target freshets volume of 11.50 MCM.

### **Flood Releases**

The flood volume of 13.55 MCM that combines the January flood volume of 4.50 MCM and the February flood volume of 9.00 MCM was released in February 2006. Another scheduled flood volume of 7.13 MCM was released in April 2006. Thus a total of 20.68 MCM was released as within-year floods, which is 15.32 MCM (43%) less than the targeted within year flood release of 36.00 MCM for the hydrological year 2005/2006 for Katse Dam.

Inflows into the Katse reservoir reduced from 90.63 MCM in October to 62.05 MCM in December 2005, and so naturally occurring floods could not be envisaged, therefore, no within-year flood releases were effected. The dry December 2005 weather conditions continued into January 2006. Rainfall patterns and naturally occurring floods did not occur in January 2006. However this situation improved towards the end of January 2006 and the total Inflow into the Katse reservoir increased to 187.85 MCM. See rainfall patterns shown in Table 3.

From Table 5 Flow data from Hydrometric Stations, the last three columns; Malibamatšo River at Katse bridge and Malibamatšo River at Paray shows that there was enough flooding during the reporting period and the required number of floods were naturally satisfied and even exceeded.

The scheduled flood of November 2005 could not be released due to operational difficulties, shortage of manpower resources (to monitor the release) and climatic weather conditions experienced during October, November and December 2005.

Hydrological field data could also not be collected on time to enable hydrological year classification process for the revision of IFR required flows to be done as scheduled.

### **Spillage**

Despite the relatively wet climatic conditions within the Katse Dam catchment area, the dam did not spill during the entire 2005/2006 hydrological year. This solemnly indicates that the inflows into the Katse Dam were not enough to take the reservoir level to its Full Supply Level. The Katse reservoir only reached a maximum level for the year of 2052.667 masl on 15<sup>th</sup> May 2006, which is 99% of the full capacity level.

### **Recorded Flows at the Katse Bridge Hydrometric Station**

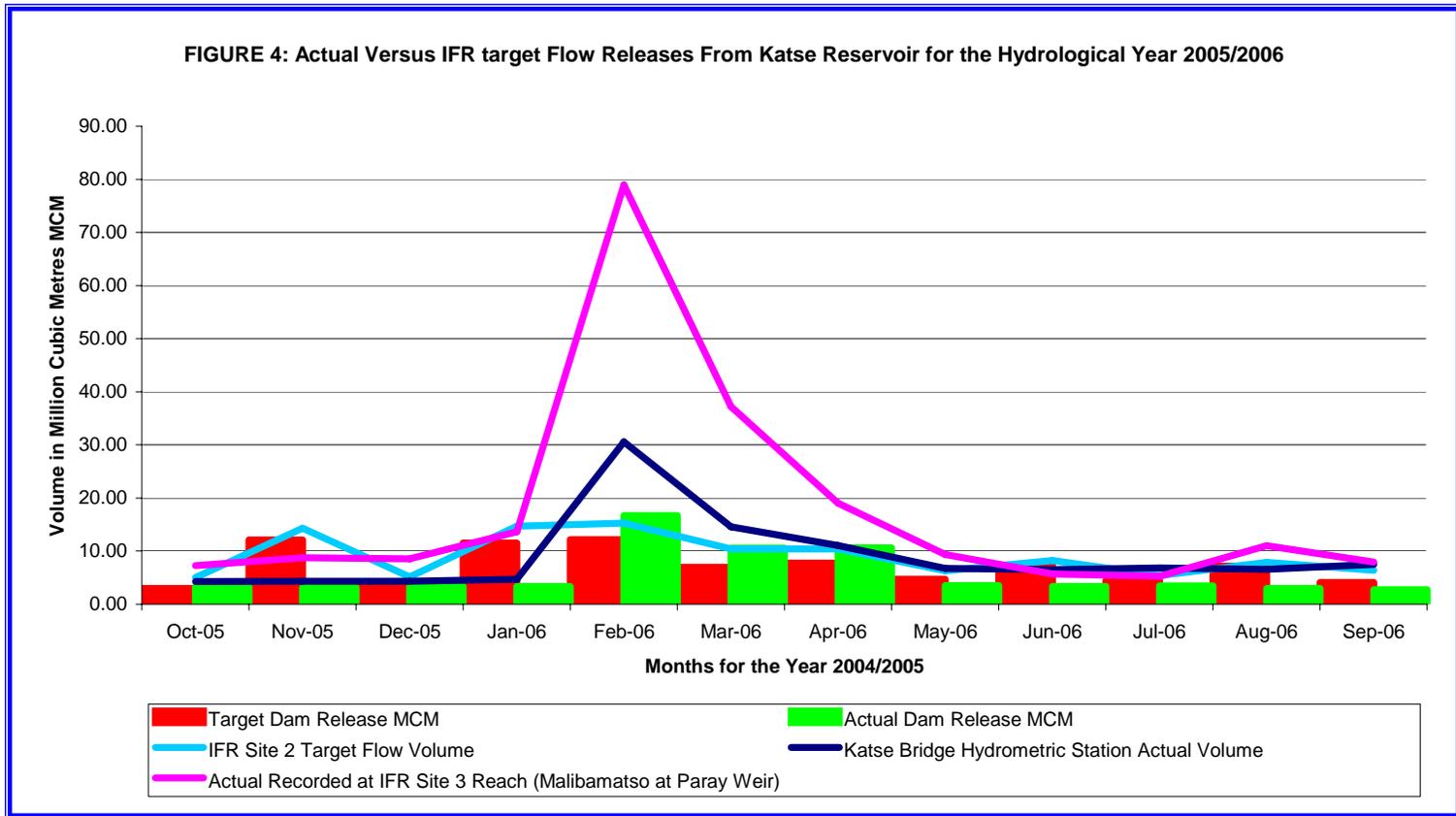
The LHDA uses the records of this flow recording station to give indications of the flows at IFR site 2 attributable to the Dam releases and the catchment contributions, due to the absence of the recording station at the actual IFR site 2, see figure 2.

The actual total volume of water recorded at the Katse Bridge Hydrometric Station was 108.04 MCM. The required target flow release at Katse dam site of 84.40 MCM was calculated to achieve the target river flow of 109.50 MCM at IFR site 2 downstream of the Katse Bridge Hydrometric Station. The actual flow of water recorded at the Katse Bridge Hydrometric Station was therefore only 1.46 MCM (1.33%) less than the stipulated IFR target flow at the IFR site.

The above figures indicate that, although a deficit occurred in dam releases, the IFR requirement was almost satisfied at the Hydrometric Station (IFR site 2 Reach). The environment was able to provide the most crucial and needed incremental catchment flows.

Figure 4 on page 11 graphically presents the recorded Monthly Flow Releases from the Katse Dam, the recorded flows at the Hydrometric station on Malibamatšo River at Paray Weir (IFR site 3 reach), the Hydrometric Station at Katse Bridge just downstream of the Katse Dam Wall (labeled IFR Site 2 Reach) and upstream of IFR site 2 reach, and the target IFR releases at both the Katse Dam site and IFR site 2.

**Figure 4:**  
**The actual Monthly flow releases versus the Target IFR flow releases from Katse dam.**



## 2. MOHALE DAM

Figure 3 provides the locations along the Senqunyane River where IFR site 7 is situated some 28 km downstream of the Mohale Dam wall.

Table 6 shows the rainfall occurrence within the Mohale catchment area during October 2005 to September 2006.

**Table 6: Rainfall patterns within the Mohale Catchment**

Month	Chehe	Rapokolana	Thaba-Putsoa
05-Oct	71.20	100.20	163.50
05-Nov	48.40	139.90	207.50
05-Dec	18.70	46.00	55.90
06-Jan	243.70	234.10	203.40
06-Feb	201.60	273.90	321.60
06-Mar	135.20	157.80	223.60
06-Apr	62.10	121.60	178.00
06-May	47.10	47.50	163.50
06-Jun	1.20	0.00	0.00
06-Jul	0.00	0.30	0.00
06-Aug	53.60	72.10	84.60
06-Sep	34.10	9.70	24.10
<b>Total</b>	<b>916.90</b>	<b>1,203.10</b>	<b>1,625.70</b>

### Inflows

The Mohale Dam received a total reservoir inflow of 625.93 MCM for the 2005/2006 hydrological year. The total volume of 412.03 MCM was also transferred to Katse Dam during this period.

### Hydrological Classes

Mohale has experienced the aggregate of 'Plus 2' hydrological year classification during period. The 'Plus 2' hydrological year class for Mohale catchment ranges from the minimum of 485.80 MCM to the maximum of 893.60 MCM as given in Table 2.2-B of the IFR Procedures and the inflows into Mohale reservoir fall within this range.

Actual quarterly hydrological classification conditions varied from 'Average to Plus 2' hydrological year classification conditions with Plus 2 class dominating the months of; January, February and March 2006.

**Table 7 : Quarterly Inflows into Mohale Reservoir**

<b>Quarter</b>	<b>Inflow into Katse Dam</b>	<b>Incremental Catchment Flows</b>	<b>Actual Inflows at IFR Site 7</b>	<b>Actual Hydrological Class</b>
Oct 2005 To Dec 2005	112.22	1.03	113.25	Plus 1
Jan 2006 To Mar 2006	393.82	27.79	421.61	Plus 2
Apr 2006 To Jun 2006	81.15	8.58	89.73	Plus 1
July 2006 To Sept 2006	38.73	5.12	43.85	Average
<b>Total</b>	<b>625.92</b>	<b>42.52</b>	<b>668.44</b>	

### **Dam Releases**

The actual total volume of water released from the Mohale Dam Outlets, including spill and seepage is 55.32 MCM, which is 19.06 MCM (34%) higher than the targeted dam releases for IFR release requirement in order to meet the required flow at IFR site 7 downstream of the Mohale Dam. The required target release at dam site was 36.26 MCM, which was calculated to achieve the target river flow of 89.10 MCM at IFR site 7 downstream of the Mohale Dam.

**Table 8:**  
**Monthly Flow Releases and the target IFR Flows from Mohale Dam**

Months Since October 2005 to September 2006	Assumed Hydrological categories	Inflows at Dam site  MCM	Target Dam Release MCM			Actual Dam Release MCM					IFR Site 7 Target Flow Volume  MCM	IFR Site 7 Actual Volume  MCM	Actual Water Delivered to Katse Dam  MCM
			Floods	Low Flows	Total	Low Flow	Floods	Spill	Seepage	Total			
Oct-05	Average	48.11	0.00	2.01	2.01	2.11	0.00	0.00	0.00	2.11	6.88	2.31	0.00
Nov-05	Average	40.37	0.00	3.27	3.27	3.02	0.00	0.00	0.00	3.02	11.26	3.68	0.00
Dec-05	Average	23.74	0.00	1.45	1.45	1.91	0.00	0.00	0.00	1.91	4.95	2.08	0.00
Jan-06	Plus 1	91.58	0.00	2.52	2.52	2.38	0.00	0.00	0.00	2.38	8.55	7.60	0.00
Feb-06	Plus 1	205.90	7.30	3.14	10.44	1.17	0.00	19.80	0.30	21.27	17.61	38.42	37.56
Mar-06	Plus 1	96.34	0.00	2.81	2.81	2.47	0.00	9.91	0.37	12.76	9.91	18.18	81.51
Apr-06	Plus 1	46.80	0.00	2.07	2.07	1.39	0.00	1.58	1.35	4.32	7.26	8.45	71.97
May-06	Plus 1	27.49	0.00	1.61	1.61	0.05	0.00	0.00	1.54	1.59	4.07	5.26	33.89
Jun-06	Plus 1	6.86	0.00	1.43	1.43	0.00	0.00	0.00	1.54	1.54	2.45	2.32	0.00
Jul-06	Plus 1	19.66	0.00	1.34	1.34	0.00	0.00	0.00	1.59	1.59	2.95	1.85	67.10
Aug-06	Plus 1	7.66	3.90	1.47	5.37	0.00	0.00	0.00	1.44	1.44	7.23	4.36	64.82
Sep-06	Plus 1	11.41	0.00	1.94	1.94	0.75	0.00	0.00	0.64	1.39	5.98	3.33	55.17
<b>Total for Year 2005/2006</b>		<b>625.93</b>	<b>11.20</b>	<b>25.06</b>	<b>36.26</b>	<b>15.26</b>	<b>0.00</b>	<b>31.29</b>	<b>8.76</b>	<b>55.32</b>	<b>89.10</b>	<b>97.86</b>	<b>412.03</b>

### **Discharges through the Low Level Outlets (LLOs)**

No releases were made through the LLOs. The scheduled within-year floods of **7.30** MCM for February 2006 and **3.90** MCM for August 2006 were also not effected. The spills that occurred from the 13<sup>th</sup> February 2006 to the 4<sup>th</sup> March 2006 far exceeded the plus 2 hydrological year class required flood releases. The rainfall situation provided a good opportunity to test the spillway. A decision was therefore taken not to release either low flows or floods through the LLOs but to test the spillway.

### **Seepage**

Consequent to the development of a crack in the dam wall, water had been seeping downstream of the dam for some time. An exercise had to be carried out to quantify the seepage water. However due to high rainfall conditions and spill events, this quantification of the seepage water could only happen after May 2006.

In order to assess and obtain the track record of the seepage downstream of Mohale dam, the 500 mm and 200 mm diameter sleeve valves were both closed from May 2006 to September 2006. The results of the assessment indicate that Seepage accounted for **8.76** MCM of the flow downstream of the dam.

### **Flood Releases**

Rainfall patterns, which dominated the Mohale catchment area, provided naturally occurring floods. As a result, no flood releases were effected from Mohale Dam for the hydrological year 2005/2006. Although there was a scheduled flood release of 3.90 MCM for the month of August 2006, this flood could not be released for this reason but also due to the exercise to assess and quantify the seepage flow.

During this same period maintenance works and repairs were also carried out on the crack that had occurred in the Mohale Dam Wall and on the LLO gates.

### **Spillage**

Mohale Dam experienced its first spill on the 13<sup>th</sup> February 2006 since its impoundment in December 2002. The total volume of 19.80 MCM spilled from the 13<sup>th</sup> to the end of February 2006. This spill event continued to the 4<sup>th</sup> March 2006 and a further volume of 9.91 MCM was recorded. The wet conditions dominated the Mohale catchment area until April 2006 with a spill volume of 1.58 MCM occurring in April. The total spilled volume for the Hydrological Year 2005/2006 amounts to 31.29 MCM.

### **Flows Recorded at IFR Site 7 Reach**

The total volume of water recorded at IFR Site 7 was 97.86 MCM. This is 8.76 MCM (9.8%) higher than the stipulated IFR target flow at this site for the considered period, October 2005 to September 2006.

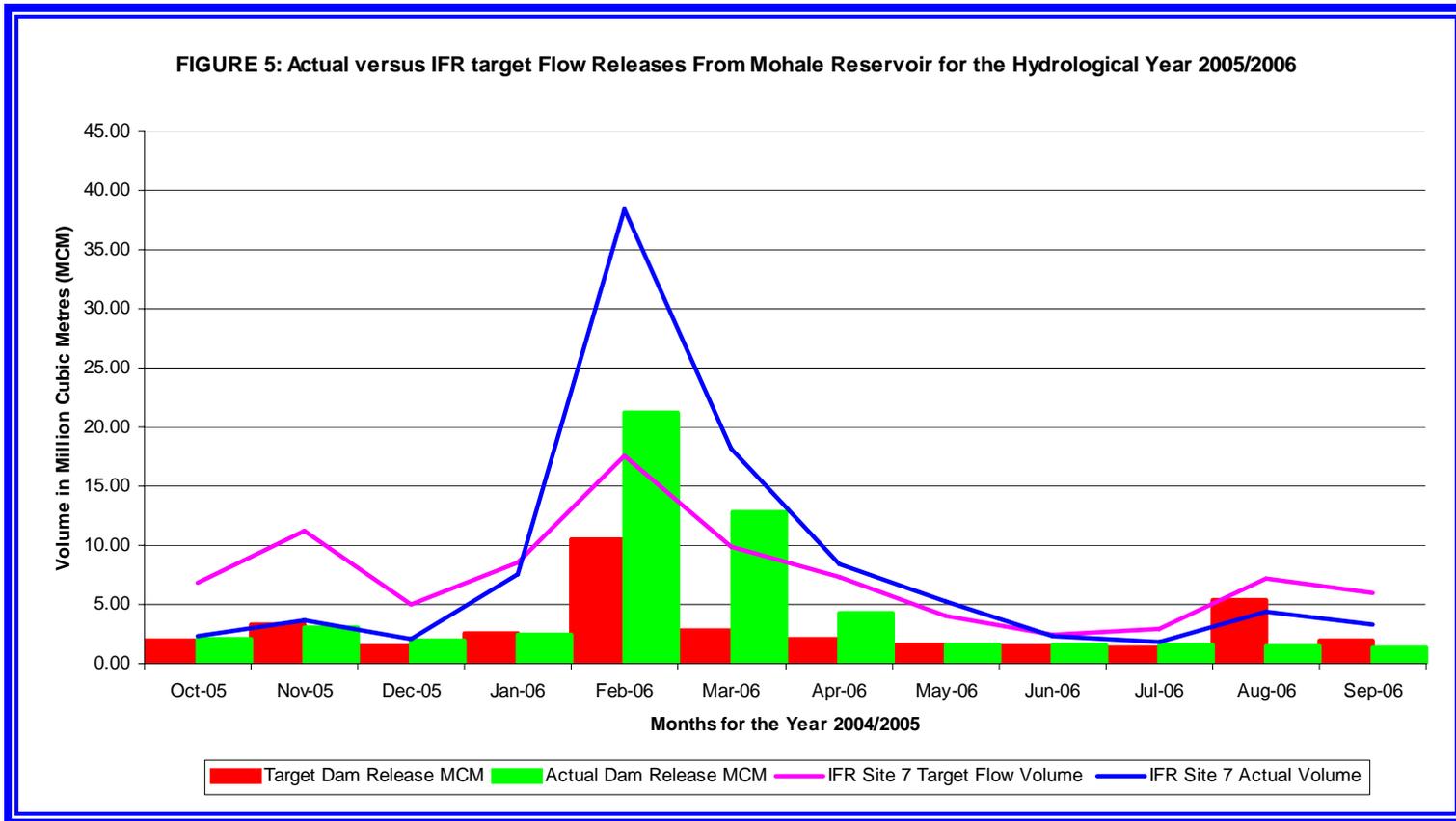
The above figures indicate that despite the disturbances that were experienced at Dam site, the IFR Policy requirements were met and exceeded with a surplus of 8.76 MCM. This was mainly due to the spill and seepage events, which more than compensated for the missed releases and shortfalls in the contribution of the incremental catchment.

Table 8 on page 14 gives the volumes of water as stipulated in the IFR Policy and Procedures, the actual released amounts from the Mohale Dam and actual recorded flows at IFR site 7. It also provides the overall total at the end of the period October 2005 to September 2006.

Figure 5 on page 17 presents the recorded Monthly Flow Releases from the Mohale Dam. It also shows the recorded flows from the Weir station on Senqunyane River at IFR site 7, the target IFR releases from the Mohale Dam site and the target flows for IFR site 7.

**Figure 5:**

**The actual Monthly flow releases versus the Target IFR flow releases from Mohale Dam.**



### **3. 'MUELA DAM**

There is no IFR requirement stipulated for 'Muela Dam since the Nqoe River flows are not considered to be part of the Treaty flows. Accordingly 100% of the Mean Annual Runoff (MAR) of Nqoe River system was released at a constant rate until November 2004 when 'Muela dam releases were reduced from 100% to 25% of Nqoe's MAR. It was agreed in December 2004 to 'bank' water in LHWP structures for later emergency releases to the Phuthi River to offset drought conditions and to meet water demand in the Maseru City during dry seasons. As a result of this agreement, 'Muela dam assumed IFR releases of 25% of Nqoe's MAR in December 2004.

Table 9 on page 19 gives the monthly volumes of water released downstream of the 'Muela Dam for period. It also provides the overall total at the end of the period.

**Table 9: Monthly Flow Releases from the 'Muela Dam**

Months Since October 2005 to September 2006	Target Dam Site Releases for IFR Requirements	Actual Dam Site Releases Measured at Hydrometric Station			Actual Recorded at Nqoe River Upstream of the 'Muela Dam	Actual Recorded at Hololo River downstream of the 'Muela Dam
	Low Flows	Floods	Spill Flow	Total Flows		
	MCM	MCM	MCM	MCM		
Oct-05	0.10	0.00	0.00	0.10	0.07	0.92
Nov-05	0.10	0.00	0.00	0.10	0.14	1.54
Dec-05	0.11	0.00	0.00	0.11	0.09	1.87
Jan-06	0.10	0.00	0.00	0.10	1.36	18.18
Feb-06	0.09	0.00	0.00	0.09	0.00	12.81
Mar-06	0.10	0.00	0.00	0.10	0.00	7.53
Apr-06	0.10	0.00	0.00	0.10	0.00	5.95
May-06	0.11	0.00	0.00	0.11	0.12	4.46
Jun-06	0.10	0.00	0.00	0.10	0.09	1.98
Jul-06	0.11	0.00	0.00	0.11	0.05	0.11
Aug-06	0.11	0.00	0.00	0.11	0.32	0.00
Sep-06	0.10	0.00	0.00	0.10	0.08	0.00
<b>Total</b>	<b>1.23</b>	<b>0.00</b>	<b>0.00</b>	<b>1.23</b>	<b>2.32</b>	<b>55.34</b>

## **Flow Releases**

The estimated volume of water at 24% long term Mean Annual Runoff (MAR) of the Nqoe River system released from the 'Muela Dam Outlets is 1.23 MCM.

A V-notch weir downstream of the 'Muela Dam exists but lacks a continuous flow recording capability to confirm downstream releases as there is no data logger or Automatic recorder at this station. In addition the V-notch weir is located in a partly inaccessible location, which makes daily observations difficult. Therefore the 'Muela downstream releases could not be confirmed.

## **Discharges through the Low Level Outlet**

There were no releases through the LLO.

## **Spillage**

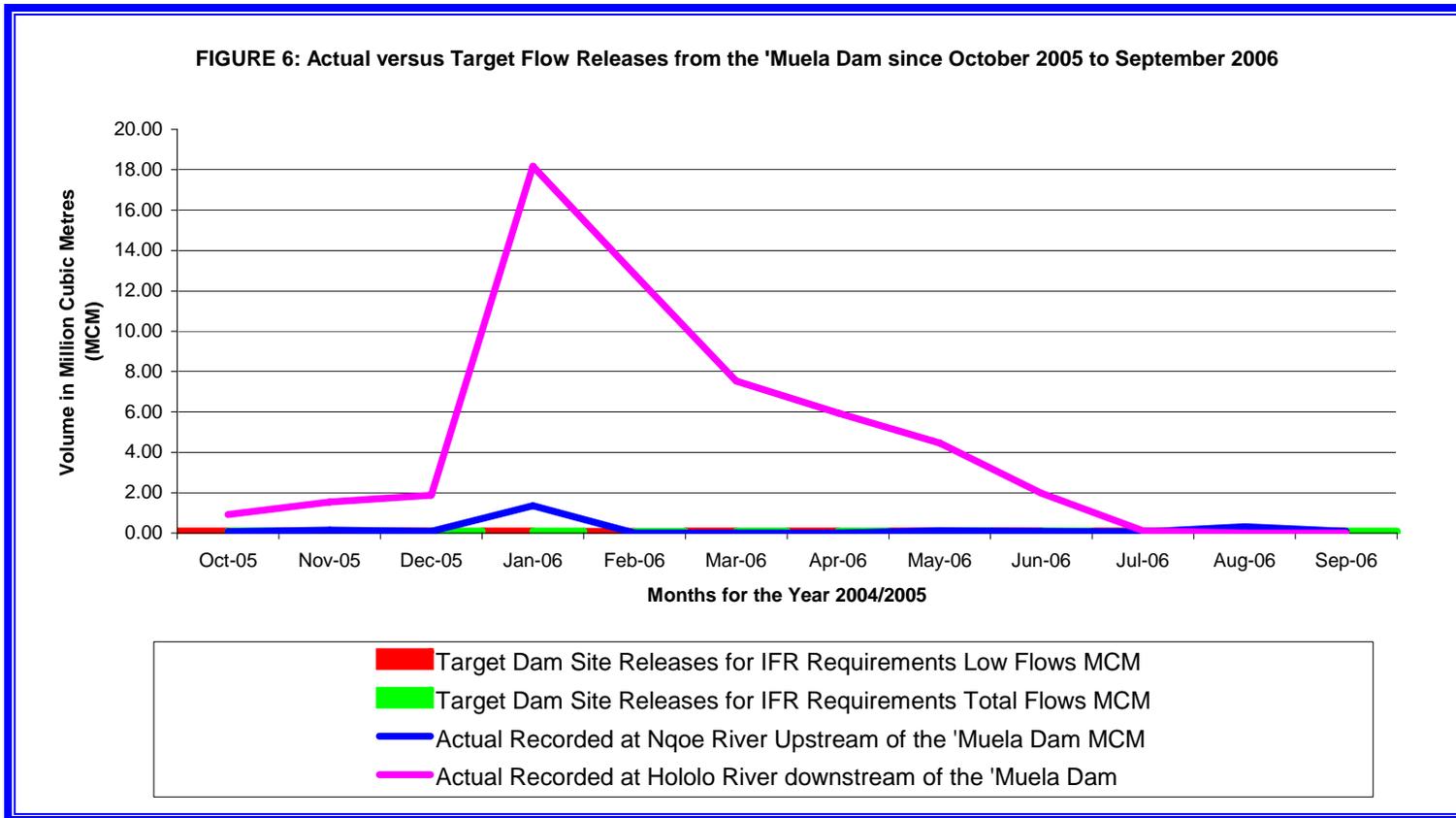
'Muela Dam did not spill during October 2005 to September 2006.

## **Flows Recorded at Hololo River Downstream of the 'Muela Dam**

The total volume of water recorded at the Hololo River System is 55.34 MCM. The total volume of water released downstream of the 'Muela Dam into Hololo River system during period amounted to 1.23 MCM, which is 24% of the long term Mean Annual Runoff of 5.05 MCM of the Nqoe River system.

Figure 6 on page 21 shows the flows from the 'Muela Dam outlets as compared with those from the Nqoe River Hydrometric Station upstream of 'Muela dam. The Hololo River flows are also shown on this figure. It is observed that the Nqoe Inflows are much higher than the 'Muela Dam Outflows and indicating that the excess water amounting to 1.09 MCM was banked. The Nqoe flows however, decreased in magnitude to 0.00 MCM for most part of the year.

**Figure 6: The actual Monthly flow releases versus the Target IFR flow releases from the 'Muela Dam.**



#### **4. MATSOKU DIVERSION WEIR AND TUNNEL**

The Matsoku Diversion Weir is a non-storage facility and it is designed to be operated automatically to satisfy the IFR requirements at IFR site 1 of the Matsoku Diversion Weir and Tunnel. The design is such that flow volumes below  $0.6 \text{ m}^3/\text{s}$  are automatically released downstream.

Table 10 on page 23 shows the Matsoku Diversion Weir and Tunnel downstream flows and Transfers to Katse dam, estimated inflows into the Matsoku Diversion Weir and Tunnel and River flows at Seshote Hydrometric Station for the period October 2005 to September 2006.

The targeted flow volume, if the flow rate of  $0.6 \text{ m}^3/\text{s}$  was constantly released downstream, amounts to 18.92 MCM for the period October 2005 to September 2006. The actual recorded downstream flow volume amounts to 8.61 MCM whilst the estimated volume, as calculated from the computed inflow into the Matsoku Weir is 18.83 MCM.

The Matsoku River Hydrometric station at Seshote was used to evaluate the performance of the Matsoku Weir. This station recorded a flow volume amounting to 78.54 MCM for the same period. The transferred water from the Weir into Katse Dam was recorded as 95.92 MCM.

##### **Matsoku Weir Releases**

The actual measured downstream flow releases from the Matsoku Diversion Weir and Tunnel amounts to 8.61 MCM. It is far too small compared to the estimated flow volume of 18.83 MCM. This could be because the measured released amount of 8.61 MCM excludes flows for the months of October and November 2005, and June and July 2006. In addition the recording equipment experienced several break down during the period such that the actual measured flows were bound to be lower than the total estimated (calculated) flows.

**Table 10: Recorded and Estimated Monthly Flows at the Matsoku Weir.**

Months Since October 2005 to September 2006	Estimated Volume Downstream Release (@ 0.6m <sup>3</sup> /s)	Actual recorded flow - Matsoku Weir Downstream Releases	Target Matsoku Weir Downstream Releases for IFR Requirements	Measured Transfers to Katse Dam	Estimated Transfers to Katse Dam	Actual Recorded at Matsoku River downstream of the Diversion Weir and Tunnel	Estimated Matsoku Weir Inflows
	MCM	MCM	MCM	MCM	MCM	MCM	MCM
Oct-05	1.55	0.00	1.61	0.00	4.42	6.64	5.98
Nov-05	1.56	0.00	1.56	0.00	2.34	4.32	3.89
Dec-05	1.61	2.28	1.61	7.60	2.78	4.88	4.39
Jan-06	1.61	1.03	1.61	12.72	3.60	5.79	5.21
Feb-06	1.45	0.98	1.45	30.89	21.67	25.69	23.12
Mar-06	1.61	1.11	1.61	27.68	7.49	10.11	9.10
Apr-06	1.56	0.88	1.56	13.71	3.14	5.22	4.70
May-06	1.61	1.00	1.61	3.32	2.31	4.35	3.92
Jun-06	1.56	0.00	1.56	0.00	0.47	2.25	2.03
Jul-06	1.57	0.00	1.61	0.00	0.14	1.90	1.71
Aug-06	1.61	0.59	1.61	0.00	1.96	3.96	3.56
Sep-06	1.56	0.75	1.56	0.00	1.53	3.43	3.08
<b>Total for Year 2005/2006</b>	<b>18.83</b>	<b>8.61</b>	<b>18.92</b>	<b>95.91</b>	<b>51.85</b>	<b>78.54</b>	<b>70.68</b>

### **Flows Recorded at Matsoku River Downstream of the Diversion Weir and Tunnel**

The actual total volume of water recorded at the Matsoku River System at Seshote Hydrometric Station is 78.54 MCM and the estimated Matsoku Diversion Weir and Tunnel Inflows, as computed, amounts to 70.68 MCM. Estimated releases from the Weir are calculated based on this computed inflows, whereas the target releases are only based on the requirement that the flow rate of 0.6 m<sup>3</sup>/s is released downstream.

### **Discharges through the Tunnel Outlet to Katse Dam**

The flow measuring devices recorded **95.91** MCM as the volume transferred from the Matsoku Weir to Katse Dam. This amount excludes flows for the months of October and November 2005, and June to September 2006. Missing data was due to malfunctioning meters. It is possible that the recorded flows are higher than it is expected as the estimated transferred volume is only **51.85** MCM for the whole year.

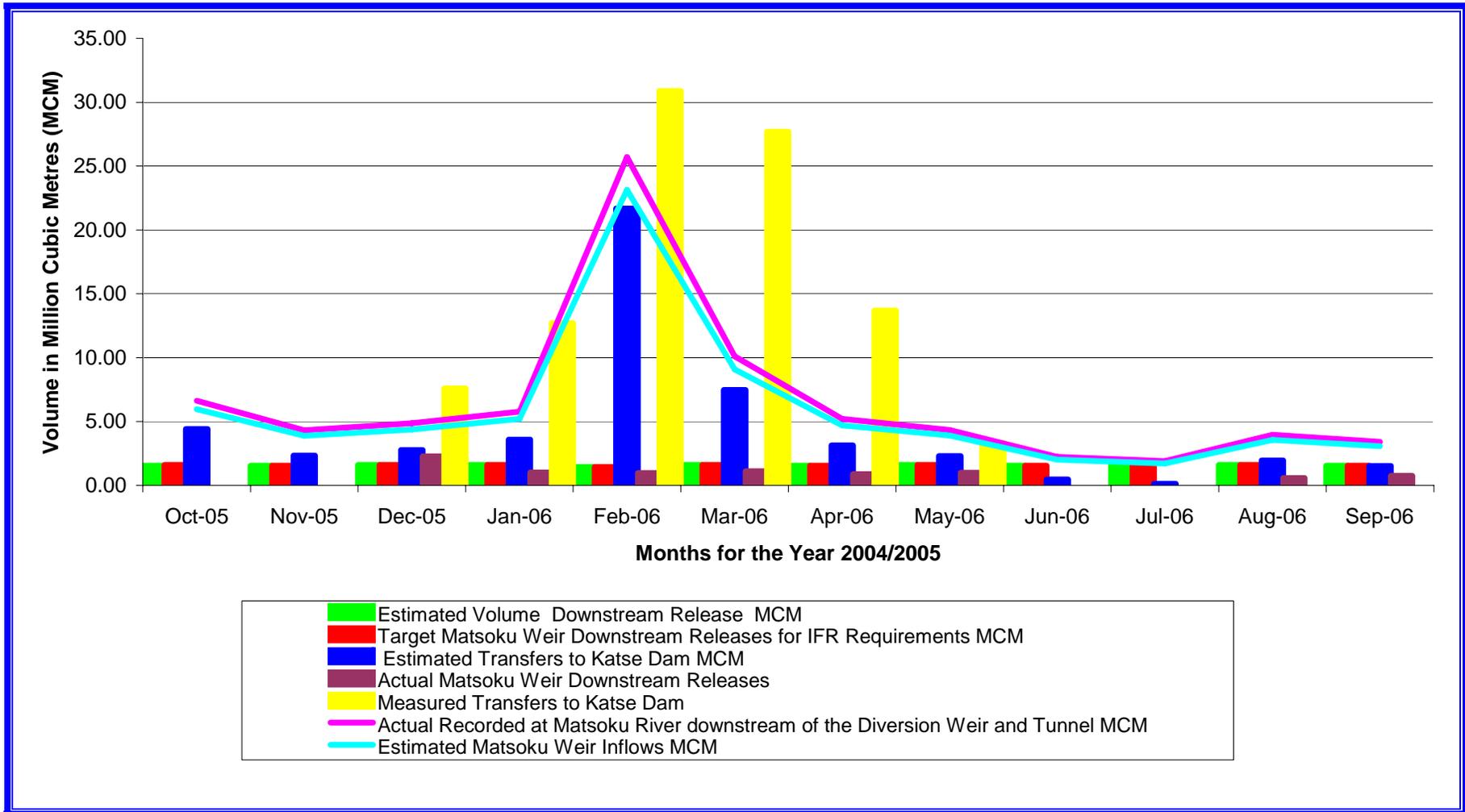
The existing gaps are in – filled with the estimated flow calculations from the Matsoku Hydrometric Station at Seshote. The measured transfers of **95.91** MCM to Katse Dam are themselves much higher than the recorded flow volume of **78.54** MCM at the downstream Hydrometric Station at Seshote. This indicates the gravity of the problem on the measuring devices at Weir site.

### **Spillage**

Matsoku Diversion Weir and Tunnel did not spill during October 2005 to September 2006. The flow volume recorded at the Matsoku River Hydrometric Station at Seshote however indicates possibilities that spill may have occurred but there is no record at the Weir site to confirm. See Table 10 for actual recorded figures.

Figure 7 on page 25 shows the measured and the estimated downstream flows from the Matsoku Diversion Weir and Tunnel as compared with the Targeted releases and the Transfers into the Katse Dam. The estimated Matsoku Weir inflow and the Matsoku Hydrometric Station at Seshote flows as required for the calculation of estimated transfers to Katse dam are also shown on this figure.

**Figure 7- The actual and estimated Monthly flow releases versus the Target releases requirement from the Matsoku Diversion Weir and Tunnel**



## 5. CONCLUSIONS

It is concluded that generally the Hydrological Year 2005/2006 has been a very wet year for both Katse and Mohale catchment areas with Plus 2 hydrological classification conditions been observed.

### **Katse Dam**

The actual hydrological year class for the Katse catchment area for the Hydrological Year 2005/2006 was, on aggregate, a 'Plus 2' class with the total inflow of 1,212.36 MCM at IFR site 2.

The actual total volume of 67.03 MCM was released from the Katse Dam during October 2005 to September 2006. The target flow release, as specified in the IFR Policy and Procedures, amounts to 84.40 MCM for the entire period, October 2005 to September 2006. The Dam releases are therefore below stipulated amounts by approximately 17.37 MCM, which is equivalent to 21% of target releases.

The volume recorded at the Katse Bridge Hydrometric Station amounts to 108.04 MCM whilst the target IFR volume at IFR site 2 stands at 109.50 MCM. The Katse Bridge Hydrometric Station is situated 2 km upstream of the IFR site 2 and therefore this station is not capturing flows at the IFR site 2 location. Thus the difference between the flows measured at the Hydrometric station and the target IFR required flows stands at 1.46 MCM (1.33%). This difference could be a surplus, as opposed to this shortfall, if the contributions from the Khohlontšo tributary and the actual flows at IFR site 2 were measured.

### **Mohale Dam**

The Mohale Reservoir has experienced, on aggregate, the 'Plus 2' hydrological year classification conditions throughout the year but actual conditions varied from Average to Plus 2. The total inflow was 625.93 MCM at IFR Site 7 for the Hydrological Year 2005/2006.

A total volume of 55.32 MCM was released from the Mohale Dam during the period though various 'outlets'. The target annual flow release as specified in the IFR Policy amounts to 36.26 MCM. Therefore actual Dam releases were greater than the target releases by 19.06 MCM (34%). The seepage and spill events more than compensated for missed floods and other scheduled dam releases that were not effected.

The volume recorded at IFR site 7 amounts to 97.86 MCM and the target IFR volume amounts to 89.10 MCM. This indicates that despite the difficulties experienced at Mohale Dam site, there was a surplus flow volume of 8.76 MCM (10%) experienced at IFR site 7 for the period October 2005 to September 2006.

#### **'Muela Dam**

The flow downstream of the 'Muela Dam has been reduced to 25% of the Mean Annual Runoff (MAR) of the Nqoe River Catchment. The Compensation valve at 'Muela Dam is therefore constantly set to release 25% of the long – term mean annual runoff of Nqoe River system, which is estimated to be **0.04** m<sup>3</sup>/s. There is no IFR implied for 'Muela Dam. Thus the total volume released from the 'Muela Dam from October 2005 to September 2006 is **1.23** MCM.

#### **Matsoku Diversion Weir**

The Hydrometric Station flows of Matsoku River at Ha – Seshote have been used to estimate the inflows into the Matsoku Diversion Weir and Tunnel. The Outflows that have been released downstream of Matsoku Weir, whilst transferring excess water into the Katse reservoir, and the tunnel transfers to Katse are measured. The volume of water transferred via the Diversion Tunnel into the Katse reservoir equates to **95.91** MCM whilst the volume of water released downstream equates to **8.61** MCM.

And finally the implementation of the IFR Policy and Procedures for 2005/2006 Hydrological Year was effectively and efficiently carried out with a lot of improvements being realized with regard to low – flow implementation. The assessment of quarterly classifications by predicting the next quarter on the bases of the actual prevailing conditions of the quarter under consideration, help keep

Dam releases in line with nature. This is seen in the minimal deviations, as well as the level of compliance that were experienced for the period October 2005 to September 2006. It is however debatable whether spills should be counted as part of Dam releases for IFR purposes, substituting for scheduled (flood) releases.

## 6.RECOMMENDATIONS

Based on the results as discussed in the report, it is recommended that:

- Hydrometric Stations be constructed at all IFR Sites so that the targeted flows at those Sites could be compared with the actual recorded flows. That is downstream of Matsoku Weir (IFR Site 1) and at IFR Site 2 downstream of the Katse Bridge Hydrometric Station and Khohlontšo tributary as examples.
- Surveys for sediment monitoring be carried out periodically at gauging station cross sections.
- Review the use of Quarterly Classification as it imposes flow targets that are representative of climatic conditions during the previous quarter that may be quite different to the actual climatic conditions of the subsequent quarter. That is the Summer flows are translated into Autumn season target flows and Winter flows are translated into Spring season target flows, possibly imposing a different season that the environment is not expecting, and may have adverse impacts on the aquatic environment.
- The IFR Policy required the use of corrigenda to correct detailed provisions and the IFR Procedures will also require a revision to be issued to correct inaccuracies, to reflect changes, and to clarify provisions. That should be done in a timely manner. In particular the ratio of flow contribution to flows at IFR site 7 from above and below Mohale Dam should be corrected based on the available data that shows a consistent pattern different to that assumed.