EARBA STORAGE

A GILKES ENERGY COMPANY

Earba Pumped Storage Hydro Scheme

CAR Licence Application Report

Appendix B: MNV Hydrology Report

December 2024

Hydrology of the Allt Loch a'Bhealaich Leamhain

12 month report

MNV Consulting Ltd

Hydrology of the Allt Loch a'Bhealaich Leamhain

12 month report

Client:	Gilkes Energy
Contributors:	[redacted]
Checked by:	

Document revisions:

Status:	**Version:**	**Date:**
Final	v1	14/10/2024

MNV Consulting Ltd
Stirling Road
Callander
Perthshire
FK17 8LE

Tel: 01877 331080

Email: info@mnvconsulting.co.uk

1 Introduction

In May 2023, Gilkes Energy contracted MNV Consulting to carry out a programme of river gauging works on the Ardverikie Estate. Three river gauging stations and one loch level station were installed with the aim of collecting 12 months of data.

The stations were installed in June 2023 but several problems were encountered with the installations and two had to be moved. Monthly visits were planned to all stations but due to weather and river conditions the sites could not be accessed for most of the winter. The data loggers continued to operate automatically during this period, so no data were lost.

This report describes the data collected over a 12 month period and the long term flow duration curve analysis for one of the stations, Allt Loch a'Bhealaich Leamhain.

2 Station details

2.1 Installation

The Allt Loch a'Bhealaich Leamhain forms the outflow from Loch a'Bhealaich Leamhain.

Table 1 gives details of the river gauging station, Figure 1 shows the location and Figure 2 shows an image of the river channel at the gauging point.

Table 1 Allt Loch a'Bhealaich Leamhain river gauging station

Station information	Details
Description of station	Natural section
Water level control	Bed rock and boulders
Equipment installed	Water level sensor with data logger and stageboard
OS grid reference	NN50981 79146
Station elevation	602m AOD
Start of data recording	29th June 2023
Logger type	SEBA Dipper PT
Logging interval	15 minutes
Location of manual gauging	At stageboard

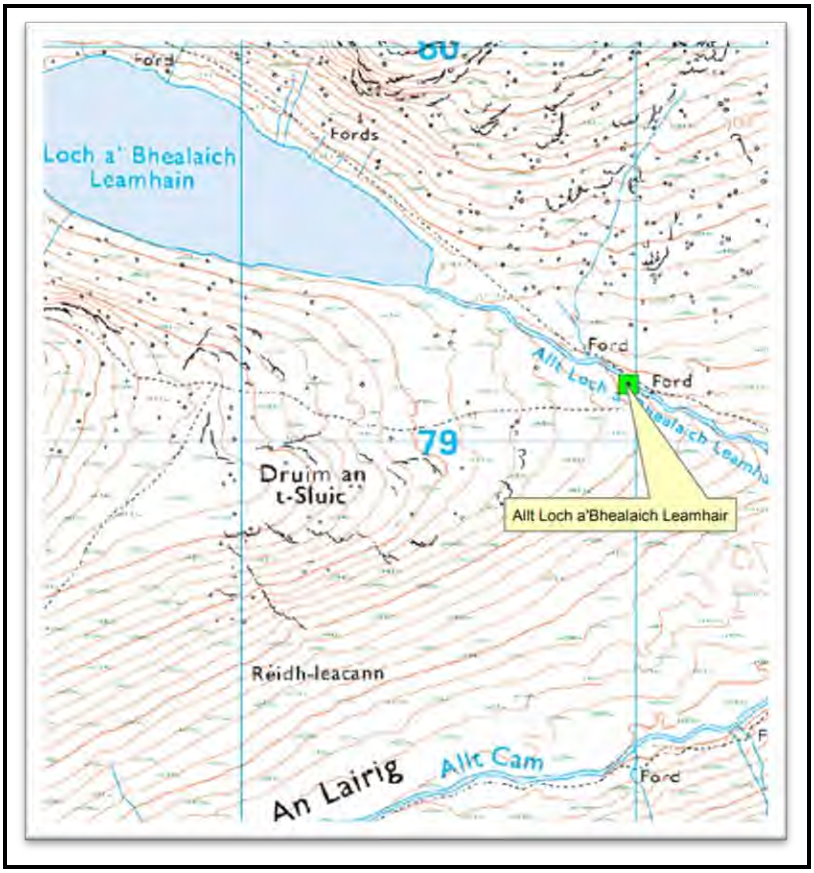

Figure 1 Location of the river gauging station

Figure 2 River channel at the gauging point

2.2 Manual flow gauging

Manual flow gaugings were undertaken at the river gauging site to develop a rating equation so that the stage data could be converted to flow. The gaugings were carried out using SEBA current meters with the flow calculated by the velocity - area method. The gauging methods followed the British Standards (BS EN ISO 748:2000). During the period July 2023 to July 2024 the site was visited 15 times; the manual flow gauging results are shown in Table 2.

Table 2 Flow gauging results for the Allt Leamhain

Date	Time	Equipment	Stage (m)	Flow (m^3/s)
06/07/2023	1200	Mini	0.265	0.2304
20/07/2023	1230	Mini	0.261	0.2210
02/08/2023	1200	Mini	0.243	0.1700
14/09/2023	1200	Mini	0.240	0.1750
18/10/2023	1300	Mini	0.241	0.1720
09/03/2024	1300	SEBA80m	0.240	0.1521
24/04/2024	1100	SEBA80m	0.245	0.1517
09/05/2024	1130	SEBA80m	0.216	0.0806
10/05/2024	1100	SEBA80m	0.212	0.0799
23/05/2024	1100	EM	0.285	0.3642
24/06/2024	1100	EM	0.218	0.1043
26/06/2024	1100	EM	0.222	0.0989
09/07/2024	1200	EM	0.251	0.1749
12/07/2024	1200	EM	0.234	0.1243
18/07/2024	1100	EM	0.201	0.0527

The rating equation calculated for the Allt Leamhain is shown below: and the stage - flow relationship is given in Figure 3.

$Q = 21.508 \times (H - 0.136)^{2.188}$

Where:
Q = flow (m^3/s)
H = stage (m)

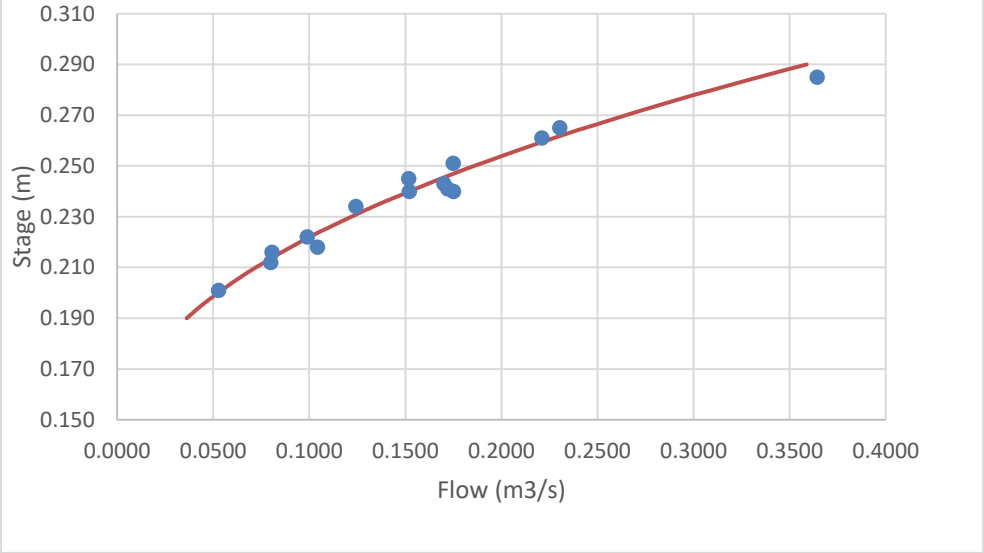

Figure 3 Stage - flow relationship for the Allt Leamhain

2.3 Logger data

The data logger worked perfectly during the 12 month period with 100% data collection. The time series of daily mean stage (DMS) is shown in Figure 4. The logger data were quality controlled by setting the logger to the stageboard at the start of each period and progressively adjusting the data to stageboard reading at the end of the period.

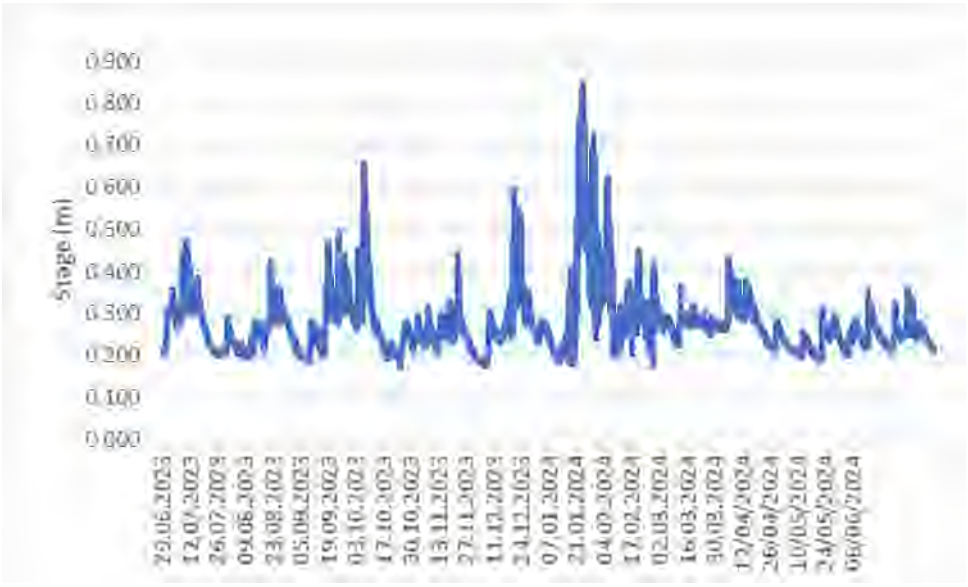

Figure 4 DMS for the Allt Leamhain

3 Flow duration curves (FDC)

3.1 Short term

The flow data from the Allt Leamhain for the 12 month period from July 2023 were used to calculate a short term FDC (Table 3).

Table 3 FDC for the Allt Arcabhi

Percentile	Flow m^3/s)
5	1.4117
10	0.8306
15	0.5880
20	0.4687
25	0.3955
30	0.3487
35	0.3163
40	0.2913
45	0.2647
50	0.2394
55	0.2117
60	0.1788
65	0.1552
70	0.1305
75	0.1135
80	0.0928
85	0.0765
90	0.0619
95	0.0473

3.2 Long term FDC

3.2.1 Analogue stations

To derive a long term FDC from the 12 months of flow data, long term analogue stations operated by SEPA were used. For the Allt Leamhain, four SEPA stations were considered:

- Tarff at Ardachy Bridge
- Tilt at Marble Lodge
- Enrick at Mill of Tore
- Foyer at Whitebridge

To assess the representativeness of the selected SEPA stations as analogue stations for the Allt Leamhain, X-Y plots were produced of the daily mean flows for the Allt Leamhain against the analogue sites (Figures 5-8).

The X-Y plots showed that there was a reasonable fit with Mill of Tore ($R^2 = 0.64$) and with Whitebridge ($R^2 = 0.59$) but a less than good fit with Ardachy Bridge ($R^2 = 0.53$) and Marble Lodge ($R^2 = 0.49$). Therefore, Mill of Tore and Whitebridge were selected as the analogue stations.

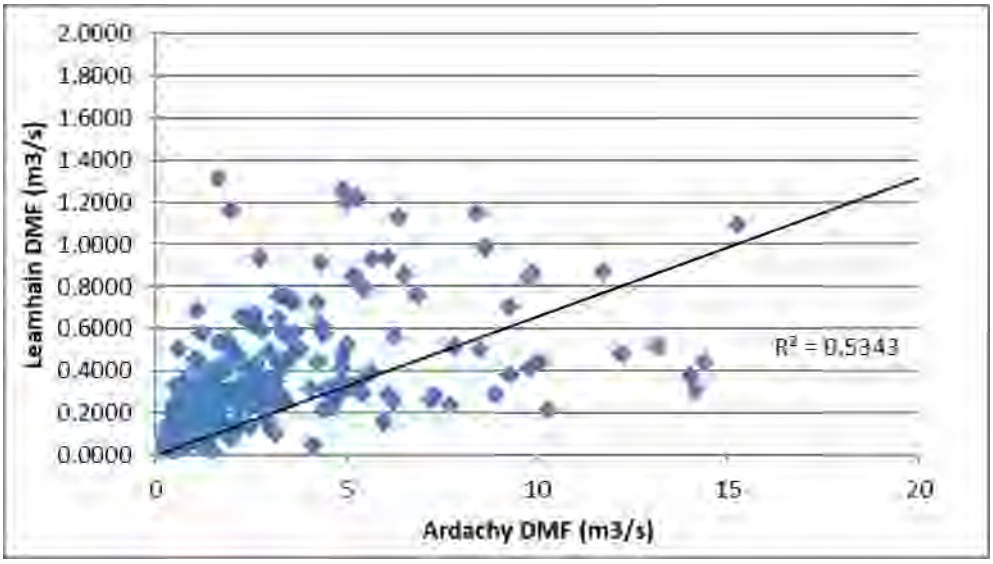

Figure 5 DMF from Allt Leamhain against Ardachy Bridge

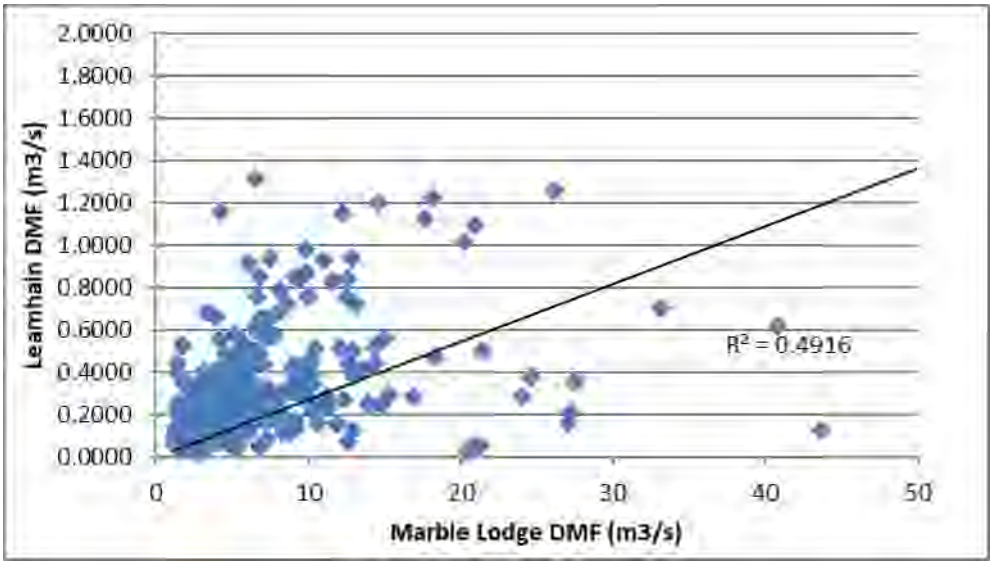

Figure 6 DMF from Allt Leamhain against Mable Lodge

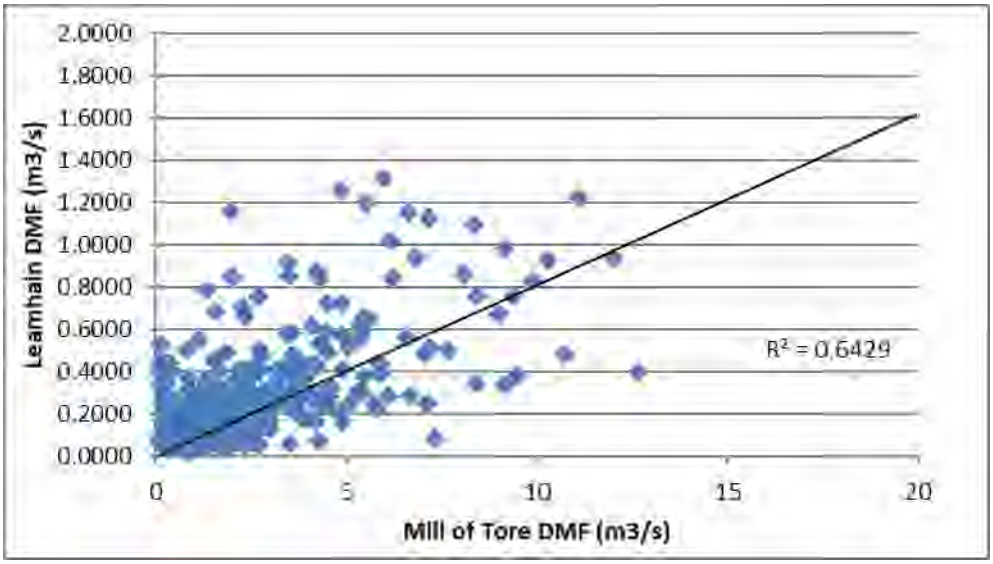

Figure 7 DMF from Allt Leamhain against Mill of Tore

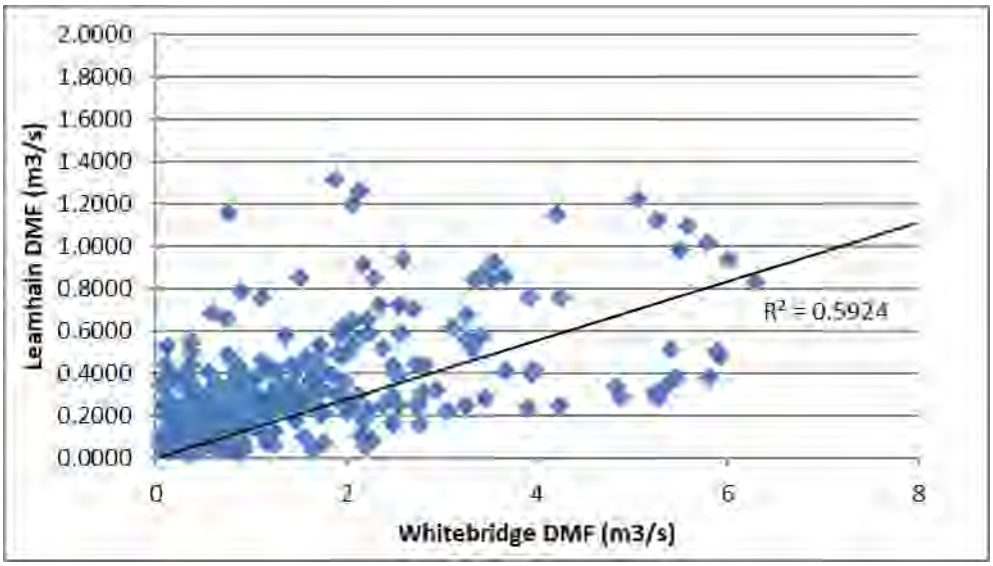

Figure 8 DMF from Allt Leamhain against Whitebridge

3.2.2 Trend analysis

The DMF values from the Allt Leamhain were plotted against the flow percentiles on the same day from the two analogue stations and a best fit trend line derived which was used to derive a FDC for the Allt Leamhain (Table 4).

Table 4 Allt Leamhain FDC derived by the trend method from analogue data

Flow Percentile (%)	Flow (m^3/s)	
	Mill of Tore	**Whitebridge**
5	0.5707	0.5289
10	0.5037	0.4738
15	0.4445	0.4245
20	0.3922	0.3802
25	0.3462	0.3406
30	0.3055	0.3051
35	0.2696	0.2734
40	0.2379	0.2449
45	0.2100	0.2194
50	0.1853	0.1965
55	0.1635	0.1761
60	0.1443	0.1577
65	0.1273	0.1413
70	0.1124	0.1266
75	0.0992	0.1134
80	0.0875	0.1016
85	0.0772	0.0910
90	0.0682	0.0815
95	0.0602	0.0730

3.2.3 Range analysis

The DMF values from the Allt Leamhain were used with the flow percentiles on the same day from the two analogue stations to calculate the average flow for each flow percentile for the Allt Leamhain (Table 5).

Table 5 Allt Leamhain FDC derived by the range method from analogue data

Flow Percentile (%)	Flow (m^3/s)	
	Mill of Tore	**Whitebridge**
5	0.6995	0.7363
10	0.6378	0.5715
15	0.5859	0.5686
20	0.4568	0.2169
25	0.3916	0.3788
30	0.2848	0.3474
35	0.3169	0.2656
40	0.2567	0.2926
45	0.1748	0.2566
50	0.2352	0.2201
55	0.1677	0.2366
60	0.1648	0.1845
65	0.1729	0.1579
70	0.1276	0.2275
75	0.1070	0.1702
80	0.1004	0.1384
85	0.0925	0.1002
90	0.0546	0.0936
95	0.0764	0.0593

3.2.4 Re-scaling analysis

The short term FDC from the Allt Leamhain was scaled up to long term FDC using the ratio between short and long term flow percentiles from the analogue stations (Table 6).

Table 6 Allt Leamhain FDC derived by the rescaling method from analogue data

Flow Percentile (%)	Flow (m^3/s)	
	Mill of Tore	**Whitebridge**
5	2.2790	2.0573
10	1.1792	1.1403
15	0.7571	0.7621
20	0.5264	0.5529
25	0.4160	0.4403
30	0.3494	0.3626
35	0.3015	0.3171
40	0.2625	0.2761
45	0.2243	0.2476
50	0.1989	0.2224
55	0.1832	0.1976
60	0.1519	0.1752
65	0.1370	0.1591
70	0.1077	0.1290
75	0.0920	0.1103
80	0.0749	0.0981
85	0.0558	0.0742
90	0.0355	0.0515
95	0.0191	0.0338

3.3 Summary of results

Analysis of the data showed a reasonable consistency in the results apart from the FDC derived using the range method.

Figure 9 shows a plot of the six flow duration curves with the two derived using the range method appearing to be a departure from the other FDCs.

Neither analogue station had a significantly better relationship with the Allt Leamhain and no single FDC was identified as the best representation. Therefore, an average of the trend and rescaled FDCs was taken as the final FDC (Table 7 and Figure 10).

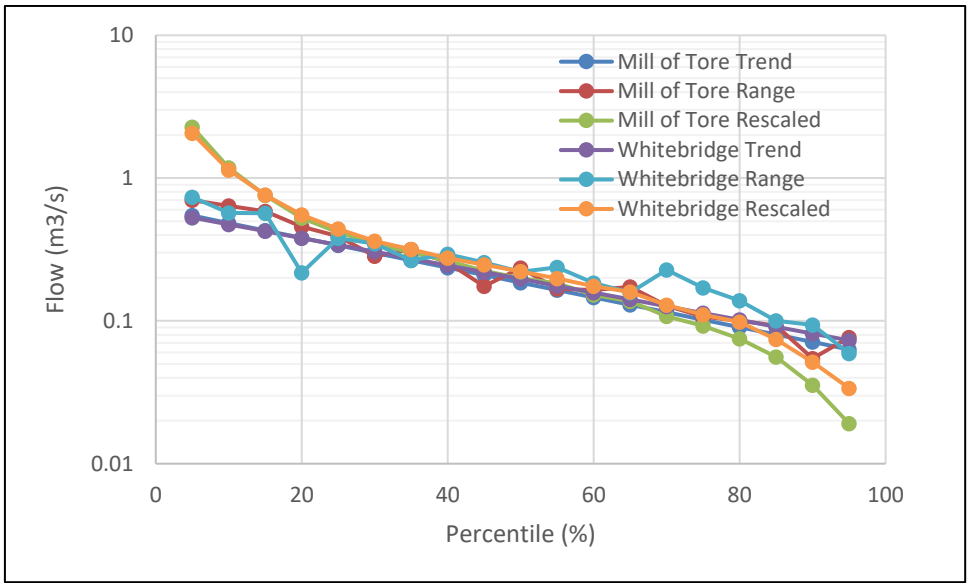

Figure 9 Allt Leamhain summary of the six FDC

Table 7 Allt Leamhain final FDC

Flow percentile (%)	Flow (m^3/s)
5	1.3530
10	0.8195
15	0.5934
20	0.4602
25	0.3838
30	0.3293
35	0.2895
40	0.2549
45	0.2251
50	0.2009
55	0.1804
60	0.1577
65	0.1417
70	0.1195
75	0.1044
80	0.0912
85	0.0753
90	0.0599
95	0.0472

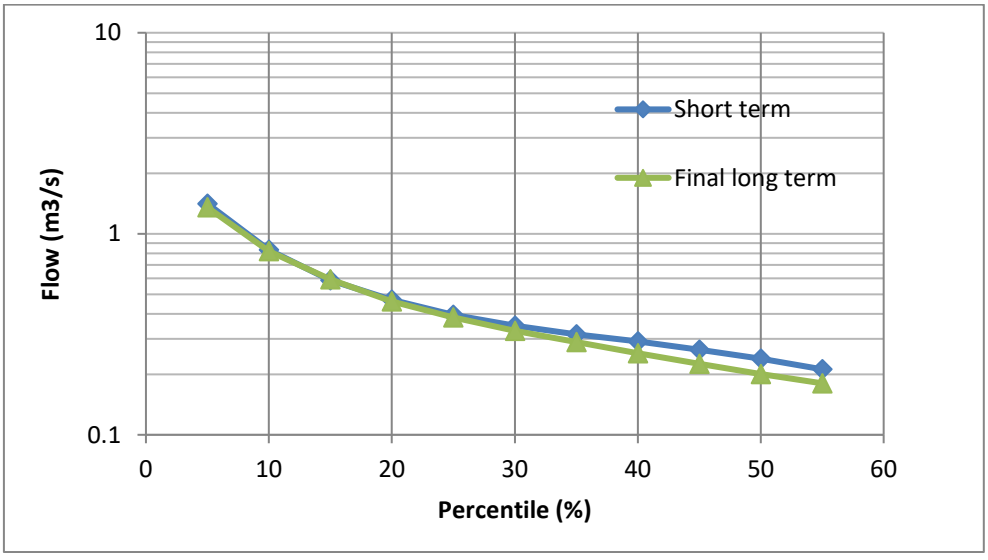

Figure 10 Final FDC with the short term FDC