



Loch Kemp Outflow

**Flow analysis – June
2025**



MNV Consulting Ltd

Loch Kemp Outflow

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 <p>MNV Consulting Ltd.</p>	<p>MNV Consulting Ltd 31 Lagrannoch Drive Callander Perthshire FK17 8DW</p> <p>Tel: [REDACTED]</p> <p>Email: info@mnvconsulting.co.uk</p>	

1 Background

In January 2022, MNV Consulting was contracted to undertake a 12-month period of flow monitoring on the outflow from Loch Kemp as part of a hydro-power development (Figure 1). The monitoring was completed and a report produced giving long term flow duration statistics.

In April 2024, MNV was asked to re-visit the site to continue the monitoring and, using the additional data, to re-evaluate the long term flow duration statistics.

This report summarises the data collected at the Loch Kemp outflow station and the analysis carried out to produce the long term flow statistics.



Figure 1 Locations of monitoring stations

2 Data collection

2.1 Loch Kemp outflow station

Table 1 gives details of the Loch Kemp outflow station and Figure 2 shows a view of the monitoring station.

Table 1 Loch Kemp outflow

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	NH 46779 16869
Station elevation	181m AOD
Date of installation	27 th January 2022
Logger type	SEBA Dipper PT
Logging interval	15 minutes
Location of manual gauging	Immediately upstream from bridge
Stage at zero flow	0.025m



Figure 2 Loch Kemp outflow gauging station

The bridge on the upstream side of the monitoring station was installed by the Estate on 9th September 2024 to enable ATV crossing of the burn in high flow conditions. The bridge rests on the ground either side of the channel and there was no disturbance to the channel bed during construction. Figure 3

shows that flows with a value on the stageboard below 0.7m will not be affected by the bridge but high, out of bank flows greater than 0.7m on the stageboard could be affected by the bridge.



Figure 3 View of the bridge and stageboard looking upstream

2.2 Data logger

The original data logger recorded stage data for the period 27/01/2022 to 21/02/2023. The logger was left in place but started to over-write so a gap in the data exists from 22/02/2023 to 25/10/2023. A new logger was installed in 2024 so that data collection has been continuous since 26/10/2023.

The time series of stage for the period January 2022 to February 2023 is shown in Figure 4 and the time series from October 2023 to May 2025 is shown in Figure 5.

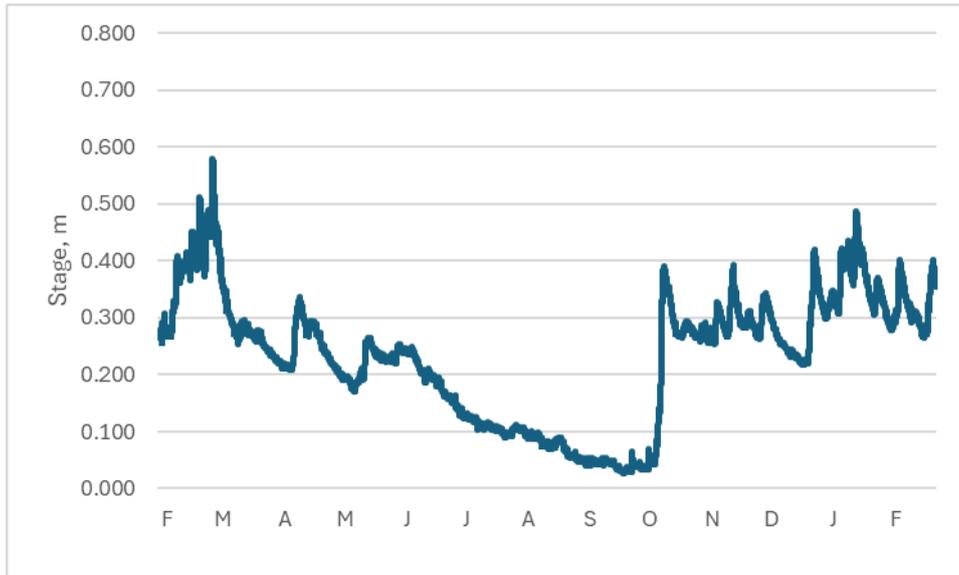


Figure 4 Time series of stage (January 2022 to February 2023)

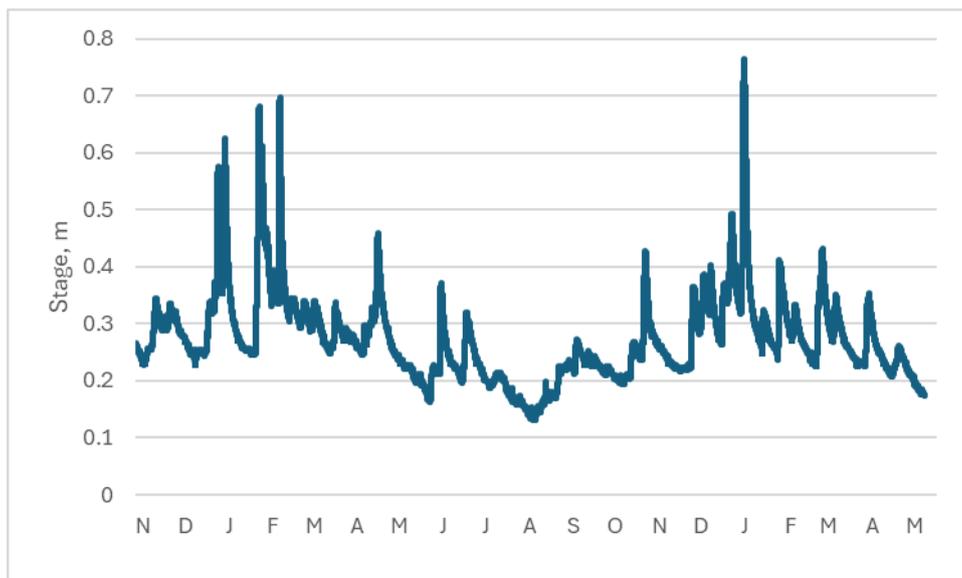


Figure 5 Time series of stage (October 2023 to May 2025)

2.3 Manual flow gaugings

Manual flow gaugings were carried out at the station over a range of stage values so that a rating equation could be developed to convert logger stage data to flow data. The gaugings are listed in Table 2.

Table 2 Gaugings at Loch Kemp outflow

Date	Time (GMT)	Stage (m)	Flow (m ³ /s)
27/01/2022	11:25	0.269	0.0640
16/03/2022	11:10	0.267	0.0674
20/04/2022	11:55	0.248	0.0507
19/05/2022	11:30	0.225	0.0350
25/05/2022	12:10	0.233	0.0396
06/07/2022	11:15	0.119	0.0020
06/07/2022	12:00	0.119	0.0021
13/07/2022	11:25	0.110	0.0002
12/10/2022	11:10	0.302	0.1023
19/10/2022	11:30	0.289	0.0754
16/11/2022	11:25	0.290	0.0770
07/12/2022	11:30	0.251	0.0523
19/12/2022	12:45	0.242	0.0465
14/02/2023	10:30	0.275	0.0679
21/02/2023	11:00	0.360	0.1731
14/01/2025	11:00	0.324	0.1666
11/02/2025	11:15	0.270	0.0787
04/03/2025	10:45	0.290	0.1034
15/04/2025	11:00	0.215	0.0249
15/04/2025	12:00	0.212	0.0248
15/04/2025	13:00	0.218	0.0281
15/04/2025	14:00	0.220	0.0318
23/04/2025	11:30	0.240	0.0452
08/05/2025	10:00	0.175	0.0150
08/05/2025	11:00	0.175	0.0146
15/05/2025	10:00	0.150	0.0063
15/05/2025	11:00	0.150	0.0067

2.4 Rating equation

The relationship between flow and stage is shown in Figure 5. Two rating equations were derived from the data, one above the lowest gauged stage value of 0.110m and another from the lowest gauged stage value down to the surveyed stage at zero flow.

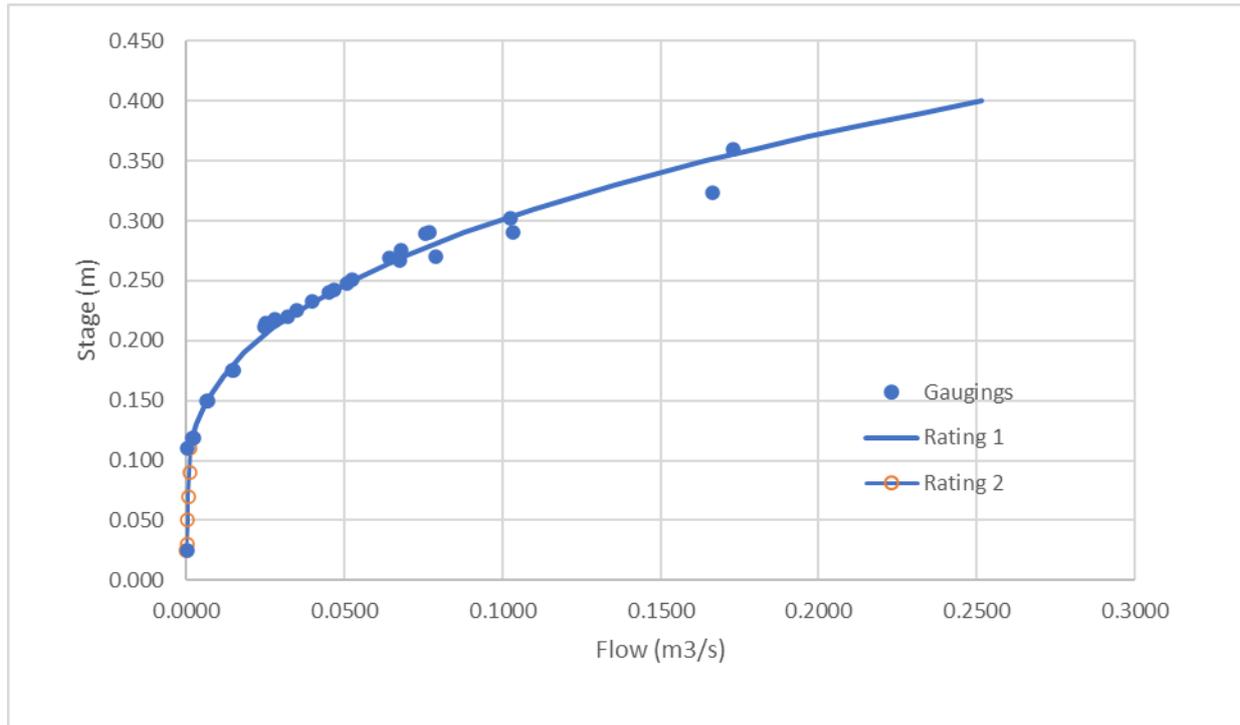


Figure 6 Relationship between flow and stage

Rating 1 ($H > 0.110\text{m}$) $Q = 4.514 \times (H - 0.068)^{2.618}$

Rating 2 ($H < 0.110\text{m}$) $Q = (H \times 0.0129) - 0.0003$

Where:

H = Stage (m)

Q = Flow (m^3/s)

3 Flow duration curve (FDC)

An analysis has been carried out to derive “short term” FDC for the site. Because there was a significant break in the logger data the analysis was carried out using three sets of data:

Analysis 1: 12 months 21/02/2022 to 20/02/2023

Analysis 2: 12 months 01/11/2023 to 31/10/2024

Analysis 3: All data 27/01/2022 to 08/05/2025

3.1 Analysis 1 (2022-23)

The 15 minute flow data were used to derive a short term FDC for 2022-23 (Table 3).

Table 3 Short term FDC (2022-23)

Flow percentile (%)	Flow (m ³ /s)
5	0.2342
10	0.1672
15	0.1314
20	0.1112
25	0.0941
30	0.0837
35	0.0740
40	0.0677
45	0.0584
50	0.0464
55	0.0391
60	0.0331
65	0.0216
70	0.0118
75	0.0019
80	0.0010
85	0.0008
90	0.0004
95	0.0003

3.2 Analysis 2 (2023-24)

The 15 minute flow data were used to derive a short term FDC for 2023-24 (Table 4).

Table 4 Short term FDC (2023-24)

Flow percentile (%)	Flow (m ³ /s)
5	0.2978
10	0.1657
15	0.1381
20	0.1185
25	0.1030
30	0.0898

Flow percentile (%)	Flow (m ³ /s)
35	0.0807
40	0.0685
45	0.0608
50	0.0560
55	0.0514
60	0.0471
65	0.0391
70	0.0348
75	0.0298
80	0.0267
85	0.0221
90	0.0140
95	0.0100

3.3 Analysis 3 (2022-25)

The 15 minute flow data were used to derive a short term FDC for 2022-25 (Table 5).

Table 5 Short term FDC (2022-25)

Flow percentile (%)	Flow (m ³ /s)
5	0.2658
10	0.1897
15	0.1465
20	0.1261
25	0.1076
30	0.0930
35	0.0827
40	0.0740
45	0.0659
50	0.0584
55	0.0522
60	0.0450
65	0.0391
70	0.0343
75	0.0293
80	0.0221
85	0.0130
90	0.0025
95	0.0006

3.4 Comparison of short term FDC

The three short term FDC are compared in Figure 7. The results highlight that the 12 month period 2022-23 had significantly lower low flows than the 12 month period 2023-24.

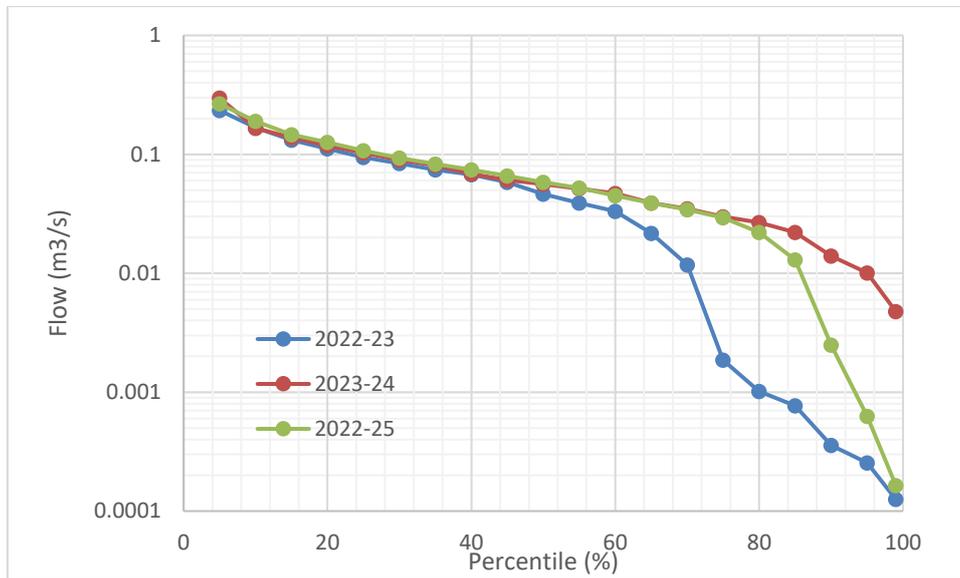


Figure 7 Comparison of short term FDC

4 Long term FDC: analogue stations

To develop the Loch Kemp Outflow short term FDC into a long term FDC, long term river gauging stations, operated by SEPA, were used as analogue stations. Four potential analogue stations were selected:

1. River Tarff at Ardachy Bridge
2. River Nairn at Balnafoich
3. River Enrick at Mill of Tore
4. River Fechlin at Whitebridge

To assess the suitability of each station as an analogue for Loch Kemp Outflow, daily mean flows for Loch Kemp Outflow were plotted against the daily mean flows for the analogue stations.

4.1 Ardachy Bridge

The comparison of daily mean flows for the three analysis periods are shown in Figures 8-10.

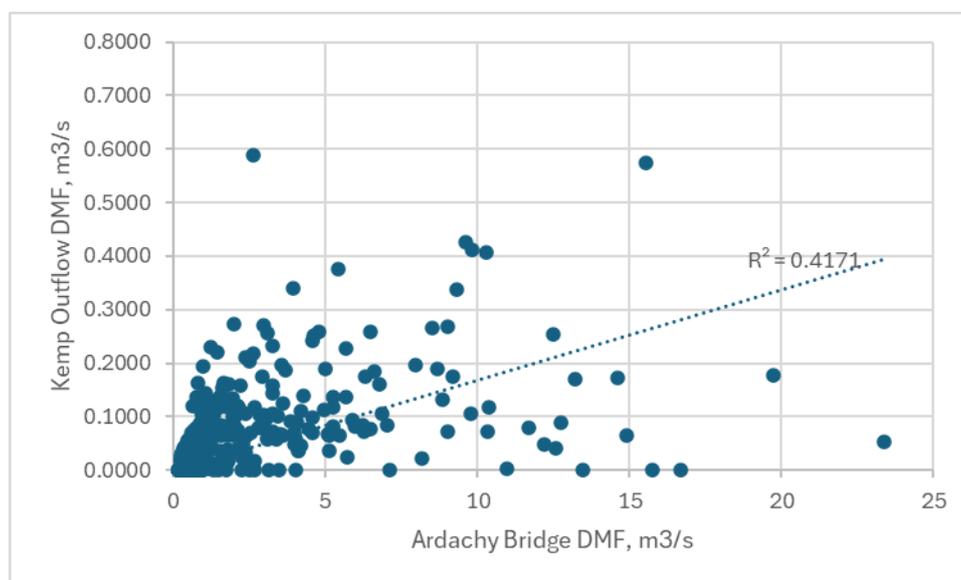


Figure 8 Comparison of daily mean flows for 2022-23

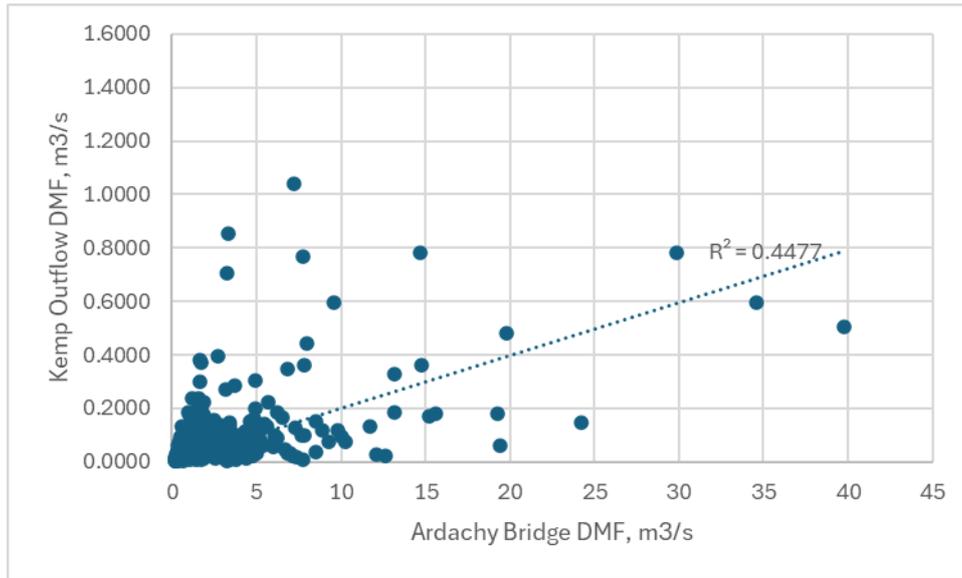


Figure 9 Comparison of daily mean flows for 2023-24

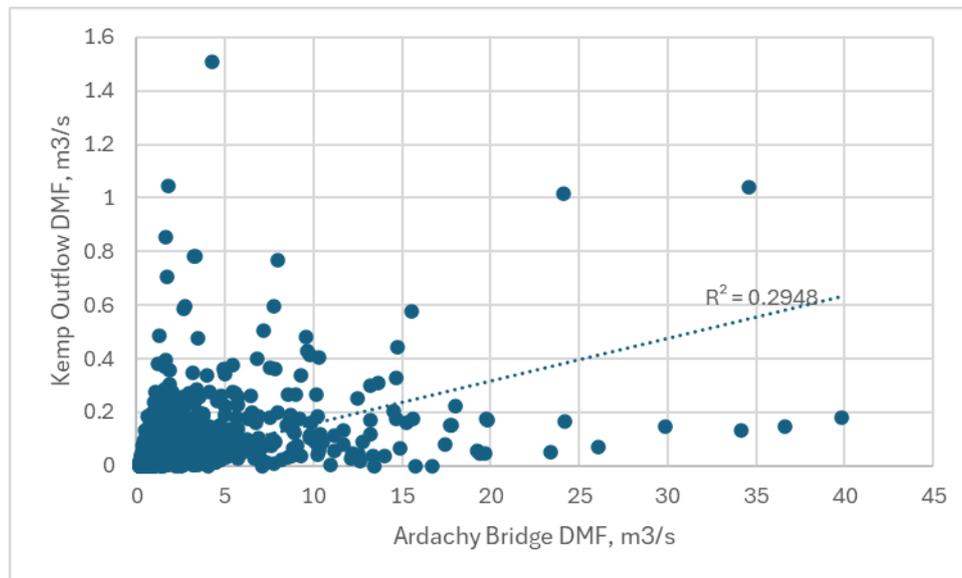


Figure 10 Comparison of daily mean flows for 2022-25

4.2 Balnafoich

The comparison of daily mean flows for the three analysis periods are shown in Figures 11-13.

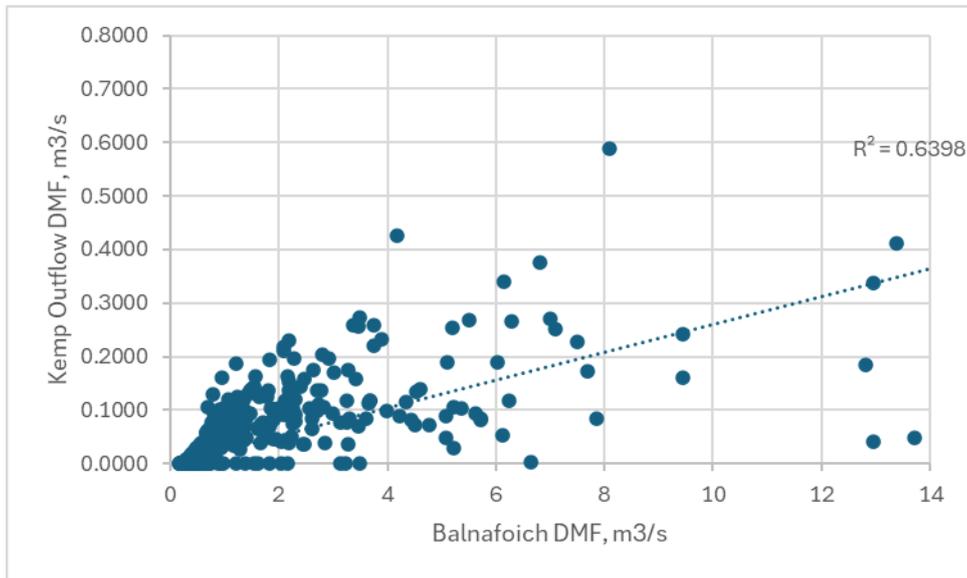


Figure 11 Comparison of daily mean flows for 2022-23

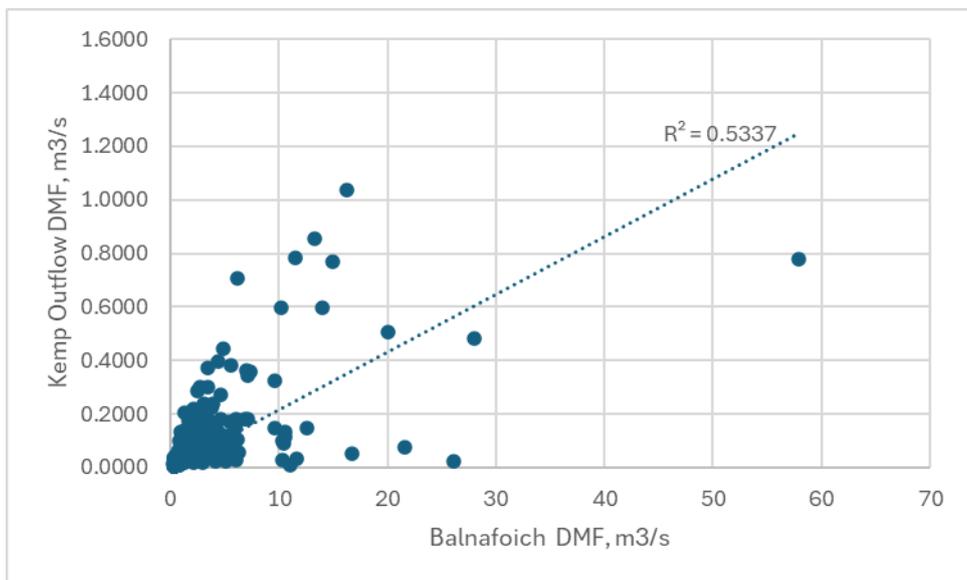


Figure 12 Comparison of daily mean flows for 2023-24

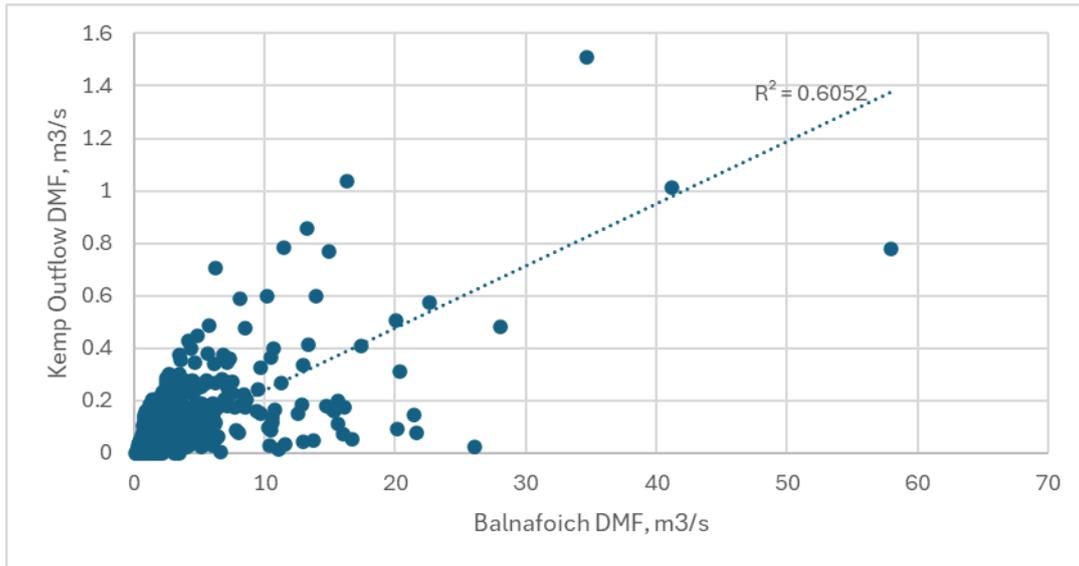


Figure 13 Comparison of daily mean flows for 2022-25

4.3 Mill of Tore

The comparison of daily mean flows for the three analysis periods are shown in Figures 14-16.

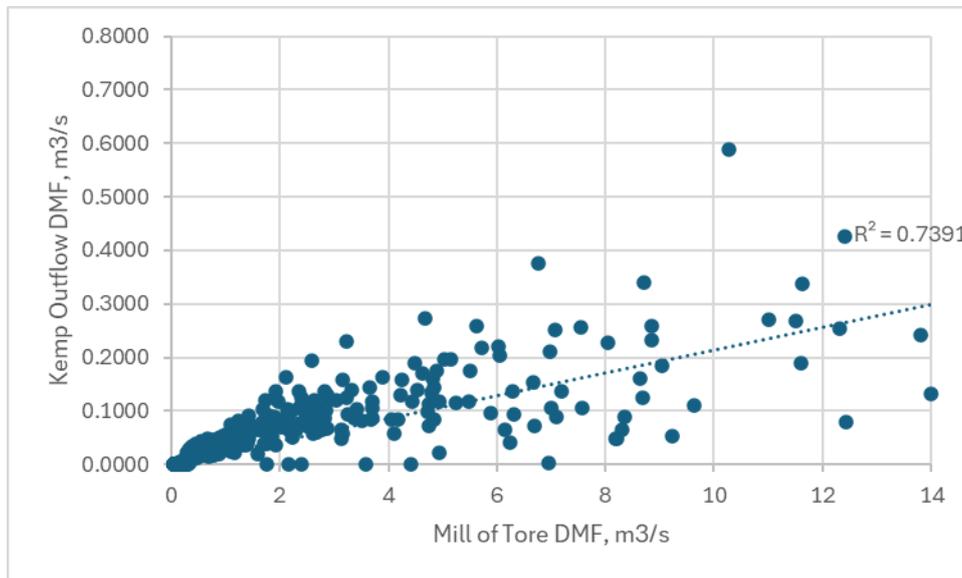


Figure 14 Comparison of daily mean flows for 2022-23

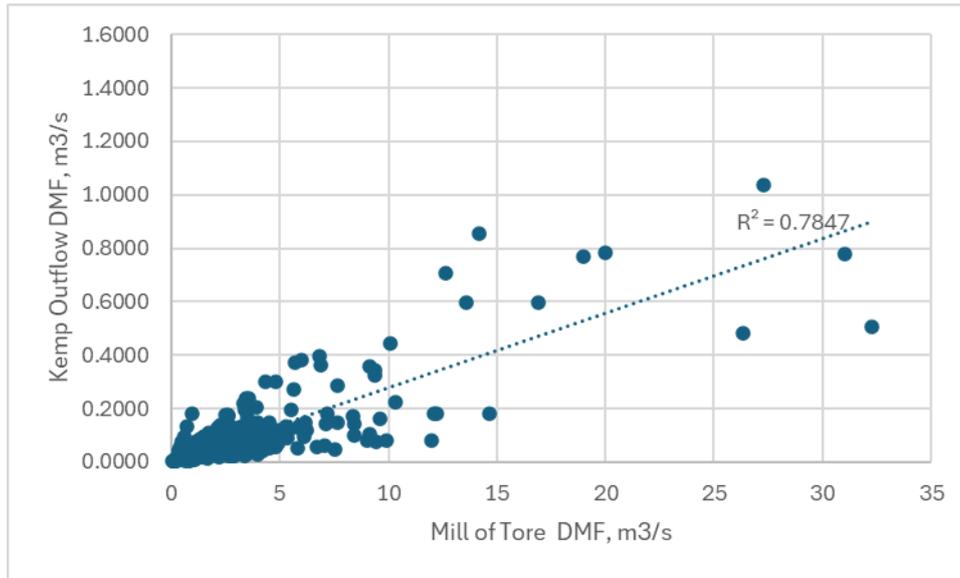


Figure 15 Comparison of daily mean flows for 2023-24

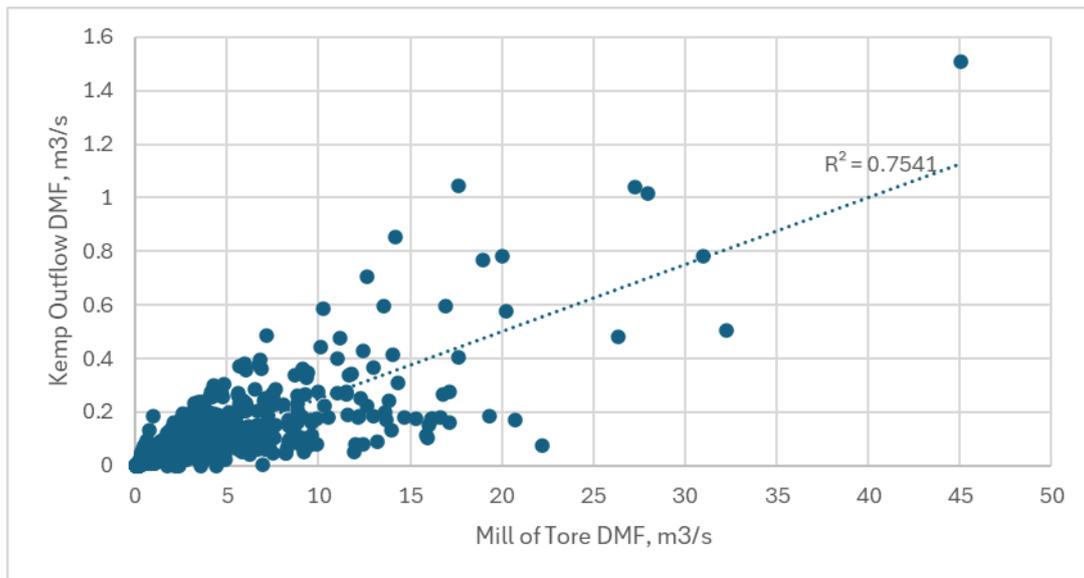


Figure 16 Comparison of daily mean flows for 2022-25

4.4 Whitebridge

The comparison of daily mean flows for the three analysis periods are shown in Figures 17-19.

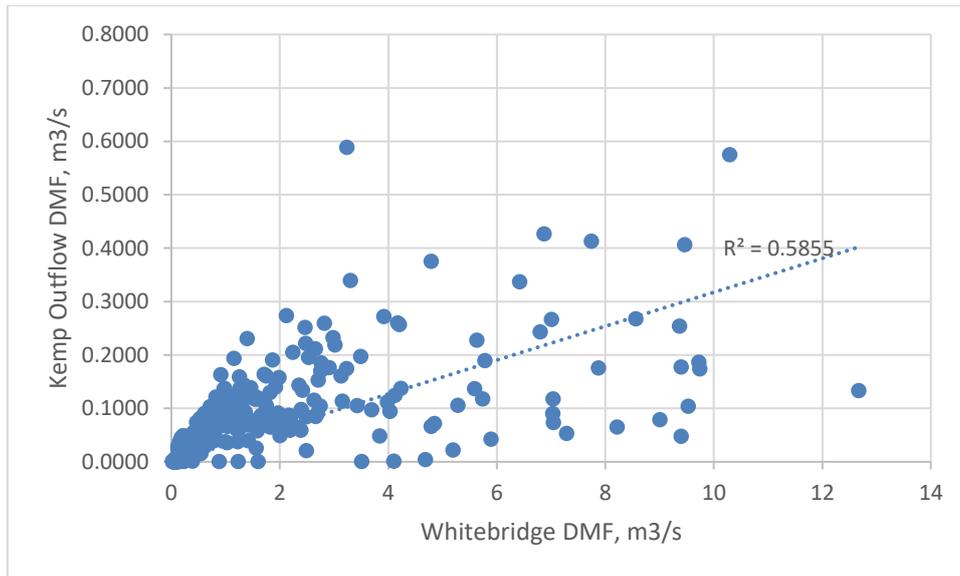


Figure 17 Comparison of daily mean flows for 2022-23

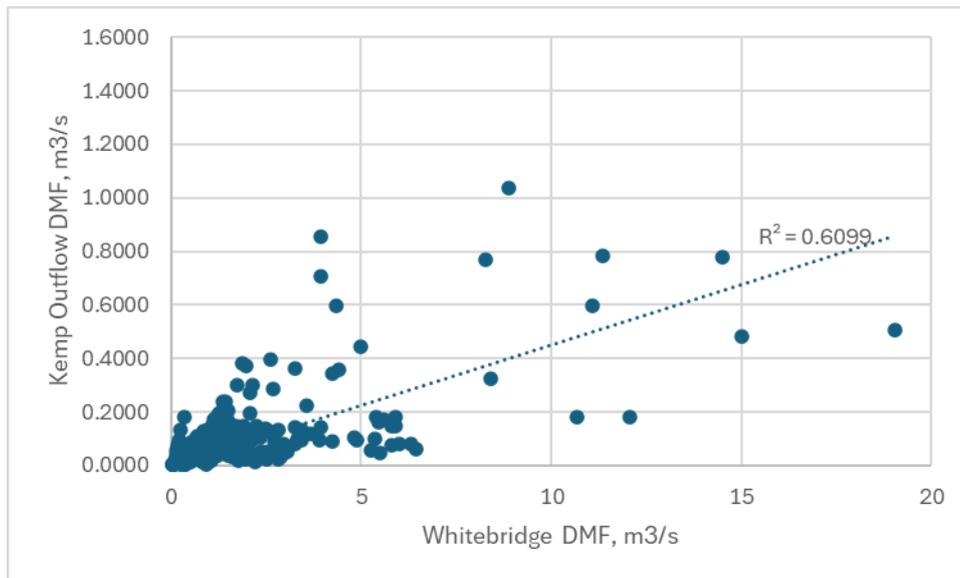


Figure 18 Comparison of daily mean flows for 2023-24

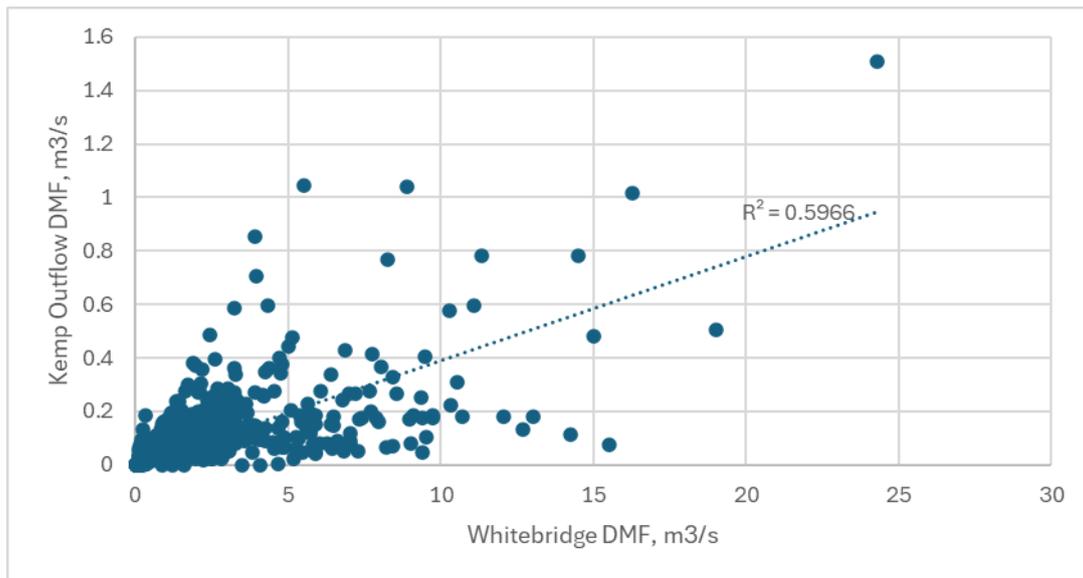


Figure 19 Comparison of daily mean flows for 2022-25

4.5 Comparison of analogue stations

The X-Y plots of daily mean flows were compared using the R^2 value for each relationship. In general an R^2 value > 0.6 is considered to be a good fit.

1. Ardachy Bridge the R^2 value was poor 0.29 to 0.44.
2. Balnafoich the R^2 value was reasonable 0.53 to 0.63
3. Mill of Tore the R^2 value was very good 0.73 to 0.78
4. Whitebridge the R^2 value was reasonable 0.58 to 0.60

The Mill of Tore therefore gave the best fit with the Loch Kemp Outflow.

5 Long term FDC: re-scaling

The short term FDC from Kemp Outflow was scaled up to a long term FDC using the ratio between the short and long term flow percentiles from the four SEPA analogue stations.

The analysis takes the ratios of the short term to long term flow percentiles in the FDC at the SEPA analogue station and applies these ratios to the short term FDC at the Loch Kemp Outflow. If the flows in the period of the short term FDC were representative of the long term flows then the ratio will be close to unity but the further away from unity indicates less representation.

5.1 Ardachy Bridge

The rescaling analysis using Ardachy Bridge is shown in Tables 6-8. The ratios for the three periods of data (Figure 20) show that in all periods of data there was a poor representation of the long term FDC.

Table 6 Rescaling analysis for the period 2022-23

Flow percentile (%)	Ardachy Bridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	9.8132	13.8650	0.7078	0.2342	0.3310
10	6.4176	8.9860	0.7142	0.1672	0.2342
15	4.8522	6.6710	0.7274	0.1314	0.1806
20	3.7374	5.1050	0.7321	0.1112	0.1519
25	3.0860	4.0660	0.7590	0.0941	0.1240
30	2.3770	3.2790	0.7249	0.0837	0.1154
35	1.9754	2.7060	0.7300	0.0740	0.1014
40	1.5816	2.2500	0.7029	0.0677	0.0963
45	1.2506	1.8970	0.6593	0.0584	0.0886
50	1.0580	1.5840	0.6679	0.0464	0.0694
55	0.8958	1.3350	0.6710	0.0391	0.0583
60	0.7382	1.1310	0.6527	0.0331	0.0507
65	0.5982	0.9550	0.6264	0.0216	0.0345
70	0.4746	0.7970	0.5955	0.0118	0.0197
75	0.4160	0.6680	0.6228	0.0019	0.0030
80	0.3552	0.5530	0.6423	0.0010	0.0016
85	0.3008	0.4510	0.6670	0.0008	0.0012
90	0.2610	0.3490	0.7479	0.0004	0.0005
95	0.2072	0.2450	0.8457	0.0003	0.0003

Table 7 Rescaling analysis for the period 2023-24

Flow percentile (%)	Ardachy Bridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	9.7405	13.8650	0.7025	0.2978	0.4238
10	6.7690	8.9860	0.7533	0.1657	0.2200
15	4.8925	6.6710	0.7334	0.1381	0.1884
20	3.9270	5.1050	0.7692	0.1185	0.1541
25	3.2400	4.0660	0.7969	0.1030	0.1293
30	2.6505	3.2790	0.8083	0.0898	0.1112
35	2.2295	2.7060	0.8239	0.0807	0.0980
40	1.7560	2.2500	0.7804	0.0685	0.0878
45	1.5825	1.8970	0.8342	0.0608	0.0729
50	1.3590	1.5840	0.8580	0.0560	0.0653
55	1.1450	1.3350	0.8577	0.0514	0.0600
60	1.0150	1.1310	0.8974	0.0471	0.0525
65	0.8723	0.9550	0.9134	0.0391	0.0428
70	0.7080	0.7970	0.8883	0.0348	0.0392
75	0.6110	0.6680	0.9147	0.0298	0.0326
80	0.5280	0.5530	0.9548	0.0267	0.0280
85	0.4655	0.4510	1.0322	0.0221	0.0214
90	0.3940	0.3490	1.1289	0.0140	0.0124
95	0.3185	0.2450	1.3000	0.0100	0.0077

Table 8 Rescaling analysis for the period 2022-25

Flow percentile (%)	Ardachy Bridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	10.4329	13.8650	0.7525	0.2658	0.3533
10	7.2009	8.9860	0.8013	0.1897	0.2367
15	5.2470	6.6710	0.7865	0.1465	0.1863
20	4.2288	5.1050	0.8284	0.1261	0.1523
25	3.2988	4.0660	0.8113	0.1076	0.1327
30	2.6830	3.2790	0.8182	0.0930	0.1137
35	2.1654	2.7060	0.8002	0.0827	0.1033
40	1.7688	2.2500	0.7861	0.0740	0.0941
45	1.4702	1.8970	0.7750	0.0659	0.0850
50	1.2070	1.5840	0.7620	0.0584	0.0766
55	1.0318	1.3350	0.7729	0.0522	0.0675
60	0.8488	1.1310	0.7505	0.0450	0.0600
65	0.7147	0.9550	0.7484	0.0391	0.0522
70	0.6146	0.7970	0.7711	0.0343	0.0444
75	0.5290	0.6680	0.7919	0.0293	0.0370
80	0.4632	0.5530	0.8376	0.0221	0.0263
85	0.3970	0.4510	0.8803	0.0130	0.0148
90	0.3292	0.3490	0.9433	0.0025	0.0026
95	0.2606	0.2450	1.0635	0.0006	0.0006

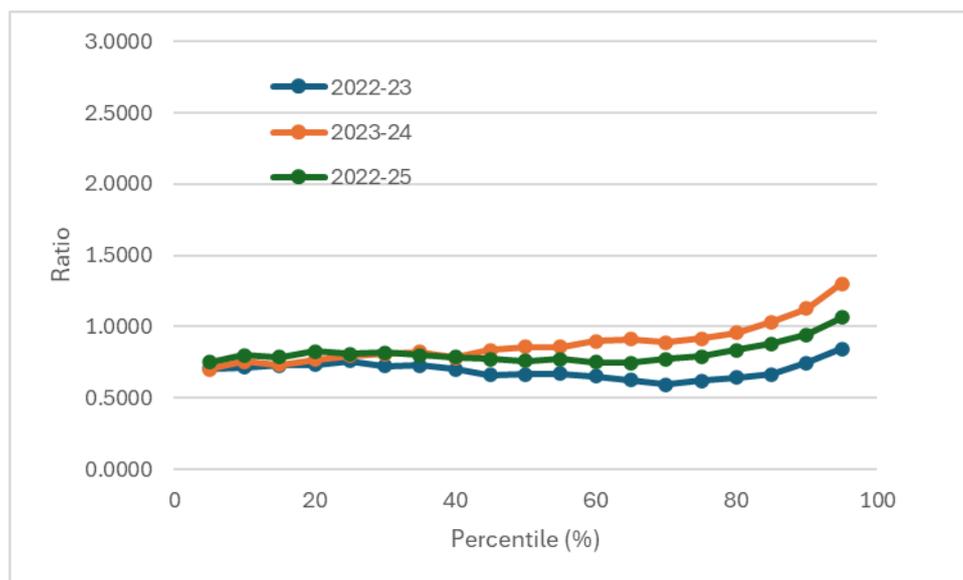


Figure 20 Comparison of the ratios of short and long term FDC at Ardachy Bridge

5.2 Banafoich

The rescaling analysis using Banafoich is shown in Tables 9-11. The ratios for the three periods of data (Figure 21) show that the flows in the period 2022-23 under-represented the long term FDC while the flows in the period 2023-24 over-represented the long term FDC. But the flows over the whole period (2022-25) were a very good representation of the long term FDC.

Table 9 Rescaling analysis for the period 2022-23

Flow percentile (%)	Banafoich			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	6.5660	9.695	0.6773	0.2342	0.3459
10	4.5840	6.236	0.7351	0.1672	0.2275
15	3.4394	4.754	0.7235	0.1314	0.1816
20	2.7210	3.733	0.7289	0.1112	0.1525
25	2.2010	3.073	0.7162	0.0941	0.1314
30	1.8956	2.593	0.7310	0.0837	0.1145
35	1.6182	2.187	0.7399	0.0740	0.1000
40	1.3178	1.881	0.7006	0.0677	0.0966
45	1.1464	1.613	0.7107	0.0584	0.0822
50	0.9500	1.382	0.6874	0.0464	0.0675
55	0.8428	1.198	0.7035	0.0391	0.0556
60	0.7756	1.018	0.7619	0.0331	0.0435
65	0.6810	0.883	0.7712	0.0216	0.0280
70	0.6056	0.758	0.7989	0.0118	0.0147
75	0.4690	0.654	0.7171	0.0019	0.0026
80	0.3856	0.557	0.6923	0.0010	0.0015
85	0.3286	0.477	0.6889	0.0008	0.0011
90	0.2584	0.395	0.6542	0.0004	0.0005
95	0.2082	0.304	0.6849	0.0003	0.0004

Table 10 Rescaling analysis for the period 2023-24

Flow percentile (%)	Balnafoich			Kemp Outflow	
	Short term	Long term	Ratio	Short term	Long term
	Flow (m ³ /s)	Flow (m ³ /s)		Flow (m ³ /s)	Flow (m ³ /s)
5	10.2658	9.695	1.0589	0.2978	0.2812
10	5.4970	6.236	0.8815	0.1657	0.1880
15	4.2898	4.754	0.9023	0.1381	0.1531
20	3.5230	3.733	0.9437	0.1185	0.1256
25	3.1648	3.073	1.0299	0.1030	0.1000
30	2.7180	2.593	1.0482	0.0898	0.0857
35	2.4153	2.187	1.1044	0.0807	0.0731
40	2.1750	1.881	1.1563	0.0685	0.0593
45	1.8218	1.613	1.1294	0.0608	0.0539
50	1.5790	1.382	1.1425	0.0560	0.0490
55	1.3775	1.198	1.1498	0.0514	0.0447
60	1.2480	1.018	1.2259	0.0471	0.0384
65	1.0735	0.883	1.2157	0.0391	0.0322
70	0.9630	0.758	1.2704	0.0348	0.0274
75	0.8100	0.654	1.2385	0.0298	0.0241
80	0.7070	0.557	1.2693	0.0267	0.0211
85	0.5458	0.477	1.1441	0.0221	0.0193
90	0.4280	0.395	1.0835	0.0140	0.0129
95	0.3688	0.304	1.2130	0.0100	0.0083

Table 11 Rescaling analysis for the period 2022-25

Flow percentile (%)	Balnafoich			Kemp Outflow	
	Short term	Long term	Ratio	Short term	Long term
	Flow (m ³ /s)	Flow (m ³ /s)		Flow (m ³ /s)	Flow (m ³ /s)
5	9.1309	9.695	0.9418	0.2658	0.2823
10	5.5809	6.236	0.8949	0.1897	0.2120
15	4.1324	4.754	0.8692	0.1465	0.1686
20	3.4238	3.733	0.9172	0.1261	0.1375
25	2.9178	3.073	0.9495	0.1076	0.1134
30	2.4800	2.593	0.9564	0.0930	0.0973
35	2.1761	2.187	0.9950	0.0827	0.0831
40	1.8164	1.881	0.9657	0.0740	0.0766
45	1.5605	1.613	0.9674	0.0659	0.0681
50	1.3150	1.382	0.9515	0.0584	0.0614
55	1.1370	1.198	0.9491	0.0522	0.0550
60	0.9868	1.018	0.9694	0.0450	0.0464
65	0.8669	0.883	0.9818	0.0391	0.0398
70	0.7680	0.758	1.0132	0.0343	0.0338
75	0.6615	0.654	1.0115	0.0293	0.0290
80	0.5498	0.557	0.9871	0.0221	0.0223
85	0.4493	0.477	0.9419	0.0130	0.0138
90	0.3747	0.395	0.9486	0.0025	0.0026
95	0.2907	0.304	0.9563	0.0006	0.0007

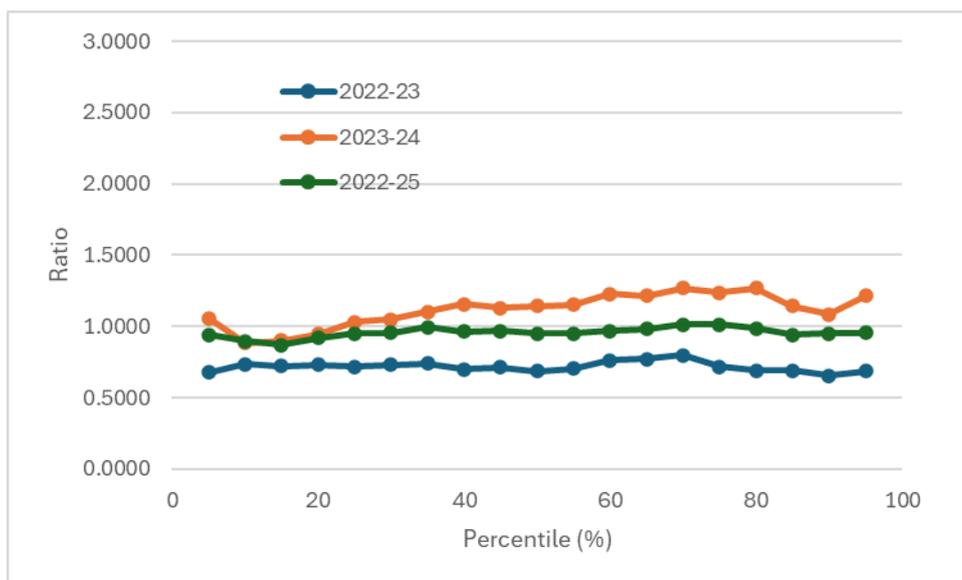


Figure 21 Comparison of the ratios of short and long term FDC Balnafoich

5.3 Mill of Tore

The rescaling analysis using Mill of Tore is shown in Tables 12-14. The ratios for the three periods of data (Figure 22) show that medium and high flows were well represented by the short term flows but the period 2022-23 under-estimated the long term FDC and the period 2023-24 over-estimated the long term FDC. Data from the full period (2022-25) were a good representation of the long term FDC.

Table 12 Rescaling analysis for the period 2022-23

Flow percentile (%)	Mill of Tore			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	10.1462	11.631	0.8723	0.2342	0.2685
10	7.0474	7.797	0.9039	0.1672	0.1850
15	5.1868	5.842	0.8878	0.1314	0.1480
20	4.2814	4.568	0.9373	0.1112	0.1186
25	3.2200	3.683	0.8743	0.0941	0.1076
30	2.6642	3.026	0.8804	0.0837	0.0950
35	2.3300	2.51	0.9283	0.0740	0.0797
40	1.9590	2.102	0.9320	0.0677	0.0726
45	1.6946	1.765	0.9601	0.0584	0.0608
50	1.3420	1.49	0.9007	0.0464	0.0515
55	0.9508	1.245	0.7637	0.0391	0.0512
60	0.6722	1.04	0.6463	0.0331	0.0512
65	0.5394	0.856	0.6301	0.0216	0.0343
70	0.4476	0.697	0.6422	0.0118	0.0183
75	0.2560	0.561	0.4563	0.0019	0.0041
80	0.1550	0.434	0.3571	0.0010	0.0028
85	0.1094	0.317	0.3451	0.0008	0.0022
90	0.0794	0.208	0.3817	0.0004	0.0009
95	0.0624	0.106	0.5887	0.0003	0.0004

Table 13 Rescaling analysis for the period 2023-24

Flow percentile (%)	Mill of Tore			Kemp Outflow	
	Short term	Long term	Ratio	Short term	Long term
	Flow (m ³ /s)	Flow (m ³ /s)		Flow (m ³ /s)	Flow (m ³ /s)
5	9.4443	11.631	0.8120	0.2978	0.3667
10	6.1900	7.797	0.7939	0.1657	0.2087
15	4.8315	5.842	0.8270	0.1381	0.1670
20	3.9540	4.568	0.8656	0.1185	0.1369
25	3.3878	3.683	0.9198	0.1030	0.1120
30	2.8220	3.026	0.9326	0.0898	0.0963
35	2.4795	2.51	0.9878	0.0807	0.0817
40	2.1890	2.102	1.0414	0.0685	0.0658
45	1.9390	1.765	1.0986	0.0608	0.0554
50	1.7500	1.49	1.1745	0.0560	0.0477
55	1.4120	1.245	1.1341	0.0514	0.0453
60	1.1940	1.04	1.1481	0.0471	0.0410
65	1.0168	0.856	1.1878	0.0391	0.0329
70	0.8975	0.697	1.2877	0.0348	0.0271
75	0.7535	0.561	1.3431	0.0298	0.0222
80	0.5970	0.434	1.3756	0.0267	0.0194
85	0.4785	0.317	1.5095	0.0221	0.0146
90	0.3990	0.208	1.9183	0.0140	0.0073
95	0.2850	0.106	2.6887	0.0100	0.0037

Table 14 Rescaling analysis for the period 2022-25

Flow percentile (%)	Mill of Tore			Kemp Outflow	
	Short term	Long term	Ratio	Short term	Long term
	Flow (m ³ /s)	Flow (m ³ /s)		Flow (m ³ /s)	Flow (m ³ /s)
5	11.6240	11.631	0.9994	0.2658	0.2660
10	7.5045	7.797	0.9625	0.1897	0.1971
15	5.8101	5.842	0.9945	0.1465	0.1473
20	4.5920	4.568	1.0053	0.1261	0.1255
25	3.6770	3.683	0.9984	0.1076	0.1078
30	3.0430	3.026	1.0056	0.0930	0.0925
35	2.5653	2.51	1.0220	0.0827	0.0809
40	2.2176	2.102	1.0550	0.0740	0.0701
45	1.9148	1.765	1.0849	0.0659	0.0608
50	1.6345	1.49	1.0970	0.0584	0.0532
55	1.3065	1.245	1.0494	0.0522	0.0497
60	1.0666	1.04	1.0256	0.0450	0.0439
65	0.8972	0.856	1.0481	0.0391	0.0373
70	0.7403	0.697	1.0621	0.0343	0.0323
75	0.6065	0.561	1.0811	0.0293	0.0271
80	0.4916	0.434	1.1327	0.0221	0.0195
85	0.3701	0.317	1.1674	0.0130	0.0111
90	0.2012	0.208	0.9673	0.0025	0.0026
95	0.0920	0.106	0.8679	0.0006	0.0007

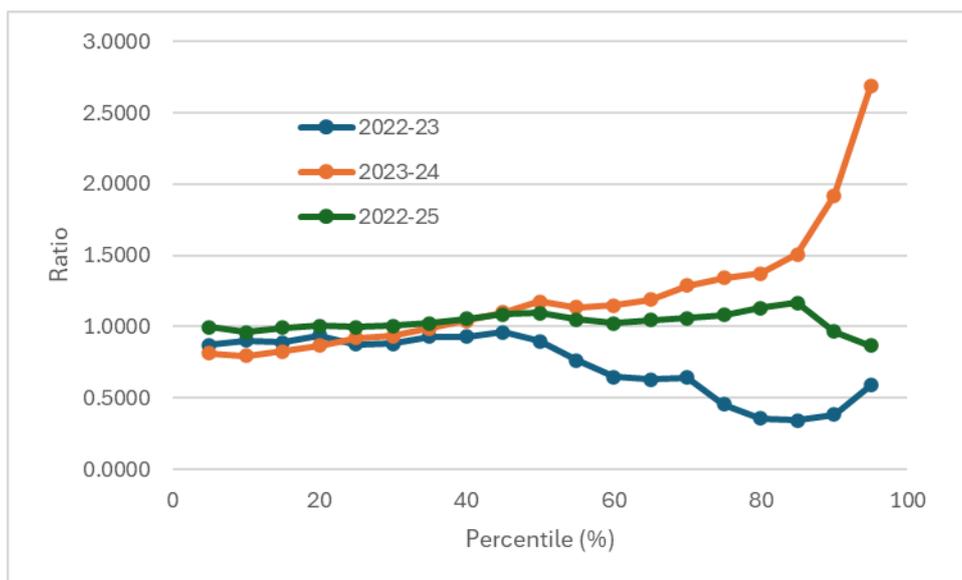


Figure 22 Comparison of the ratios of short and long term FDC Mill of Tore

5.4 Whitebridge

The rescaling analysis using Whitebridge is shown in Tables 15-17. The ratios for the three periods of data (Figure 23) show that neither of the periods 2022-23 or 2023-24 gave a good representation of the long term FDC and the full period of data (2022-25) was only representative of the long term for medium and high flows.

Table 15 Rescaling analysis for the period 2022-23

Flow percentile (%)	Whitebridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	6.9804	6.8740	1.0155	0.2342	0.2307
10	4.1140	4.4570	0.9230	0.1672	0.1812
15	2.7846	3.2370	0.8602	0.1314	0.1527
20	2.2482	2.4850	0.9047	0.1112	0.1229
25	1.8060	1.9350	0.9333	0.0941	0.1008
30	1.4142	1.5470	0.9142	0.0837	0.0915
35	1.2072	1.2640	0.9551	0.0740	0.0775
40	1.0320	1.0500	0.9829	0.0677	0.0688
45	0.8222	0.8780	0.9364	0.0584	0.0624
50	0.6230	0.7390	0.8430	0.0464	0.0550
55	0.4502	0.6160	0.7308	0.0391	0.0535
60	0.3184	0.5190	0.6135	0.0331	0.0540
65	0.2564	0.4300	0.5963	0.0216	0.0363
70	0.2162	0.3520	0.6142	0.0118	0.0191
75	0.1290	0.2910	0.4433	0.0019	0.0042
80	0.0944	0.2350	0.4017	0.0010	0.0025
85	0.0750	0.1810	0.4144	0.0008	0.0019
90	0.0584	0.1300	0.4492	0.0004	0.0008
95	0.0414	0.0840	0.4929	0.0003	0.0005

Table 16 Rescaling analysis for the period 2023-24

Flow percentile (%)	Whitebridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	5.4705	6.8740	0.7958	0.2978	0.3741
10	3.4835	4.4570	0.7816	0.1657	0.2120
15	2.5725	3.2370	0.7947	0.1381	0.1738
20	2.0680	2.4850	0.8322	0.1185	0.1424
25	1.7245	1.9350	0.8912	0.1030	0.1156
30	1.5045	1.5470	0.9725	0.0898	0.0924
35	1.2643	1.2640	1.0002	0.0807	0.0807
40	1.1210	1.0500	1.0676	0.0685	0.0642
45	0.9580	0.8780	1.0911	0.0608	0.0558
50	0.8450	0.7390	1.1434	0.0560	0.0490
55	0.6738	0.6160	1.0938	0.0514	0.0470
60	0.5540	0.5190	1.0674	0.0471	0.0441
65	0.4630	0.4300	1.0767	0.0391	0.0363
70	0.3880	0.3520	1.1023	0.0348	0.0316
75	0.3373	0.2910	1.1589	0.0298	0.0257
80	0.2650	0.2350	1.1277	0.0267	0.0237
85	0.2103	0.1810	1.1616	0.0221	0.0190
90	0.1755	0.1300	1.3500	0.0140	0.0103
95	0.1330	0.0840	1.5833	0.0100	0.0063

Table 17 Rescaling analysis for the period 2022-25

Flow percentile (%)	Whitebridge			Kemp Outflow	
	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)	Ratio	Short term Flow (m ³ /s)	Long term Flow (m ³ /s)
5	6.8212	6.8740	0.9923	0.2658	0.2679
10	4.3469	4.4570	0.9753	0.1897	0.1945
15	3.1558	3.2370	0.9749	0.1465	0.1503
20	2.4588	2.4850	0.9895	0.1261	0.1275
25	1.9620	1.9350	1.0140	0.1076	0.1062
30	1.6204	1.5470	1.0474	0.0930	0.0888
35	1.2840	1.2640	1.0158	0.0827	0.0814
40	1.1378	1.0500	1.0836	0.0740	0.0683
45	0.9438	0.8780	1.0749	0.0659	0.0613
50	0.7705	0.7390	1.0426	0.0584	0.0560
55	0.6213	0.6160	1.0086	0.0522	0.0517
60	0.4780	0.5190	0.9210	0.0450	0.0489
65	0.3970	0.4300	0.9233	0.0391	0.0423
70	0.3231	0.3520	0.9179	0.0343	0.0373
75	0.2648	0.2910	0.9098	0.0293	0.0322
80	0.2200	0.2350	0.9362	0.0221	0.0236
85	0.1610	0.1810	0.8895	0.0130	0.0146
90	0.1097	0.1300	0.8438	0.0025	0.0030
95	0.0620	0.0840	0.7381	0.0006	0.0009

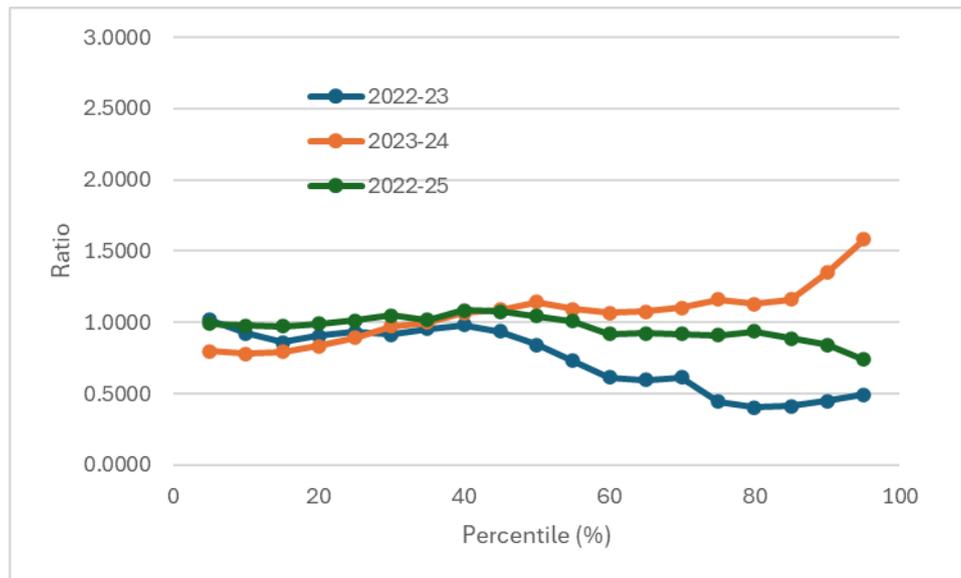


Figure 23 Comparison of the ratios of short and long term FDC Whitebridge

5.5 Comparison of the rescaling analysis

The rescaling method of deriving a long term FDC used four SEPA analogue stations and three periods of data from the Loch Kemp Outflow. Using the ratios of the short term to long term FDC from the analogue stations the results showed that the data set 2022-25 from Balnafoich and 2022-25 from Mill of Tore were representative of the long term FDC. Using the Loch Kemp Outflow data from this period, with the two analogue stations will give the most reliable result from the rescaling analysis.

6 Long term FDC: matched pairs

The matched pairs analysis takes the daily mean flows from Loch Kemp Outflow and the SEPA analogue stations, uses the analogue station long term FDC to derive the equivalent flow percentile for each day and applies that percentile to the Loch Kemp Outflow data. The long term FDC is then compiled from the average flows for each flow percentile.

6.1 Ardachy Bridge

The daily mean flow values from Loch Kemp Outflow were used with the long term flow percentiles on the same day from Ardachy Bridge to derive a long term FDC for each period of data (Table 18 and Figure 24).

Table 18 Long term FDC derived by the matched pairs method

Flow percentile (%)	Flow (m ³ /s)		
	2022-23	2023-24	2022-25
5	0.1576	0.2205	0.1930
10	0.2119	0.2600	0.1730
15	0.1337	0.1945	0.1504
20	0.1266	0.1169	0.1139
25	0.0886	0.0495	0.1048
30	0.0971	0.2076	0.1589
35	0.1755	0.1232	0.0755
40	0.0837	0.0984	0.0637
45	0.1055	0.1009	0.1526
50	0.0943	0.1026	0.0884
55	0.0937	0.0777	0.0675
60	0.0716	0.0849	0.0965
65	0.0931	0.0748	0.0747
70	0.0690	0.0506	0.0727
75	0.0471	0.0396	0.0412
80	0.0318	0.0531	0.0435
85	0.0152	0.0380	0.0341
90	0.0150	0.0292	0.0245
95	0.0021	0.0135	0.0078

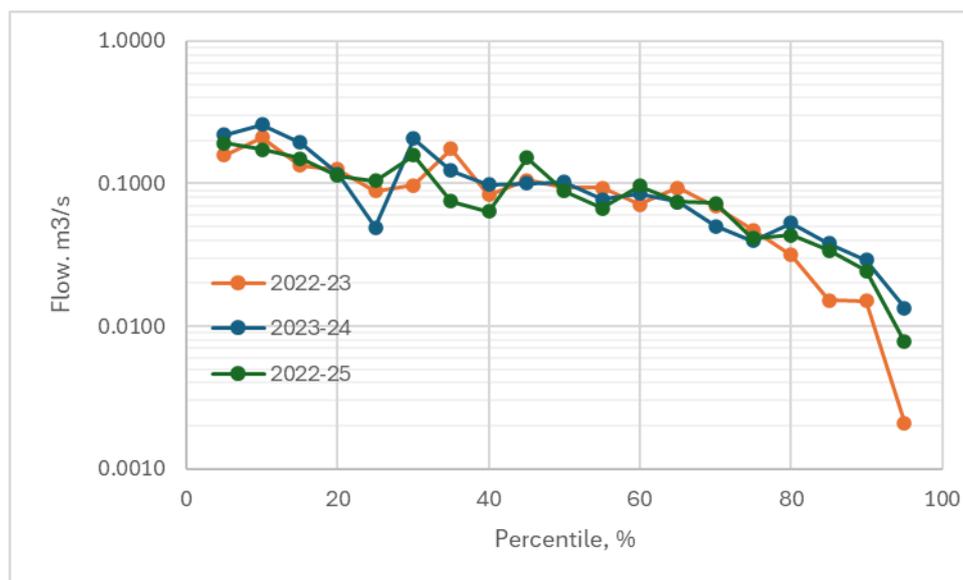


Figure 24 Flow values derived by the matched pairs method

6.2 Balnafoich

The daily mean flow values from Loch Kemp Outflow were used with the long term flow percentiles on the same day from Balnafoich to derive a long term FDC for each period of data (Table 19 and Figure 25).

Table 19 Long term FDC derived by the matched pairs method

Flow percentile (%)	Flow (m ³ /s)		
	2022-23	2023-24	2022-25
5	0.2276	0.2409	0.2212
10	0.1848	0.2237	0.1758
15	0.1111	0.1446	0.1586
20	0.1601	0.1169	0.1561
25	0.0983	0.1110	0.1310
30	0.1013	0.1142	0.1073
35	0.1055	0.0666	0.1030
40	0.0786	0.0744	0.0657
45	0.0854	0.0742	0.0807
50	0.0794	0.0681	0.0729
55	0.0716	0.0588	0.0770
60	0.0592	0.0513	0.0540
65	0.0489	0.0464	0.0563
70	0.0350	0.0329	0.0345
75	0.0342	0.0239	0.0368
80	0.0159	0.0276	0.0284
85	0.0105	0.0264	0.0241
90	0.0071	0.0170	0.0151
95	0.0025	0.0117	0.0031

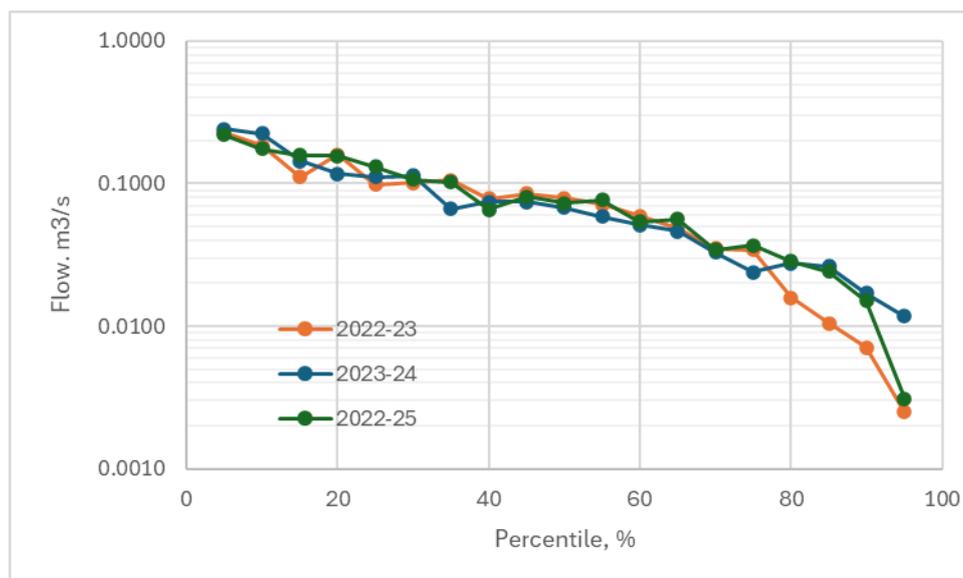


Figure 25 Flow values derived by the matched pairs method

6.3 Mill of Tore

The daily mean flow values from Loch Kemp Outflow were used with the long term flow percentiles on the same day from Mill of Tore to derive a long term FDC for each period of data (Table 20 and Figure 26).

Table 20 Long term FDC derived by the matched pairs method

Flow percentile (%)	Flow (m ³ /s)		
	2022-23	2023-24	2022-25
5	0.2637	0.3261	0.2528
10	0.1294	0.1569	0.1483
15	0.1505	0.1832	0.1997
20	0.1329	0.1166	0.1210
25	0.1028	0.1226	0.1116
30	0.1126	0.0766	0.0991
35	0.0925	0.0935	0.0810
40	0.0893	0.0607	0.0698
45	0.0748	0.0563	0.0612
50	0.0644	0.0609	0.0682
55	0.0542	0.0543	0.0563
60	0.0495	0.0314	0.0369
65	0.0388	0.0388	0.0393
70	0.0350	0.0423	0.0401
75	0.0306	0.0360	0.0308
80	0.0200	0.0261	0.0262
85	0.0148	0.0167	0.0162
90	0.0022	0.0087	0.0052
95	0.0007	0.0053	0.0010

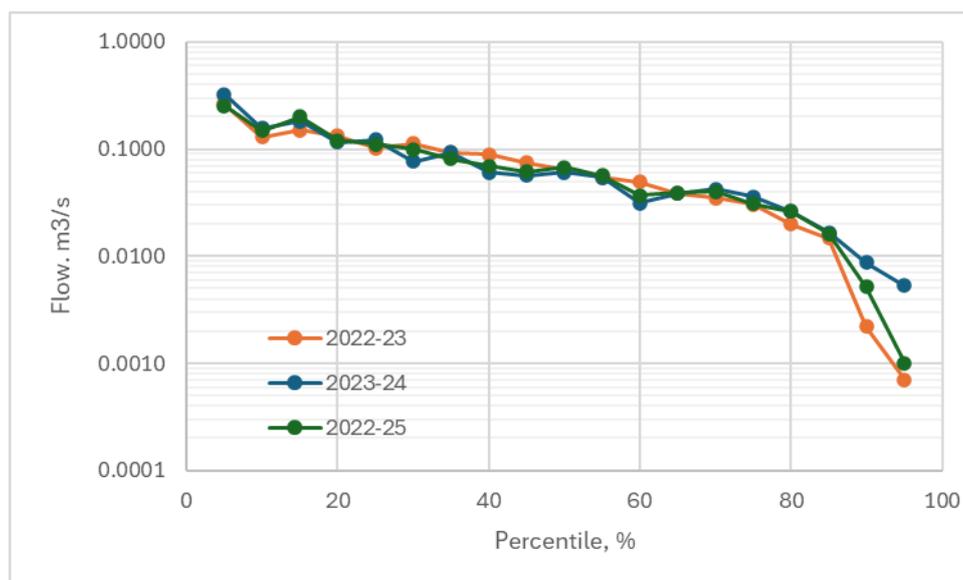


Figure 26 Flow values derived by the matched pairs method

6.4 Whitebridge

The daily mean flow values from Loch Kemp Outflow were used with the long term flow percentiles on the same day from Whitebridge to derive a long term FDC for each period of data (Table 21 and Figure 27).

Table 21 Long term FDC derived by the matched pairs method

Flow percentile (%)	Flow (m³/s)		
	2022-23	2023-24	2022-25
5	0.1778	0.3212	0.1774
10	0.1283	0.2771	0.2133
15	0.2023	0.1123	0.2196
20	0.1369	0.0789	0.1568
25	0.1133	0.1393	0.1160
30	0.0901	0.0922	0.0897
35	0.0898	0.1126	0.1189
40	0.0763	0.0786	0.0745
45	0.0827	0.0654	0.0623
50	0.0700	0.0614	0.0815
55	0.0602	0.0538	0.0705
60	0.0506	0.0480	0.0563
65	0.0472	0.0528	0.0491
70	0.0383	0.0442	0.0430
75	0.0348	0.0400	0.0381
80	0.0236	0.0382	0.0310
85	0.0197	0.0288	0.0285
90	0.0104	0.0232	0.0233
95	0.0017	0.0076	0.0022

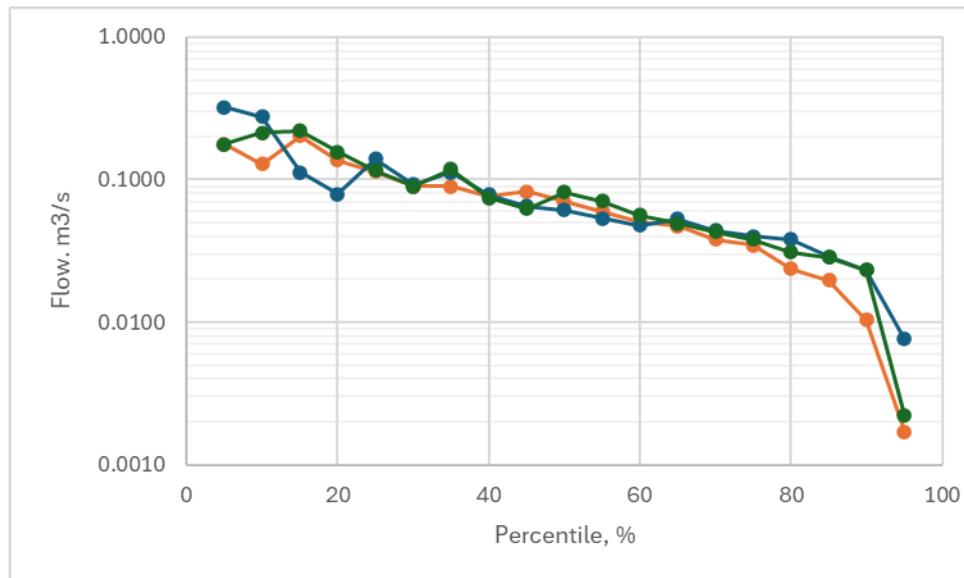


Figure 27 Flow values derived by the matched pairs method

6.5 Comparison of the matched pairs results

The matched pairs results from all four analogue stations show a large amount of scatter. While this scatter could be smoothed by removing outlier points it would be very subjective which points to remove. The matched pairs method is therefore considered to be unsuitable for the Loch Kemp Outflow analysis.

7 Final results

The outflow from Loch Kemp was monitored from January 2022 to May 2025. A gap in the data exists from February 2023 to October 2023 when the logger was overwriting. The data was therefore split into three periods:

12 months: 2022-23

12 months: 2023-24

All data: 2022-25

Manual flow gaugings were undertaken to derive a robust rating equation which was used to convert the logger stage data to flow data. Short term flow duration curves (FDC) were derived for each of the three periods of data.

To derive a long term FDC for the Loch Kemp Outflow site, four long term SEPA stations were used as analogue sites. Comparing the daily mean flows for the period 2022-25 from Loch Kemp Outflow with the analogue stations showed the SEPA stations at Balnafoich ($R^2 = 0.60$) and Mill of Tore ($R^2 = 0.75$) had good relationships with Loch Kemp Outflow.

A rescaling analysis was carried out for each period of data and using all four analogue stations. The results showed that the data sets 2022-25 from Balnafoich and 2022-25 from Mill of Tore were representative of the long term FDC.

A matched pairs analysis was carried out for each period of data and using all four analogue stations. The results showed a large scatter in the results so these results were discounted.

The results therefore showed that the period of data 2022-25 should be used in the final analysis along with the two analogue stations Balnafoich and Mill of Tore. Little difference exists between the estimates of the long term FDC from the two analogue stations so the average of the two was calculated. This is the final long term FDC for the Loch Kemp Outflow (Table 22).

Table 22 Final FDC for Loch Kemp Outflow

Flow percentile (%)	Loch Kemp Outflow (m ³ /s)		
	Derived from Balnafoich	Derived from Mill of Tore	Final FDC Average of Balnafoich and Mill of Tore
5	0.2823	0.2660	0.2742
10	0.2120	0.1971	0.2046
15	0.1686	0.1473	0.1580
20	0.1375	0.1255	0.1315
25	0.1134	0.1078	0.1106
30	0.0973	0.0925	0.0949
35	0.0831	0.0809	0.0820
40	0.0766	0.0701	0.0734
45	0.0681	0.0608	0.0645
50	0.0614	0.0532	0.0573
55	0.0550	0.0497	0.0524
60	0.0464	0.0439	0.0452
65	0.0398	0.0373	0.0386
70	0.0338	0.0323	0.0331
75	0.0290	0.0271	0.0281
80	0.0223	0.0195	0.0209
85	0.0138	0.0111	0.0125
90	0.0026	0.0026	0.0026
95	0.0007	0.0007	0.0007