MOTT MACDONALD

Loch Pattack Hydrology modelling

Technical Note

Project:	Gilkes Hydro – Loch Pattack modelling		
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Subject:	Hydrology modelling update for Pattack scheme		

1 Background

Mott MacDonald have undertaken a hydrology study to consider the impact of upstream Loch Pattack on the 5MW Pattack scheme.

The Pattack scheme has a total scheme capacity of 5MW comprised of two horizontal axis Francis turbines (2MW and 3MW).The 2MW turbine (T1) was commissioned in 2017 and the 3MW turbine (T2) was commissioned at the start of 2018.

We have undertaken work assessing the benefits of adding the upstream storage of Loch Pattack to the scheme, and this technical note outlines the basis and summary of this assessment. The CAR license granted to Pattack scheme in 2015 also covered four additional diversion, referred in this note as consented diversions. These diversions haven't been built yet and this note explores the benefits of the additional diversion flows alongside Loch Pattack.

2 Hydrology

2.1 Introduction

Long-term flow series have been estimated for the scheme intake location, based on recorded flows at a SEPA analogue gauge, adjusting to the intake location by comparing against local recorded flows for an overlapping period, and incorporating adjustments for catchment area and average rainfall where appropriate. The detailed steps involved in this process are as follows:

1. Review the gauging station, 15-minute water level records and flow gaugings for the target site;
2. Derive a revised rating curve and derive a 15-minute flow series for the target site;
3. Review and select an appropriate analogue station;
4. Review the 15-minute flow data, including considering infilling any short gaps in the data (for example by interpolation or by comparing flow hydrographs at nearby stations);
5. Convert both target and analogue series to an hourly series (averaging the four values in each hour);
6. Calculate FDCs using hourly flows for the following:
   a. The target site;
   b. Analogue site for the exact period of data at the subject site;
   c. Analogue site for the longest period of complete years;
7. Compare the FDCs for the analogue site for the two periods and derive factors between the shorter and longer periods;
8. Apply these factors to the target site FDC to produce an estimated long-term FDC for the target site;
9. Compare the long-term FDCs for the two stations and derive factors between the analogue and target sites;
10. For each hourly flow value at the analogue site, determine its position on the long-term FDC;
11. Look up the factor for this percentile and apply it to the flow value to give estimated flow at the target site; and,
12. Scale the estimated flows at the long-term target site to the intake location(s) by a catchment area ratio, and if necessary to take account of differences in catchment rainfall. Adjustments for differences in average rainfall are made by means of the ratio of annual average rainfalls in the respective catchments (derived from the Flood Estimation Handbook or FEH).

This approach was followed for the main Pattack intake and also for the Allt Mhainistier to allow flow estimates to be made for the intakes at the additional consented abstraction points. The area-scaling to the main intake was a very minor adjustment as the areas are almost the same (64.5 for the gauge and 64.26km^2 for the intake). More substantial adjustment was required for the additional consented abstractions; for one of them (Allt Beinn Eildh) the adjustment used a formula derived from spot measurements rather than area-scaling.

Using SEPA's analogue tool the highest-scoring gauging stations are those at Claggan and Ardachy Bridge. However, the catchment conditions for those are notably different from Pattack, including much higher rainfall. Marble Lodge was therefore selected as the analogue; this is further to the east and has much lower rainfall, but it was considered that it might yield more realistic flow patterns. Flow duration curves are shown in Figure 2.1, and a flow summary in Table 2.1. The derived runoff is high at over 90%, but is slightly lower than found when using Claggan as the analogue. Annual average flows (Figure 2.2) show no indication of significant trend. The driest year in the period (2003) shows average flow more than 25% lower than the next worst year, and nearly 40% lower than the long-term average.

Figure 2.1: Flow duration curves – Pattack and Marble Lodge

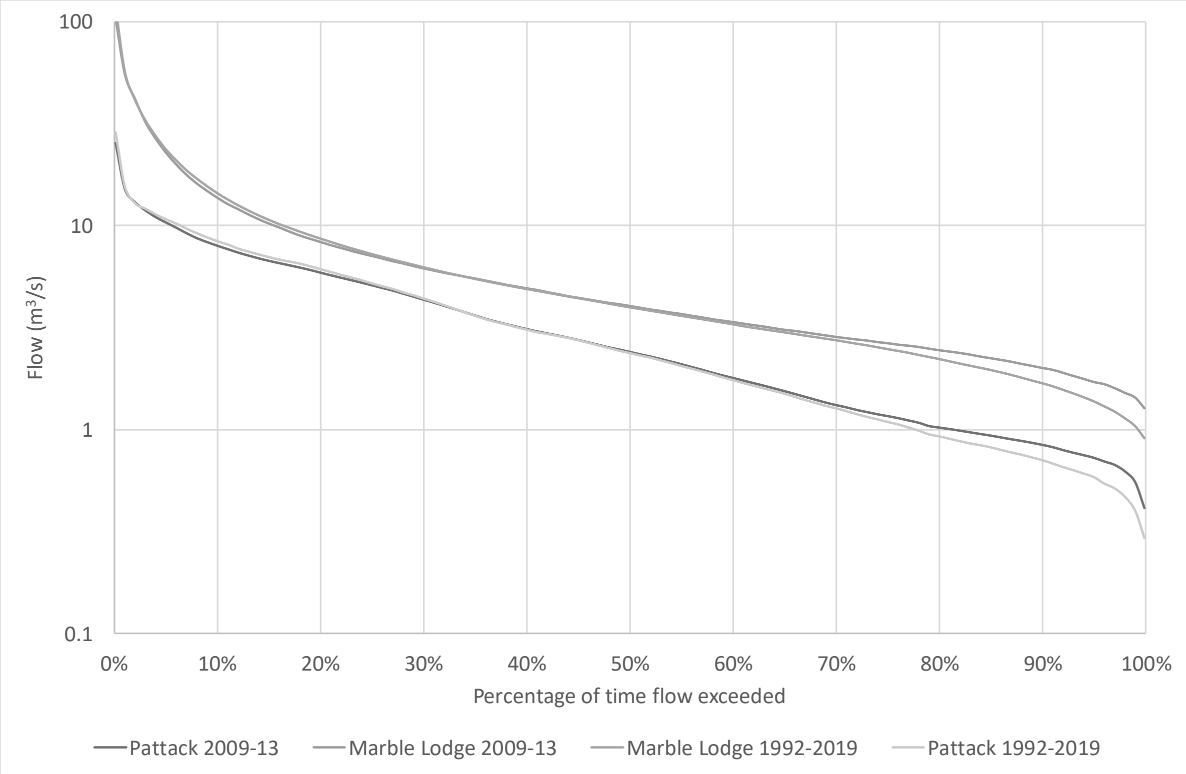


Figure 2.2: Estimated annual mean flows at Pattack intake

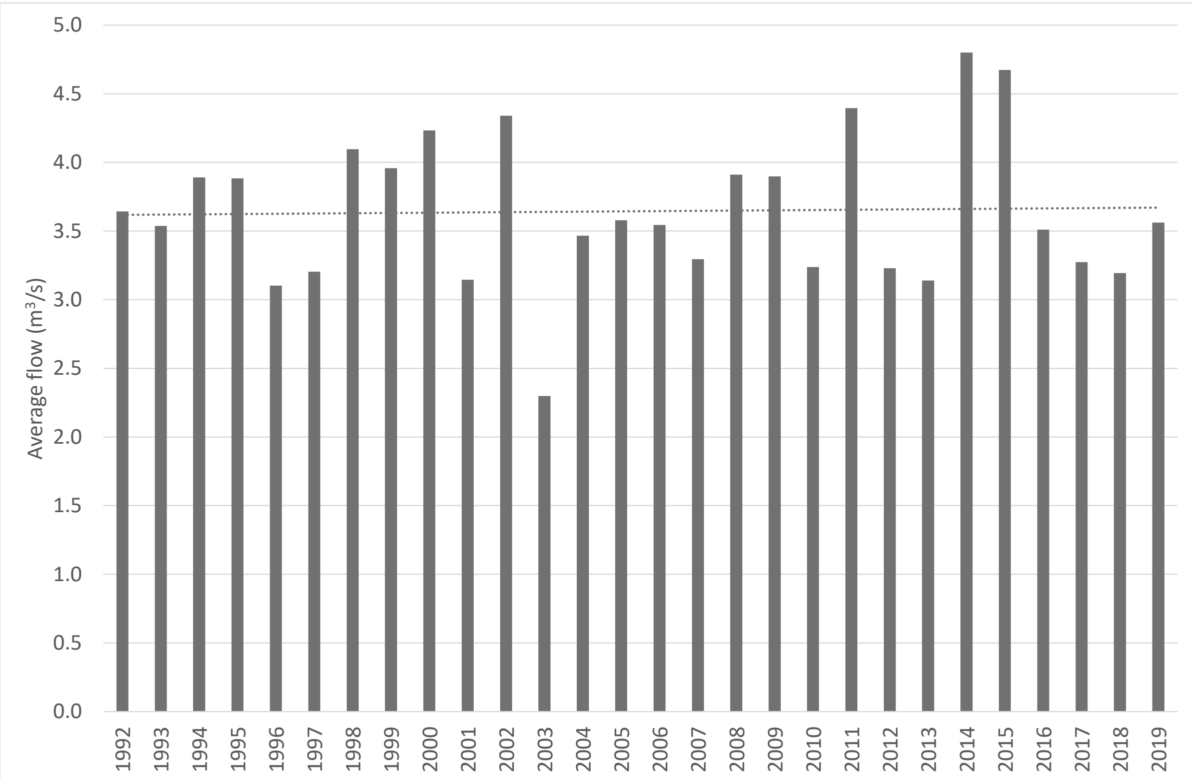


Table 2.1: Pattack flow summary

	Pattack 2009-13	Marble Lodge 2009-13	Marble Lodge 1992-2019	Pattack 1992-2019	Intake
Mean flow (m^3/s)	3.60	7.10	7.17	3.66	3.64
Area (km^2)	64.50	166.47	166.47	64.50	64.26
Runoff (mm)	1763	1345	1360	1790	1790
SAAR (mm)			1316	1939	1939
Runoff %			103%	92%	92%

Source: Mott MacDonald analysis. Note that SAAR values are for 1961-90 and average rainfall in the period may differ.

2.2 Consented diversions

Flow summary for the four additional consented diversions is presented below in Table 2.2.

Table 2.2: Flow summary for consented diversions

	Abstraction 1 - Pattack	Abstraction 2 - Allt Mhainistier	Abstraction 3 - Allt Mhainistier (central)	Abstraction 4 - An Caochan Cuil	Abstraction 5 - Allt Beinn Eildh
Mean flow (m^3/s)	3.64	0.04	0.18	0.07	0.07
Area (km^2)	64.26	0.85	3.64	1.39	2.17
Runoff (mm)	1790	1562	1562	1562	1048
SAAR (mm)	1939	1782			
Runoff %	92%	88%			

Source: Mott MacDonald analysis. Note that SAAR values are for 1961-90 and average rainfall in the period may differ.

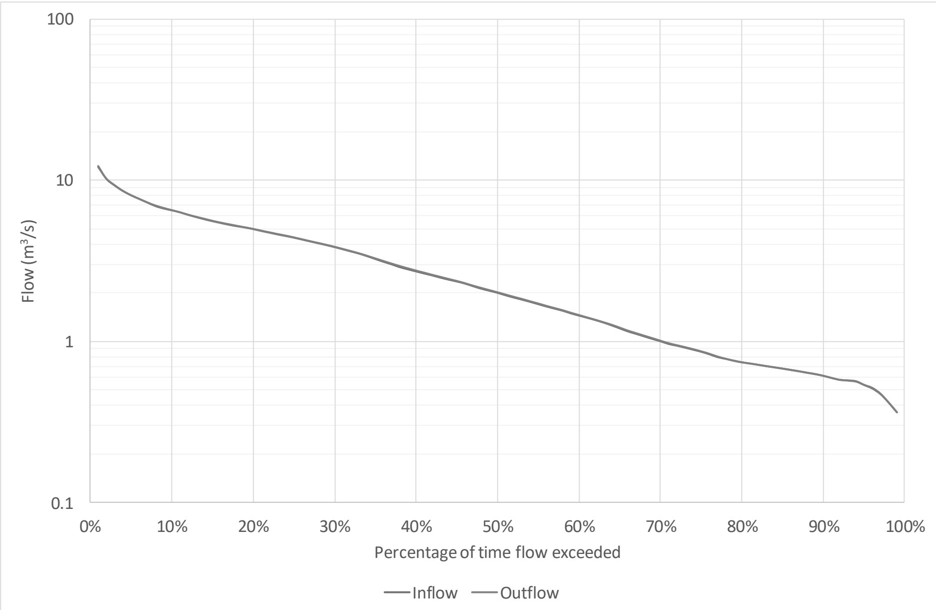
2.3 Impact of Loch Pattack

The flows recorded at Pattack between 2009 and 2013 reflect natural attenuation of flow by Loch Pattack which intercepts runoff from about three quarters of the catchment. The derived long-term series implicitly reflects this natural attenuation. The power and energy modelling considers various possible controls on loch outflows through a dam and gates; the analysis will assess the likely impact of such operations on power generation from the Pattack intake further downstream. In this modelling the derived inflow series is split by catchment area between the areas upstream and downstream of the loch. Gilkes raised a query as to whether there would be double-counting of the attenuation benefits by combining operational attenuation with natural attenuation.

In principle the model will be double-counting the attenuation benefits. In theory the derived inflow series should first be adjusted to convert from a “with loch” to a theoretical “without loch” condition. Then the model would correctly simulate the effects of changing loch storage through operational decisions. Adjusting the flow series would be difficult because it combines natural runoff from about a quarter of the catchment and attenuated runoff from the other three quarters. The scale of attenuation was therefore reviewed by applying an inflow series scaled from the derived Pattack flows to a model of the loch. This model assumed that the natural control on outflow from the loch could be approximated by a broad-crested weir of length 20m (the approximate width of the outflow channel), and used elevation-storage estimates provided by Gilkes. The loch surface area is estimated to be 700,000m^2 at an elevation of 420m, rising to about 760,000m^2 at 420.5m.

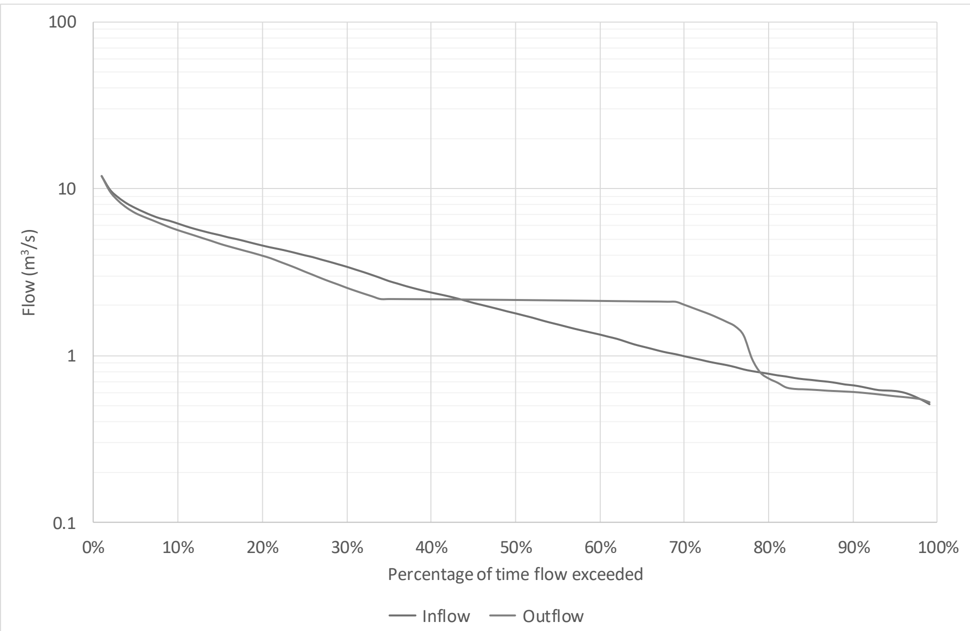
The loch attenuates the highest inflows, but the impact on the FDC is extremely small, as illustrated in Figure 2.3 for a sample 10-year period. It is also insignificant when compared to the changes that would arise from the proposed dam and operating rules (Figure 2.4). As a result it is considered that the double-counting of the effects of attenuation can be ignored. For assessing power generation at the main intake the loch outflows are added to the flow from the downstream part of the catchment.

Figure 2.3: Estimated flow duration curves for Loch Pattack



Source: Mott MacDonald analysis

Figure 2.4: Estimated flow duration curves for proposed future operation of Loch Pattack



Source: Mott MacDonald analysis