Loch Pattack Weir Design Basis Statement

Project Title	Pattack Weir	**Document No.**	GEL/PAT/DOC/101
Subject	Design Basis Statement	**Date of First Issue**	10/05/21

Revision	Date	Originator	Checker	Approver	Description
0	10-05-21	[redacted]	[redacted]	[redacted]	First Issue

Item	Text
1.0	**Introduction** Blencathra Hydro Limited, With assistance from Gilkes Energy Limited, are proposing to increase the energy yield of the River Pattack Hydro Scheme by means of adding loch storage at Loch Pattack, just upstream of the Pattack Hydro Reservoir. The proposed development consists of a new variable weir on the downstream river outlet of Loch Pattack, located within the Ardverikie Estate, to the south of Kinloch Laggan near Newtonmore. The existing 1.5km long reach of river immediately downstream of Loch Pattack to the old Ardverikie 'Top Bridge' is very flat with only 0.4m fall and this provides a natural bottleneck for river flows out of the Loch. The new weir will be located just downstream of this bottleneck at the Ardverikie top bridge, which will impound water back to Loch Pattack. This Design Statement sets out the civil design basis for the Pattack Weir. This document focuses on the design philosophy but also includes narrative on the approach to construction, operation and decommissioning of the dam. The overall aim of the design is to achieve a good balance between safety, operational function, energy output, physical robustness, cost and environmental impact. The following key issues will be considered: • Meet the requirements of Blencathra Hydro Ltd relating to safety, operation of the dam, maintenance & access to the dam; • Minimise the environmental impact; • Minimise costs by standardisation of design, simplification of structures and minimal groundwork; and • Meet the requirements of the landowner particularly in terms of aesthetics

Item	Text
2.0	**Access/ Location**
	The Ardverikie Estate, where the Pattack Weir will be built, is accessible via the A85 trunk road at Kinloch Laggan. The existing estate tracks would be used for access to the weir site. Loch Pattack and its local tracks are accessible via existing estate tracks from Ben Alder Estate via the A889 just north of Dalwhinnie.
3.0	**Pattack Weir - Design**
3.1	**Key Design Points/Philosophy**
	The existing Loch Pattack has a routine loch level variation of approximately 1.5m, between its dry weather low level of 422.0m AOD and an upper inundation level of 423.5m AOD in normal annual wet weather flood conditions, with a loch inflow of approximately 35- 40 cumecs. The reach of river between the loch and the old bridge is very flat and acts as a natural bottleneck constraining the loch outlet and causing the back up in the loch in wet weather.
	The proposed weir will impound water over this natural range between 422.0 and 423.5 and with a loch surface area of approximately 70 Ha, this will add an additional loch volume of up to approximately 1Mm3 of water depending on the variable weir height. This will bring it under the Reservoir and Dam Safety Regulations.
	However in addition to reservoir safety, the key difference from a fixed spillway is that the weir will lower in wet weather and will effectively be invisible to flood flows, which will pass through the structure in the same way as the current river profile as if the weir was not there. The loch inundation levels will not therefore rise to levels higher than would be the case with the same flood flow through the existing natural loch outlet. The variable weir will drop during flood events and that the open channel left will allow passage of floods at least as efficiently as the current loch outlet.
	In addition to the variable weir, in order to safe guard the loch's existing access track from inundation under proposed normal impoundment or annual flood conditions it is proposed to raise the existing loch track by 300-500mm to maintain it above the 423.5m AOD annual flood level.
3.2	**Reservoir Operational Levels (Operational Philosophy)**
	The Pattack Weir will be designed with a likely spillway crest level of 423.5 m AOD. This will define the Top Water level (TWL). Recent survey information has confirmed that the existing river bed level at the site is approximately 2.0 m below TWL at a level of 421.5 m AOD.
	In low water conditions, the existing minimum water level in the upstream loch is approximately 422.0m AOD and at the river, approximately 421.6m AOD with 0.4m of fall over the reach.

Item	Text

The top 2 m of water below the variable weir crest (423.5 – 421.5) will be used for generation at the downstream Pattack hydro scheme. Allowing for the 0.4 - 0.5m fall in the river, this will correspond with 1.5m variation in loch level of between 423.5 – 422.0 at low water. The reservoir will generally be drawn down as early as possible using the appropriate generation flows to maximise available loch storage under high flow events.

Compensation flow requirements are discussed in the following section.

The operating levels for the reservoir formed by the Pattack Weir are given in the following table and figure:

Table 1 Reservoir Operation Levels

Criteria	Water Level	Abbreviation	Level (mAOD)	Approximate Volume of reservoir (m3)	Comments
Maximum Water Level	Flood Water Level	(FWL)	TBC	TBC	A function of the acceptable discharge over the weir
Reservoir Maximum Operating Level	Top Water Level	(TWL)	423.5	1,000,000	Reservoir held at this level. Should the Hydro turbines require flow then this would be over-ruled
Minimum water level at Loch	Minimum Generation Water Level	(MGWL)	422.0	0	Loch Level with Weir fully open
Bottom Water Level at Weir	Minimum Water Level	(MGWL)	421.6	0	Water level at Weir when fully open

Item	Text

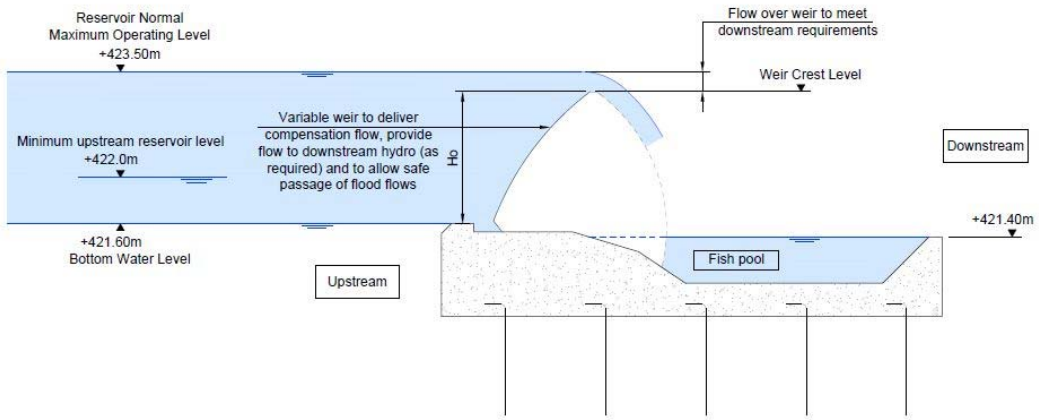

Figure 1 Section through the variable weir

3.3 Compensation Flow

It is expected that the compensation flow requirements will be a 'Hands Off' Compensation flow of Q95. Based on the Q95 compensation requirement at the Pattack Hydro Dam of 726 l/s it is estimated, through catchment scaling, that the Pattack Weir compensation flow will be 612 l/s. This compensation flow will be passed downstream under all normal operating conditions.

No requirement for freshet release is expected, however the fully variable weir will be able to pass full river flows when required in flood or for other reasons to draw down Loch Pattack to its current natural levels.

3.4 Flood and Reservoir Safety Criteria

The following points set out the normal reservoir safety criteria:

- As it is proposed that the fixed elements of the Pattack Weir will be of concrete construction, some overtopping is considered tolerable during extreme floods. However, for a new construction the guide recommends that the general flood standard be used.
- The spillway will be designed to accommodate the design flood standard for a Category A reservoir with a design flood return period of 10,000 years. This will be

Item	Text

accommodated within the spillway (with the variable weir lowered) and with some overtopping of the wing walls, subject to Construction Engineer approval.

- The spillway will also be checked against the PMF safety check flood and again this will overtop the wing walls of the structure subject to Construction Engineer approval.
- The dam and abutments will be designed to withstand the overtopping discharge due to wave action during a 1:10,000 year flood and will be completed to ensure the safety check flood can be passed without compromising the safety of the structure.
- Wave surcharge will be calculated following the criteria given in the ICE guide to 'Floods and Reservoir Safety' (4th Edition).

Table 2 Flood, wind and wave combinations

Flood	Initial Reservoir Condition	Flood Return Period	Wind Speed and Wave Surcharge	Overtopping
Construction Design Flood	Empty	1: 10 year flood	-	None
Design Flood	Just full (NTWL), but gate will be dropped in advance of flood	1: 10,000 year flood	Greater of: Wave surcharge resulting from mean annual maximum hourly wind speed; Or, 0.6m	Yes overtopping of wing walls. TBC
Safety Check Flood	Just full (NTWL), but gate will be dropped in advance of flood	PMF	-	Yes overtopping of wing walls. TBC

However since the variable weir will be designed to lower under all normal wet weather conditions, it will not actually be an impounding structure under flood conditions and so only the effects of the fixed wing and training walls need be assessed in the above design and safety checks, subject to approval of the ARP Engineer.

3.5 Draw-Down Facility

The weir will be able to lower to reduce impoundment to zero under normal operation. In addition, a draw-down facility will be provided through the permanent diversion channel and gate plus stop-logs in the flank of the weir. The gate will likely be situated on the hydraulic left of the variable weir with the flow discharging beyond the fish pool. The gate will enable the release of the compensation flow when the ford is operational and the gate plus stop-logs will provide for emergency draw-down as well as weir maintenance capability. There is an option to discharge compensation flow from the proposed draw down facility in the permanent state. This facility would be an actuated gate to regulate the compensation flow in fluctuating reservoir levels.

Item	Text
3.6	**Design life** The design life of the dam sub-structure shall be a minimum of 50 years. Similar structures may survive hundreds of years. Gates, variable weirs and other appurtenant structures will likely be designed to a lower durability standard, 20-30 years, dependant on the costs associated with construction and maintenance.
3.7	**Design Methodology** **3.7.0 Key Criteria** The design aim of the new weir will be to ensure a key criterion is met: 1. That the fixed elements of the structure will not cause additional inundation of Loch Pattack under annual flood conditions with maximum level kept at or below 423.5mAOD in annual flood of approx 40 cumecs. It is considered that the existing loch outlet is currently constrained by both the river banks beneath the top bridge, which form a bottleneck, and the flat reach of river upstream of the bridge. One dimensional HECRAS river flood modelling will be carried out to confirm the existing flood profile at the natural control points on the river. As discussed above these points are at the bridge abutments and within the fairly flat reach of river upstream of the bridge as the river flows from the loch to the bridge. The new weir structure will be added to the model to check that there will be no adverse effects upstream and downstream of the weir in the weir open position under annual floods and no change to the flood profile upstream under any flood conditions up to the 1 in 200 year return period. Refer to the separate Loch Pattack Weir Flood Assessment Document which summarises this flood level modelling and calculations. **3.7.1 Dam & Variable Weir Selection** The concrete structure at the dam will be a reinforced concrete foundation and slab with foundation cut off, cast directly onto clean river formation. The wing walls will be constructed in reinforced concrete. The concrete spillway slab requires to be robust as it houses the cast in variable weir elements and the anchors to hold the variable weir in place. Therefore a reinforced concrete base is the only material option for this part of the structure. The wing walls are relatively short structures linking the base into the banks of the river. The wing walls will also be designed as reinforced concrete core walls with cut-offs in the foundation.

Item	Text

The width of the variable weir will be minimised as far as possible whilst maintaining the key performance criteria, i.e. that flood flows will not inundate the loch banks any more than the existing case.

A number of considerations including ability to control, cost, lifetime and construction risk, performance during flood events and site suitability will be considered during the assessment of the variable weir. The selected type of variable weir being considered is an air filled weir with a hinged steel upstream plate forming the spillway gate. Key points to note are as follows:

Air filled inflated spillway gate with steel plate (Obermeyer style)

- Less vulnerable to overtopping than simple air/water filled
- Seal between the plates when they are set at different levels for discharge purposes
- More accurate flow control , can use inclinometers as well as pressure sensors
- May not be accurate enough to pass compensation flow across the full weir

3.7.2 Catchment Hydrology and Flood Modelling

Hydrology

The catchment hydrology has been determined using FEH data.

The following flood flows were calculated:

Table 3 Flood flow for a range of return periods

Return Period	Flow m3/s with Climate Change uplift
2	55
10	159
100	252
200	293

Flood Modelling

The flood model has been developed as follows:

- Upstream and Downstream flood modelling was used to ascertain the performance of the variable weir and dam wing walls to pass each flood flow. The input to the flood modelling was the inflow data outlined above. A comparison of the existing condition and a range of weir widths was undertaken to find the optimum arrangement.
- Just full TWL will be used as the initial reservoir condition, it is then assumed that the weir will drop until it is fully down before the reservoir level exceeds 423.5m AOD.

Item	Text
	3.7.2 Fish pool and Draw down The following points are considered valid for the design of the downstream fish pool and the draw down facility: • The downstream fish pool will be included within the dam structure and be immediately downstream of the variable weir. As generally required by SEPA the pool depth will be 1/3 of the minimum fall which correspondences to a depth of approximately 700mm minimum. • The draw-down penstock gate valve and stop log system will be designed to have the capability of passing the compensation flow and also be suitable for dewatering the reservoir to the top of the slab for future maintenance of the weir. The flow therefore required to be discharged to allow adequate periods of maintenance will be Q95 as a minimum (612 l/s) and the gate will be designed to pass this flow. The stop log system will allow greater bypass flows during maintenance.
4.1	**Control Kiosk and associated cabling** The location and design of the control Kiosk will be focused on providing a cost effective small building adjacent to the weir with roofline concealed by the existing landform, which should meet the aspirations of the landscaping, landowner, operations and the variable weir contractor. A small timber clad building approximately 5x3.5m should meet these requirements. It is proposed that the electrical system will be an off grid solution powered by a combination of small scale renewables including solar panels, wind and or hydro using part of the hands off flows at the weir.
5.1	**Loch Pattack Track Levels** As discussed above the design philosophy is to size the variable weir such that it does not lead to a greater risk of flooding than currently present. One of the key reasons for this is to avoid inundation of an estate track that runs along the loch-side. However the existing track currently runs along the shore of Loch Pattack just above low level and routinely floods in wet weather, with adjacent exposed edges of blanket peat bog peat being eroded by loch waves under these conditions. It is proposed that the track be raised on a berm in these areas above the proposed inundation level and this would also protect the edges of the blanket bog to prevent further erosion of the Class 1 peatland.

Item	Text
6.1	**Construction Methodology** It is considered likely that the Civil Engineering Contractor will require to form temporary works to divert the water to one side of the proposed weir. In most cases the concrete section housing the variable weir will likely be constructed in two sections, with the half of the structure containing the permanent diversion channel constructed in the near bank first stage, then the river being diverted through this channel in order to construct the second half. It is expected that the Contractor will design the diversion channel and coffer dams to accommodate the annual flood and this will be incorporated into the construction methodology and sequence. The Civil Engineering Contractor will likely install the diversion on the hydraulic left side and utilise the diversion channel to complete the hydraulic left wing wall after the installation of the variable weir.
6.2	**Decommissioning methodology** The intention for decommissioning of the weir would be to completely remove the variable weir structure and leave the concrete slab, foundation & wing walls plus the bridge in place. There are two main reasons that this approach is preferred: • The weir will be designed so that when the variable weir is fully down the impact of the structure on flood flows does not cause additional inundation compared to the existing case. Therefore removing the weir only and leaving the concrete plus bridge will not leave a constraint on the Loch outlet. • Secondly the dam will be designed with a diversion channel sufficiently sized so that the river can be diverted through the structure to facilitate maintenance or, in this case, full removal of the variable weir.