Lochluichart Estate

Flooding / Erosion
Key Issues Report

November 2017

FAIRHURST

CONTROL SHEET

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Contents

1 Introduction

1.1 Background

Fairhurst has been commissioned by Lochluichart Estates LLP (the Client) to provide engineering advice following a flood event on 25th August 2017 that resulted in erosion within an existing watercourse channel, and damage to property and infrastructure within Lochluichart Estate (the Estate).

The watercourse that is the subject of this report (which is not named on current Ordnance Survey (OS) mapping) outfalls to Loch Luichart immediately to the southwest of Lochluichart Lodge at National Grid Reference (NGR) NH 334 632.

Fairhurst visited the Estate on two separate occasions:

- Site Visit 1 on 12th October 2017, when the weather was dry initially with light rain developing and moderate flows in the watercourse; and
- Site Visit 2 on 2nd November 2017 when weather conditions were dry and flows in the watercourse were low to moderate.

Site Visit 1 was undertaken to initially inspect the extent of damage, while Site Visit 2 was undertaken to refine the objectives of the commission and view work undertaken in the catchment since Site Visit 1.

The objectives of the commission are to:

- Provide advice to the Client on the potential effects of development within the catchment of the watercourse, and specifically infrastructure work associated with the Loch Luichart Windfarm (the Windfarm) operated by Enerco;
- Advise on earthworks drainage reinstatement associated with the servitude for the electrical grid connection for the Windfarm;
- Inspect the grid connection route as it crosses the watercourse;
- Inspect areas of erosion along the watercourse corridor;
- Consider safety and ongoing operational activity of the Estate;
- Advise on key residual issues based on inspection and qualitative assessment; and
- Make recommendations on areas for future design or assessment work to achieve stabilisation of the watercourse and reinstatement to meet the requirements of the Estate.

During the site visits, the Client advised that costs of any recommendations should be minimised, with any methods presented using labour and equipment available to the Estate. This is the context for advice provided within this report.

1.2 Study areas

For the purpose of this report, the watercourse has been subdivided into reaches based on characteristics and the mode of erosion. Each reach is described below starting from the upstream extent of the watercourse. A key plan is included in Appendix A for reference.

- Reach 1: The section of the watercourse in proximity to the Windfarm's electrical grid connection crossing centred on NGR NH 336 649.
- Reach 2: The upper plain of the watercourse which has been previously modified to create impoundment (the earth dam for which has since been breached) centred on NGR NH 335 645.

- Reach 3: The section of deep erosion / cut between Reach 1 and the confluence of the major tributary from the east centred on NGR NH 334 643.
- Reach 4: The middle plain area centred on NH 333 639.
- Reach 5: The reach between Reach 4 and the A832 trunk road (including the culvert under the A832) centred on NGR NH 333 636.
- Reach 6: Downstream of the A832 to the outfall to Loch Luichart.

A separate section is provided on pre-earthworks drainage along the grid connection servitude.

1.3 Site visits

As described in section 1.1, Fairhurst has undertaken two site visits – an initial walkover to assist in scoping the more detailed inspection undertaken during Site Visit 2.

During Site Visit 2, Fairhurst met with Enerco and their contractor who was undertaking remedial works along the grid connection route for the Windfarm, and within Reach 1 of the watercourse. While recommendations are set out in this report, the advice was discussed informally with Enerco during Site Visit 2 to allow work to progress.

At the time of Site Visit 2, the Client was undertaking earthworks and reinstatement adjacent to the downstream extent of Reach 6. This comprised levelling of deposited silt and top soiling with a view to reseeding the area immediately upstream of the rail culvert. The assessment provided in this report considers this condition as the ‘baseline’ for recommendations.

1.4 Assessment and report approach

This report sets out a preliminary assessment of the scale of the flood event that resulted in erosion based on readily available data. For each reach, a qualitative review of conditions during Site Visit 2 is provided with recommendations for future assessment / design effort.

Detailed assessment of existing conditions based on numerical modelling of flows, geomorphology and bank stability do not form part of the scope. We set out in our recommendations where such assessments may be required to achieve objectives.

The report concludes with an assessment of risk and prioritisation of activities to both support the Estate and to demonstrate reasonable process to SEPA.

2 Flood sensitivity

2.1 Evaluation of the 25th August 2017 event

The Client reported that flooding had occurred previously in 2008, however it was described by a witness as being much less severe than the event of the 25th August 2017.

It was reported that the severity of the event was localised to the area between Corriemoille and Lochluichart, where flood damage to the A832 trunk road forced a road closure, and there was wash out of the rail line.

Review of the SEPA flood maps indicates that fluvial flooding may occur during a medium likelihood event or greater in Reach 6, specifically where the watercourse crosses the railway and discharges into Loch Luichart.

A medium event is classified by SEPA as a flood event which is likely to occur on average once in every two hundred years. The client advised that the area upstream of the railway was flooded and severely eroded on August 25th 2017 forcing closure of the rail line. This correlates with the SEPA map, and indicates that the severity of the flood could have been in the region of the 1 in 200 year flood or greater. A copy of the SEPA flood map is provided in Appendix B.

3 Key issues and recommendations

3.1 Pre-earthworks drainage along windfarm grid servitude

3.1.1 Conditions

During both site visits, a pre-earthworks drainage ditch was observed along the Windfarm grid connection servitude. At the time of Site Visit 2, conditions were dry, but there were quite significant flows in the ditch which discharged directly into the watercourse at Reach 1.

The ditch had two effects: it introduced flows to the watercourse higher in the catchment than would naturally occur; and it concentrated flows as a point source thereby losing the attenuation effects of natural sub-surface or overland flow. Both of these factors contributed to higher flows in the watercourse than would have occurred prior to construction of the Windfarm.

Temporary sit fence in drainage	**Looking downstream towards watercourse**
	

3.1.2 Future stability

Without mitigation, the conditions observed during Fairhurst's site visits would continue, and point source flows to the watercourse would be higher than during natural conditions before the Windfarm was constructed.

3.1.3 Recommendation

The purpose of the ditch was to reduce ground water levels and intercept surface water uphill of the grid connection servitude. However, as can be seen from the photographs, this had limited benefit with the servitude remaining wet and easily disturbed by tracked excavator.

During the Site Visit 2, Fairhurst recommended that the pre-earthworks ditch be infilled. This could be progressed using locally won materials and locally sourced forestry waste to create check dams at 3-5 metre centres extended to surface level. The check dams would allow the water table to return to

pre-construction levels, and allow surcharged flows to shed overland downhill rather as a point source to the watercourse within Reach 1.

3.2 Reach 1

3.2.1 Conditions

Conditions at Reach 1 represented a highly modified channel relative to the original watercourse arrangement. The head of the watercourse is a short distance upstream and the natural channel alternates between overland flow, subterranean flow and containment within a narrow vegetated channel typical of upland burns.

Significant erosion has occurred at the windfarm grid cable crossing as shown in the photographs below.

It is understood from the Client that, prior to the August 2017 flood event, the grid cable passed under the watercourse (constructed using open trench methods). The trench was backfilled, and a culvert was placed in the watercourse to allow formation of a servitude access. The flood event washed out the culvert crossing and eroded the channel exposing the cable marker tape.

Reach 1 Looking upstream **Site Visit 1**	**Reach 1 Looking upstream** **Site Visit 2**
	

3.2.2 Future stability

During Site Visit 1, there had been no mitigation or protection work within Reach 1. By the time of Site Visit 2, a gabion mattress had been constructed over the grid connection cable to protect it from future erosion, and rip-rap stone had been placed in the banks and bed of the watercourse to stabilise the cross section.

These works had been undertaken without consultation with SEPA, although the scale of the work may have attracted a simple licence under the Water and Environment (Controlled Activities)(Scotland) Regulations 2011 (the CAR Regulations).

While the works provide a localised solution to protecting the grid connection cable, the result was a linear, steep and smooth channel. The risk arising from this is the acceleration of water during higher flow events which has the potential to cause erosion downstream as the watercourse returns to its natural channel.

Reach 1 Looking downstream Site Visit 1	Reach 1 Looking downstream Site Visit 2
	

3.2.3 Recommendation

During the Site Visit 2 it was recommended that the constructed channel be further modified to include baffles and offset barriers using the rip-rap stone to create localised pools and small meanders in the stabilised section. These would act to reduce flow velocities, increase the flow length (and therefore reduce the gradient) and attract the deposition of bed material.

It was further recommended that the bank protection be narrowed and raked back to create an angle rather than a vertical face. This would allow the surfaces to be dressed with topsoil to encourage re-vegetation.

The stabilisation activities implemented by Enerco were considered necessary by them to mitigate erosion which was a risk to the grid cable. Erosion at Reach 1 is considered to be a direct result of the Windfarm construction.

Performance of the re-constructed channel should be monitored on an ongoing basis to assess the regeneration of vegetation on the banks, and the stability of the natural channel downstream.

3.3 Reach 2

3.3.1 Conditions

Reach 2 is formed within an upper plain of the watercourse where the gradients are low, and the alignment is sinuous. The Client advised that this area had been modified in the past to create a low dam to impound water. The purpose of this was to provide a reliable flow during drier periods for water supply to the Estate downstream.

Water was originally controlled and released via a pipe through the retaining structure, but the dam had since breached and flows pass through unimpeded.

There is a significant quantity of sand and larger stones deposited across Reach 2 as can be seen in the photographs. This is likely to comprise previous build up behind the dam, and material washed down from Reach 1 during the August 2017 flood event.

Reach 2 looking downstream	Downstream face of earth dam
	

3.3.2 Future stability

The gradients in this section were relatively flat, and it is not considered that there was a risk of instability from erosion in the short term as the watercourse passed through this area.

However Reach 2 is immediately upstream of Reach 3 (described below), and there may be a longer term risk with continued erosion that the steeper gradients migrate upstream.

3.3.3 Recommendations

The natural / man-made bowl feature at Reach 2, along with the remains of the earth dam create the opportunity for the formation of flood storage at this location. Any solution would have the purpose of attenuating peak flows rather than storing water for the long term.

The area would be dry during normal flow conditions, and a constrained outlet would hold back a proportion of higher flows to reduce peak conveyance.

A detailed assessment of the storage area available against flows arising would be required to derive a design for a flow control structure, as well as consultation with SEPA to determine CAR requirements.

The structure itself would need to be of a simple / low cost nature, yet robust enough to contain flows and higher velocities. This might be achieved through the use of timber or concrete stop logs, or a stepped gabion arrangement to provide a narrowed notch or channel.

3.4 Reach 3

3.4.1 Conditions

Heavy erosion was visible on the higher west bank in the upper sections of the reach, and in some sections this had been eroded to a height of 3 to 4 metres. There was evidence of cobbles and rubble that had been washed into the main channel during the August 2017 flood event.

At the downstream extent of the reach before the confluence with another tributary, the channel narrows and the depth of the erosion increases.

Within much of the reach, the banks were loose and overhanging, and it was anticipated that material will continue to migrate downstream until a stable cross section and gradient is achieved.

Reach 3 Upper west bank looking downstream	Reach 3 Further south looking downstream
	
Reach 3 Near confluence looking upstream	**Reach 3 East bank of tributary near confluence**
	

3.4.2 Future stability

In areas where the bank has been eroded to a slope of 1:1 or closer to vertical, the bank is likely to be unstable and a slip is likely.

The bed of the watercourse is unstable and movement during higher flows is likely.

3.4.3 Recommendations

The surrounding land was not in agricultural use, and was steep and generally of low economic value limited to sheep grazing and deer stocking. There are potential safety risks as a result of bank instability through normal management activities and during stalking.

Given the dynamic nature of this reach, it is recommended that local controlled works are undertaken to stabilise overhanging sections of banks with material used to reinstate the toe areas, encouraging establishment of existing vegetation. It may be necessary to fence off some sections for protection during periods of Estate activity.

The bed load will continue to migrate downstream until a stable section is created.

3.5 Reach 4

3.5.1 Conditions

The slope of the watercourse reduces within Reach 6 to form this middle plain area. The watercourse banks were less well defined and much of the material that was eroded from Reach 3 was deposited

on the west bank. The Client advised that there had been a track crossing / ford approximately midway along this reach which was washed out during the August flood event.

At the time of Site Visit 2, the track had been reconstructed with a culverted crossing.

Reach 4 Looking downstream towards culvert crossing	Reach 4 Looking downstream from culvert crossing
	

3.5.2 Future stability

The loose material in the burn channel may move during higher flows. The river banks were less defined upstream of the culvert and further erosion may occur on the east bank.

3.5.3 Recommendations

The toe of the east bank may be strengthened using loose boulders that have been displaced and deposited locally. Further temporary stabilisation and better definition of the bank could be achieved using brushwood faggots or using felled tree material supported with stakes with material backfilled to create a clear edge to the watercourse.

Out with the channel the objective would be to stabilise the deposited silt material through top soiling and revegetation with trees and grasses that over time would be colonised by more local vegetation or managed for livestock.

3.6 Reach 5

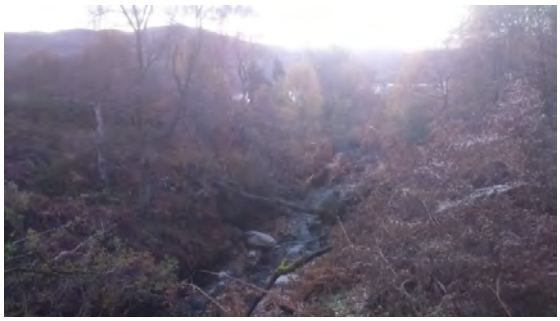
3.6.1 Conditions

At the upstream extent of Reach 5, the watercourse flowed in a narrow ravine. A large number of trees at the lower levels adjacent to the watercourse have been washed out during the flood event in August and at the time of the visit lay beside or across the watercourse. A water supply was taken from a natural rock shelf within ravine, with an intake formed by a low concrete weir and block chamber. The concrete and block had been washed out by the flood event.

Downstream of the ravine, the topography levelled out and there was significant deposition of gravel, stones and boulders over a wide fan area. There were properties close to the newly formed banks on both sides of the watercourse.

The flow channel was poorly defined with the deposition fan creating a flat wide area that was stable during low flows, but likely to be mobilised during higher flow events.

An asphalt surfaced access road crossed the watercourse towards the downstream extent of the reach which was reconstructed following the August flood. The A832 trunk toad crosses the watercourse a further 50m (approximately) downstream.

Reach 5 Looking downstream across ravine	**Reach 5 End of ravine section looking upstream**
	
Reach 5 Open area near properties looking upstream	**Reach 5 Poorly defined channel section looking upstream to nearby property**
	
Reach 5 Access road crossing	**Reach 5 A832 trunk road crossing from access road crossing**
	

3.6.2 Future stability

Bedrock was exposed in the bed and banks of the ravine section at the upper extent of Reach 5. The banks are stable, and save the washing out of the water supply infrastructure and trees, the channel was largely stable. There was some evidence of deposited silt and stone, however water velocities through the ravine would have been high during the August 2017 flood event resulting in much of the bed load being carried through to the lower sections.

In the wider plain in downstream section of Reach 5, conditions were similar to Reach 4 where loose gravel, stones and boulders had the potential to be washed downstream. In this section the banks are were less evident due to the large displacement of gravel and boulders.

The property access road and culvert was reconstructed following the August 2017 flood event, but erosion had been identified immediately downstream due to scour.

The levels of the A832 trunk road, result in a culvert invert that is quite significantly lower than the upstream watercourse bed level. The drop into the culvert was formed in the bedrock. While the section is stable, the drop arrangement is a risk area for deposition and future blockage.

3.6.3 Recommendations

Reach 5 has a higher sensitivity due route of the A832 trunk road and the proximity of the properties on either side of the watercourse.

The evidence of erosion from scour immediately downstream of the access road culvert confirms the need for bank reinforcement and protection. It is recommended that the watercourse banks upstream of the access road culvert, and downstream to the A832 culvert be protected to stabilise the channel and prevent further erosion / instability.

For the section of Reach 5 between the ravine and the access road the channel should be defined placing the larger boulders washed downstream along the toe the channel. Above the boulders, seeded coir matting, small tree planting or willow brash would encourage growth and protect the bare slopes on the banks.

Within the wider area of the deposition fan, topsoil, seeding and larger tree planting would supper longer term stabilisation in this area.

3.7 Reach 6

3.7.1 Conditions

The final reach from the A832 to the watercourse outfall to Loch Luichart was subject to significant deposition of silt and natural realignment during the August 2017 flood event. Damage was caused to the rail line resulting in closure.

The lower section of Reach 6 was considered by the Client to be of high amenity value as part of the landscaped areas surrounding Lochluichart Lodge. It is also highly sensitive due to the risk to the rail line.

At the time of Site Visit 2, a new channel alignment had formed naturally and the Client was progressing with work distributing deposited silt and top soiling with a view to seeding / stabilising the areas adjacent to the banks.

The bank and bed material in this area was fine and highly susceptible to erosion. The new watercourse channel had two bends approaching 90 degrees where erosion would be concentrated. The potential for washing out of fines and deposition of material from upstream makes this area unstable unless action is taken.

During Site Visit 2, options for bank protection were discussed considering rip-rap stone, or a hessian or other reinforced matting that could create a ‘green’ solution in the long term.

Reach 6 Looking upstream towards the A832 crossing	Reach 6 Looking downstream at the access bridge towards the railway crossing
	
Reach 6 Outer bend before railway crossing	**Reach 6 Landscaped area on west bank**
	

3.7.2 Future stability

The watercourse had formed a natural channel across the deposition area within Reach 6. The bank material was predominantly silt and topsoil and highly vulnerable to future erosion. In addition this was a deposition areas for material washed down from the upper reaches.

The presence of the rail crossing at the downstream end of Reach 6 is a significant risk associated with ongoing stability and management of the watercourse.

3.7.3 Recommendations

The material deposited during the August 2017 flood event in Reach 6 appeared to be fine and vulnerable to erosion. While conditions appeared relatively benign during Site Visit 2, the flows that can arise in the watercourse are a stability risk in the short term.

Bank stabilisation is essential, and this must be designed to provide a permanent solution that protects both the property and the rail asset. The length of the section effected, and the works required are likely to attract the requirement for CAR licencing, although it is noted this work is now of an urgent nature.

It is recommended that a design is progressed and SEPA be invited to inspect the site to achieve the appropriate balance between regulatory compliance and speed of resolution.

Out with the watercourse, and protected by the measures noted above, top soiling and planting is a priority as this area will likely be subject to future inundation due to the presence of the culvert downstream.

4 Conclusions

Based on site visit and inspection and ongoing reports from the Client, the watercourse has been significantly altered following the August 2017 flood event. While development activity in the upper catchment associated with the Loch Luichart Windfarm had impacted on the flow regime, the significance in terms of the effects is not concluded.

The watercourse had undergone a rapid change and is now in dynamic state with material transfer occurring during regularly occurring flow events. This is a significant risk both to the Estate and to the strategic infrastructure comprising the A832 trunk road and the rail line.

This report describes conditions observed during the site visits and sets out preliminary recommendations across the 6 defined reaches as well as for the pre-earthworks drainage (PED) along the grid servitude. There is an interconnection between the reaches caused by the continued migration of bed material and silt. This reinforces the need for a strategy that progressively considers stability issues, but focuses initially on risk to valued property and critical assets including the rail line and A832 trunk road.

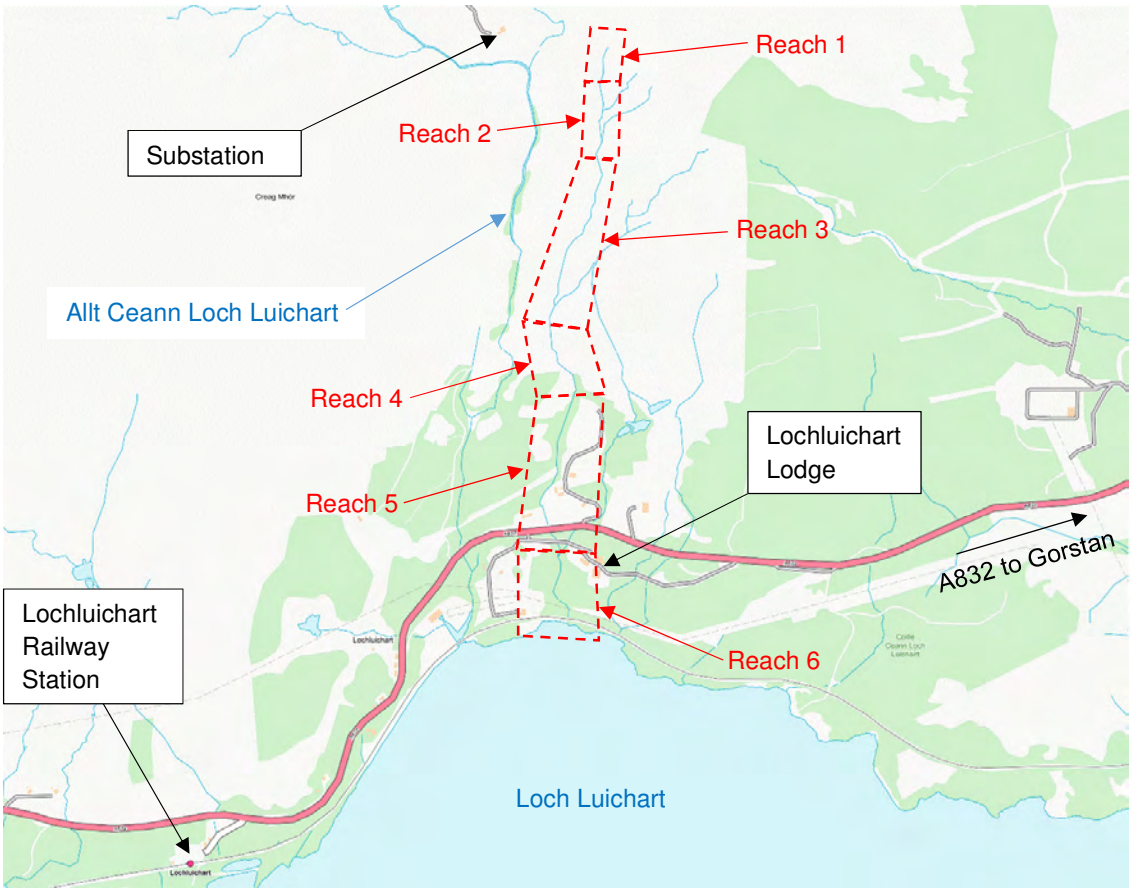
Having defined a strategy that acknowledges risk, priorities and recommendations, this report provides a basis for consultation with SEPA on matters relating to CAR compliance.

The table below summarises a priority ranking and defines the next steps that may be progressed.

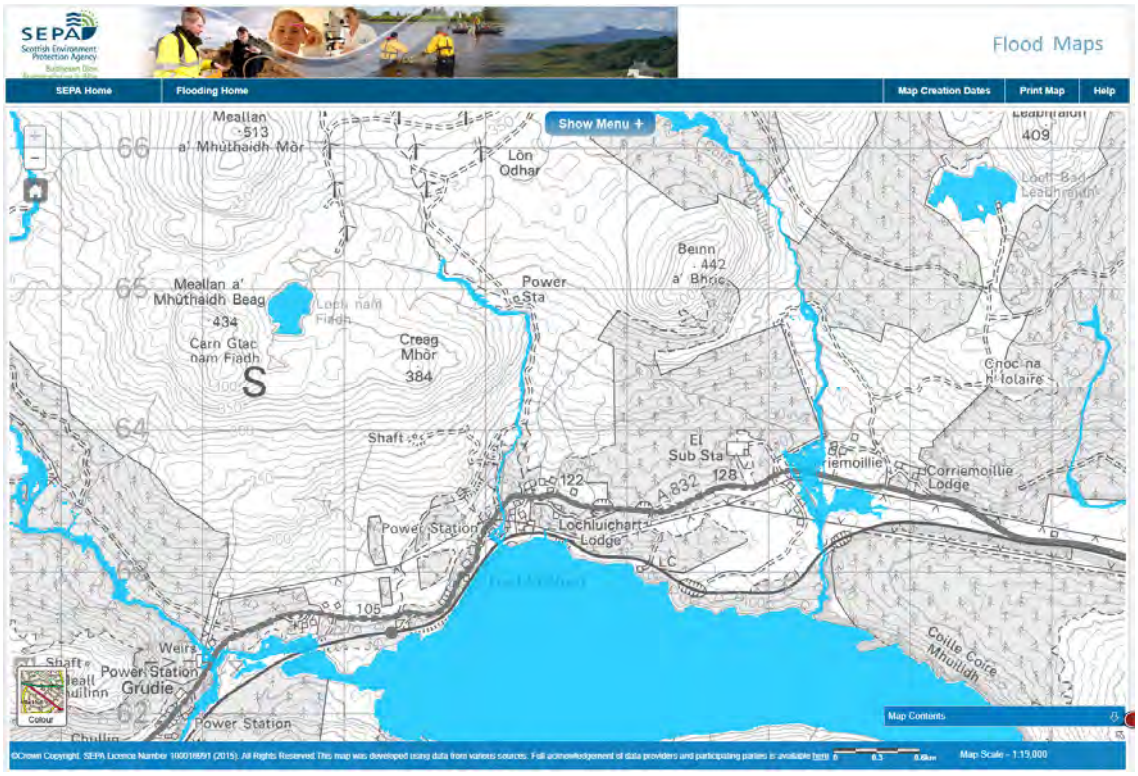
Rank	Reach	Risk	Action
1	6	Bank stability / risk to rail line	Design and implementation of bank protection to provide stable channel with sufficient capacity to carry normal flows and bed load. Will require consultation with SEPA and a CAR Licence strategy acknowledging critical nature and risk.
2	6 & 5	Movement of bed material into reach 6 and risk to A832 trunk road	Design and implement measures to slow down or arrest bed material (temporarily). Potentially within Reach 5 / ravine area where bed rock may provide a secure base for a temporary containment structure.
3	6	Floodplain stability	Following above actions, prioritise stability of areas adjacent to watercourse. Potential need for temporary measures over winter prior to planting in spring.
4	4	Bank and adjacent area stability	Area acts to intercept material from Reach 3 before conveying downstream. Stabilisation of channel would reduce migration, and reinstatement of adjacent areas would provide secure floodplain.
5	5	Bank and adjacent area stability	Similar to item rank 4, this is a dynamic area where the objective is to achieve a stable section in long term through sympathetic bank protection and reinstatement.
6	3	Cut slope stabilisation	This is a relatively steep section that is highly unstable. It presents a safety risk during Estate activities, and consideration should be given to securing overhanging areas, and potentially fencing off sections.

7	2	Storage creation	The upper plain area that forms Reach 2 has an important function in slowing run-off from the upper catchment. Due to previous works, this could be modified at low cost to provide limited attenuation. This has the potential to assist in stabilisation / protection of Reach 3. Modelling of flows and storage is required to allow an effective design to be developed to achieve objectives.
Complete	1	Modification of channel	This area was highly disturbed by the Windfarm, and then again following erosion during August 2017 flood event. It is now a modified channel. Advice provided to Windfarm operator on measures to reduce velocities.
Complete	PED	Point source outfall to watercourse	Pre-earthworks drainage ditches accelerated flows to a point source outfall to the watercourse. Advice provided on ditch infilling to reinstate water table levels and allow sheet flow across land to replicate pre development conditions.

5 Appendix A – Location Plan



6 Appendix B – SEPA Flood Map



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