Appendix 7.1

Flood Risk Assessment

SPEN

Glenlee Substation Extension Development, St John's Town of Dalry

Flood Risk Assessment

FINAL

AUGUST 2019

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SEPA Checklist

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019)

This document must be attached within the front cover of any Flood Risk Assessments issued to Local Planning Authorities (LPA) in support of a development proposal which may be at risk of flooding. The document will take only a few minutes to complete and will assist SEPA in reviewing FRAs, when consulted by LPAs. This document should not be a substitute for a FRA.

Development Proposal Summary				
Site Name:		Glenlee - Substation Extension		
Grid Reference:	Easting:	260717	Northing:	580425
Local Authority:		Dumfries and Galloway Council		
Planning Reference number (if known):				
Nature of the development:		Infrastructure	If residential, state type:	
Size of the development site:		1.4 Ha		
Identified Flood Risk:	Source:	Fluvial	Source name:	Numerous (Water of Ken + Coom Burn) and Burn 1
Land Use Planning				
Is any of the site within the functional floodplain? (refer to SPP para 255)		No	If yes, what is the net loss of storage?	m³
Is the site identified within the local development plan?		No	Local Development Plan Name: / Year of Publication: / Allocation Number / Reference:	
If yes, what is the proposed use for the site as identified in the local plan?		Select from List	If Other please specify:	
Does the local development plan and/or any pre-application advice, identify any flood risk issues with or requirements for the site.		No	If so, please specify:	
What is the proposed land use vulnerability?		Essential Infrastructure	Do the proposals represent an increase in land use vulnerability?	Select from List
Supporting Information				
Have clear maps / plans been provided within the FRA (including topographic and flood inundation plans)?		Yes		
Has sufficient supporting information, in line with our Technical Guidance, been provided? For example: site plans, photos, topographic information, structure information and other site specific information.		Yes		
Has a historic flood search been undertaken?		Yes	If flood records in vicinity of the site please provide details:	
Is a formal flood prevention scheme present?		Yes	If known, state the standard of protection offered:	Substation protected to 1000+CC
Current / historical site use:		Substation and other power-related infrastructure		
Is the site considered vacant or derelict?		No		
Development Requirements				
Freeboard on design water level:		NA m		
Is safe / dry access and egress available?		Select from List	Min access/egress level:	See Report m AOD
Design levels:	Ground level:	See Report m AOD	Min FFL:	See Report mAOD
Mitigation				
Can development be designed to avoid all areas at risk of flooding?		Select from List		
Is mitigation proposed?		Select from List		
If yes, is compenstory storage necessary?		Select from List		
Demonstration of compensatory storage on a "like for like" basis?		Select from List		
Should water resistant materials and forms of construction be used?		Select from List	*Site is protected up to 1 in 1000+30% CC*	

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019)

Hydrology				
Is there a requirement to consider fluvial flooding?		Yes		
Area of catchment:		Numerous km²	Is a map of catchment area included in FRA?	Yes
Estimation method(s) used (please select all that apply):		Pooled Analysis; Single Site Analysis; Enhanced Single Site; ReFH2; FEH RRM; Other	If Pooled analysis have group details been included?	No *Most conservative flows used*
			If other (please specify methodology used):	
Estimate of 200 year design flood flow:		Many m³/s		
Qmed estimate:		Many m³/s	Method:	Select from List
Statistical Distribution Selected:		Select from List	Reasons for selection:	Most conservative used
Hydraulics				
Hydraulic modelling method:		2D	Software used:	Flood Modeller
			If other please specify:	& 1D HEC-RAS. Models are "Checks" for comp. to prev. work done by Halcrow
Number of cross sections:		25		
Source of data (i.e. topographic survey, LiDAR etc):		Topographic survey	Date obtained / surveyed:	2017 when FRA undertaken
Modelled reach length:		More than 1 model m		
Any changes to default simulation parameters?		No	If yes please provide details:	
Model timestep:		More than 1 model		
Model grid size:		More than 1 model		
Any structures within the modelled length?		Combination	Specify, if combination:	Yes, many. More than 1 model.
Maximum observed velocity:		More than 1 model m/s		
Brief summary of sensitivity tests, and range:				
variation on flow (%)		Varies %	Please specify climate change scenario considered:	Orig. 30% - Comp. with 44%/55% now provided
variation on channel roughness (%)		Varies %		
blockage of structure (range of % blocked)		Varies %		
boundary conditions:		**Upstream**		**Downstream**
(1) type		Flow		Normal depth
	Specify if other		Specify if other:	Some models Water Level
(2) does it influence water levels at the site?		Yes		Yes
Has model been calibrated (gauge data / flood records)?		No		
Is the hydraulic model available to SEPA?		No		
Design flood levels:	200 year	Varies m AOD	200 year plus climate change	m AOD
Cross section results provided?		Yes		
Long section results provided?		Yes		
Cross section ratings provided?		Yes		
Tabular output provided (i.e. levels, velocities)?		No	*Shown visually - See Appendix*	
Mass balance error:		Low %		
Coastal				
Is there a requirement to consider coastal / tidal flooding?		No		
Estimate of 200 year design flood level:		m AOD		
Estimation method(s) used:		Select from List	If other please specify methodology used:	
Allowance for climate change (m):		m		
Allowance for wave action etc (m):		m		
Overall design flood level:		m AOD		
Comments				
Any additional comments:		Work was originally undertaken in 2017. FRA updated to meet current guidelines. Many models built. However, modelling is only for comparison with more detailed work undertaken by Halcrow which was used to protect the existing infrastructure.. SEPA happy with Pre-App		
Approved by:	Yusuf Kaya			
Organisation:	Kaya Consulting			
Date:				16/05/2019

Note: Further details and guidance is provided in 'Technical Flood Risk Guidance for Stakeholders' which can be assessed here:- CLICK HERE

1 Introduction

Kaya Consulting Ltd was commissioned by Scottish Power Energy Networks (SPEN), through Land Use Consultants, to undertake a Flood Risk Assessment (FRA) in support of the proposed Glenlee Substation Extension at Glenlee Power Station in Glenlee, close to St John's Town of Dalry.

The site considered in the FRA comprises the area of proposed permanent development only (i.e. the substation extension and associated infrastructure, permanent drainage, including the culvert realignment works). The wider site area considered in the planning application and EIA covers a much wider area, which will be used during construction of the development.

It should be noted that this FRA was originally undertaken in 2017. Since this time SEPA have made changes to their various guidance documents. Efforts have been made to update this report to reflect these changes, such as with respect to increases to climate change uplifts. Please note that when originally submitted to SEPA as part of pre-application consultation in March 2019, SEPA indicated that they would be unlikely to object to the proposals and did not require any additional information.

The site is currently mostly undeveloped greenfield land located adjacent to the existing Glenlee Power Station and substation. The site measures approximately 1.4ha in area.

The site is bounded to the north by the existing power station and substation and local road; to the east by residential housing and a local road; to the south by undeveloped greenfield and to the west by the penstock of the Glenlee Power Station and undeveloped greenfield.

There are numerous watercourses within the vicinity of the site. The Water of Ken is a large watercourse that lies 550m to the east of the site. The Glenlee Tailrace lies approximately 90m from the site at its closest and conveys flows from the power station. This "watercourse" is conveyed in an easterly direction and discharged into the Water of Ken. The Coom Burn lies approximately 200m to the north of the site and flows in an easterly direction before discharging into the Water of Ken. Dickson's Strand is a smaller watercourse that lies approximately 50m to the east of the site, at its closest. This watercourse discharges into a marshland area and onto the Glenlee Tailrace. The Park Burn lies some 170m to the east and south-east of the site, at its closest. This watercourse conveys flows in a north-easterly direction and discharges into the Glenlee Tailrace just upstream of the confluence of the Park Burn with the Water of Ken. An unnamed watercourse (Burn 2) flows approximately 130m to the west of the site before discharging into the Coom Burn. An additional unnamed watercourse (Burn 1) flows through the site and under the existing substation via a culvert, discharging into the marshland area to the north and onto the Glenlee Tailrace.

Consultation of the SEPA flood map indicates that fluvial flooding may occur close to the site at the confluences of the many watercourses and the Water of Ken. Some limited surface water flooding is identified on the mapping within close proximity to the site. A more detailed assessment of flood risk from all sources is required.

The scope of work includes the following:

- Walkover site visit;
- Review of historical maps and available historical flood records;
- Liaison with local council regarding any known flooding issues;
- Liaison with SPEN to obtain details of existing culvert;

- Calculation of design flows for any watercourse within and close to the site and assessment of flood risk based on available topographical data;
- Assessment of flood risk from existing culvert;
- Assessment of flood risk due to proposals to extend the length of existing culvert;
- Assessment of risk from surface water runoff;
- Assessment of flood risk from Coom Burn and Water of Ken. This would be done using a 2D modelling approaching, using LiDAR topographic data of site and surrounding area;
- Assessment of risk from local drainage;
- Assessment of risk from groundwater;
- Preparation of a report suitable to be included with a planning application, assuming all flood management measures can be mitigated for.

Information made available to Kaya Consulting Ltd. for the study includes the following:

- Site location map;
- Topographic site survey;
- Indicative development plan;
- 1m resolution LiDAR DTM data;
- Halcrow (2011) Glenlee Substation Flood Risk Assessment, Draft Report, August 2011;
- SPEN (2017) Glenlee Drainage Strategy, First Issue, October 2017.
- SPEN (2017) Glenlee Extension – Enabling Works – Drainage Layout" (1CA-2-11HD-DO-SPENEC-4106).

A general location map of the site is shown in Figure 1.

Figure 1: General location of site

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2 Legislative and Policy Aspects

2.1 National Planning Policy

The current version of the Scottish Planning Policy (SPP) was published in June 2014 and replaces the previous version which was published in February 2010. The SPP sets out national planning policies which reflect Scottish Government's priorities for operation of the planning system and for the development and use of land. It relates to:

- the preparation of development plans;
- the design of development, from initial concept through to delivery; and
- the determination of planning applications and appeals.

The National Planning Framework (NPF) provides a statutory framework for Scotland's long term spatial development and sets out the Scottish Government's spatial development priorities for the next 20 to 30 years. The SPP sets out the policy that will help to deliver the objectives of the NPF.

Relevant extracts from the SPP concerning flooding risk are listed below:

Policy Principles

255. The planning system should promote:

- *a precautionary approach to flood risk from all sources, including coastal, water course (fluvial), surface water (pluvial), groundwater, reservoirs and drainage systems (sewers and culverts), taking account of the predicted effects of climate change;*
- *flood avoidance: by safeguarding flood storage and conveying capacity, and locating development away from functional flood plains and medium to high risk areas;*
- *flood reduction: assessing flood risk and, where appropriate, undertaking natural and structural flood management measures, including flood protection, restoring natural features and characteristics, enhancing flood storage capacity, avoiding the construction of new culverts and opening existing culverts where possible; and*
- *avoidance of increased surface water flooding through requirements for Sustainable Drainage Systems (SuDS) and minimising the area of impermeable surface.*

256. To achieve this, the planning system should prevent development which would have a significant probability of being affected by flooding or would increase the probability of flooding elsewhere. Piecemeal reduction of the functional floodplain should be avoided given the cumulative effects of reducing storage capacity.

257. Alterations and small-scale extensions to existing buildings are outwith the scope of this policy, provided that they would not have a significant effect on the storage capacity of the functional floodplain or local flooding problems.

Key Documents

- *Flood Risk Management (Scotland) Act 2009.*
- *Updated Planning Advice Note on Flooding.*
- *Delivering Sustainable Flood Risk Management (Scottish Government, 2011).*
- *Surface Water Management Planning Guidance (Scottish Government, 2013).*

Delivery

258. Planning authorities should have regard to the probability of flooding from all sources and take flood risk into account when preparing development plans and determining planning applications. The calculated probability of flooding should be regarded as a best estimate and not a precise forecast. Authorities should avoid giving any indication that a grant of planning permission implies the absence of flood risk.

259. Developers should take into account flood risk and the ability of future occupiers to insure development before committing themselves to a site or project, as applicants and occupiers have ultimate responsibility for safeguarding their property.

Development Planning

260. Plans should use strategic flood risk assessment (SFRA) to inform choices about the location of development and policies for flood risk management. They should have regard to the flood maps prepared by Scottish Environment Protection Agency (SEPA), and take account of finalised and approved Flood Risk Management Strategies and Plans and River Basin Management Plans.

261. Strategic and local development plans should address any significant cross boundary flooding issues. This may include identifying major areas of the flood plain and storage capacity which should be protected from inappropriate development, major flood protection scheme requirements or proposals, and relevant drainage capacity issues.

262. Local development plans should protect land with the potential to contribute to managing flood risk, for instance through natural flood management, managed coastal realignment, washland or green infrastructure creation, or as part of a scheme to manage flood risk.

263. Local development plans should use the following flood risk framework to guide development. This sets out three categories of coastal and watercourse flood risk, together with guidance on surface water flooding, and the appropriate planning approach for each (the annual probabilities referred to in the framework relate to the land at the time a plan is being prepared or a planning application is made):

- ***Little or No Risk** – annual probability of coastal or watercourse flooding is less than 0.1% (1:1000 years)*
  - *No constraints due to coastal or watercourse flooding.*
- ***Low to Medium Risk** – annual probability of coastal or watercourse flooding is between 0.1% and 0.5% (1:1000 to 1:200 years)*
  - *Suitable for most development. A flood risk assessment may be required at the upper end of the probability range (i.e. close to 0.5%), and for essential infrastructure and the most vulnerable uses. Water resistant materials and construction may be required.*
  - *Generally not suitable for civil infrastructure. Where civil infrastructure must be located in these areas or is being substantially extended, it should be designed to be capable of remaining operational and accessible during extreme flood events.*
- ***Medium to High Risk** – annual probability of coastal or watercourse flooding is greater than 0.5% (1:200 years)*
  - *May be suitable for:*
    - *residential, institutional, commercial and industrial development within built-up areas provided flood protection measures to the appropriate standard already exist and are maintained, are under construction, or are a planned measure in a current flood risk management plan;*
    - *essential infrastructure within built-up areas, designed and constructed to remain operational during floods and not impede water flow;*
    - *some recreational, sport, amenity and nature conservation uses, provided appropriate evacuation procedures are in place; and*
    - *job-related accommodation, e.g. for caretakers or operational staff.*

  - *Generally not suitable for:*
    - *civil infrastructure and the most vulnerable uses;*
    - *additional development in undeveloped and sparsely developed areas, unless a location is essential for operational reasons, e.g. for navigation and water-based recreation, agriculture, transport or utilities infrastructure (which should be designed and constructed to be operational during floods and not impede water flow), and an alternative, lower risk location is not available; and*
    - *new caravan and camping sites.*
  - *Where built development is permitted, measures to protect against or manage flood risk will be required and any loss of flood storage capacity mitigated to achieve a neutral or better outcome.*
  - *Water-resistant materials and construction should be used where appropriate. Elevated buildings on structures such as stilts are unlikely to be acceptable.*

Surface Water Flooding

- *Infrastructure and buildings should generally be designed to be free from surface water flooding in rainfall events where the annual probability of occurrence is greater than 0.5% (1:200 years).*
- *Surface water drainage measures should have a neutral or better effect on the risk of flooding both on and off the site, taking account of rain falling on the site and run-off from adjacent areas.*

Development Management

264. It is not possible to plan for development solely according to the calculated probability of flooding. In applying the risk framework to proposed development, the following should therefore be taken into account:

- *the characteristics of the site;*
- *the design and use of the proposed development;*
- *the size of the area likely to flood;*
- *depth of flood water, likely flow rate and path, and rate of rise and duration;*
- *the vulnerability and risk of wave action for coastal sites;*
- *committed and existing flood protection methods: extent, standard and maintenance regime;*
- *the effects of climate change, including an allowance for freeboard;*
- *surface water run-off from adjoining land;*
- *culverted watercourses, drains and field drainage;*
- *cumulative effects, especially the loss of storage capacity;*
- *cross-boundary effects and the need for consultation with adjacent authorities;*
- *effects of flood on access including by emergency services; and*
- *effects of flood on proposed open spaces including gardens.*

265. Land raising should only be considered in exceptional circumstances, where it is shown to have a neutral or better impact on flood risk outside the raised area. Compensatory storage may be required.

266. The flood risk framework set out above should be applied to development management decisions. Flood Risk Assessments (FRA) should be required for development in the medium to high category of flood risk, and may be required in the low to medium category in the circumstances described in the framework above, or where other factors indicate heightened risk. FRA will generally be required for applications within areas identified at high or medium likelihood of flooding/flood risk in SEPA's flood maps.

267. Drainage Assessments, proportionate to the development proposal and covering both surface and foul water, will be required for areas where drainage is already constrained or otherwise problematic, or if there would be off-site effects.

268. Proposed arrangements for SuDS should be adequate for the development and appropriate long-term maintenance arrangements should be put in place.

2.2 SEPA Flood Maps

The SEPA flood maps show the likely extent of flooding for high, medium and low likelihood for fluvial, pluvial (surface water) and tidal flows.

Consultation of the SEPA flood map indicates that fluvial flooding may occur close to the site at the confluences of the many watercourses and the Water of Ken. Some limited surface water flooding is identified on the mapping within close proximity to the site. A more detailed assessment of flood risk from all sources is required.

2.3 SEPA Technical Flood Risk Guidance

The latest version of SEPA 'Technical Flood Risk Guidance for Stakeholders' would need to be consulted when undertaking flood risk assessments (current version is 12 May 2019). This technical guidance document is intended to outline methodologies that may be appropriate for hydrological and hydraulic modelling and sets out what information SEPA requires to be submitted as part of a Flood Risk Assessment.

SEPA Policy 41 sets out roles and responsibilities of SEPA and Planning Authorities.

2.4 Flood Risk Management (Scotland) Act 2009

The Flood Risk Management (Scotland) Act 2009 came into force on 26 November 2009. The Act repealed the Flood Prevention (Scotland) Act 1961 and introduces a more sustainable and streamlined approach to flood risk management, suited to present and future needs and to the impact of climate change. It encourages a more joined up and coordinated process to manage flood risk at a national and local level.

The Act brings a new approach to flood risk management including a framework for coordination and cooperation between all organisations involved in flood risk management, new responsibilities for SEPA, Scottish Water and local authorities in relation to flood risk management, a revised and streamlined process for flood protection schemes, new methods to enable stakeholders and the public to contribute to managing flood risk; and SEPA to act as a single enforcement authority for the safe operation of Scotland's reservoirs.

2.5 Controlled Activities Regulations (CAR)

The Water Environment (Controlled Activities) (Scotland) Amended Regulations 2013 (CAR) brings new controls for discharges, abstractions, impoundments and engineering works in or near inland waters. Any such work requires authorisation (licence) from the Scottish Environment Protection Agency (SEPA) who are responsible for the implementation of the Act. The Regulations include a requirement that surface water discharge must not result in pollution of the water environment. It also makes Sustainable Drainage Systems (SuDS) a requirement for new development, with the exception of runoff from a single dwelling and discharges to coastal waters.

2.6 Climate Change

The SPP states that "*planning system should promote a precautionary approach to flood risk from all sources, including coastal, water course (fluvial), surface water (pluvial), groundwater, reservoirs and drainage systems (sewers and culverts), taking account of the predicted effects of climate change.*"

One of the sustainable policy principles within the National Planning Framework is supporting climate change mitigation and adaptation including taking account of flood risk.

SEPA previously recommended a 20% increase in peak flow for the 0.5% AEP (1:200) event, in accordance with DEFRA (Department of Environment, Food and Rural Affairs) and Scottish Government research.

SEPA has recently released updated climate change recommendations by River Basin region, based on UKCP18. These climate change uplifts range from 24% to 56%. For smaller catchments, an increase in peak rainfall intensity allowances of between 35% and 55% are now recommended.

It is recommended that any site drainage design considers future estimates of increased precipitation and follows an adaptive approach.

The Climate Change (Scotland) Act 2009 also makes reference to adaptation to climate change.

3 Site Location and Description

3.1 Site Description

The site is currently predominantly undeveloped greenfield land located adjacent to the existing Glenlee Power Station and substation. The site measures approximately 1.4 ha in area.

The site is bounded to the north by the existing power station and substation and local road; to the east by residential housing and a local road; to the south by undeveloped greenfield and to the west by the penstock of the Glenlee Power Station and undeveloped greenfield. Figure 2 shows the site boundary and location.

Figure 2: Site boundary and location

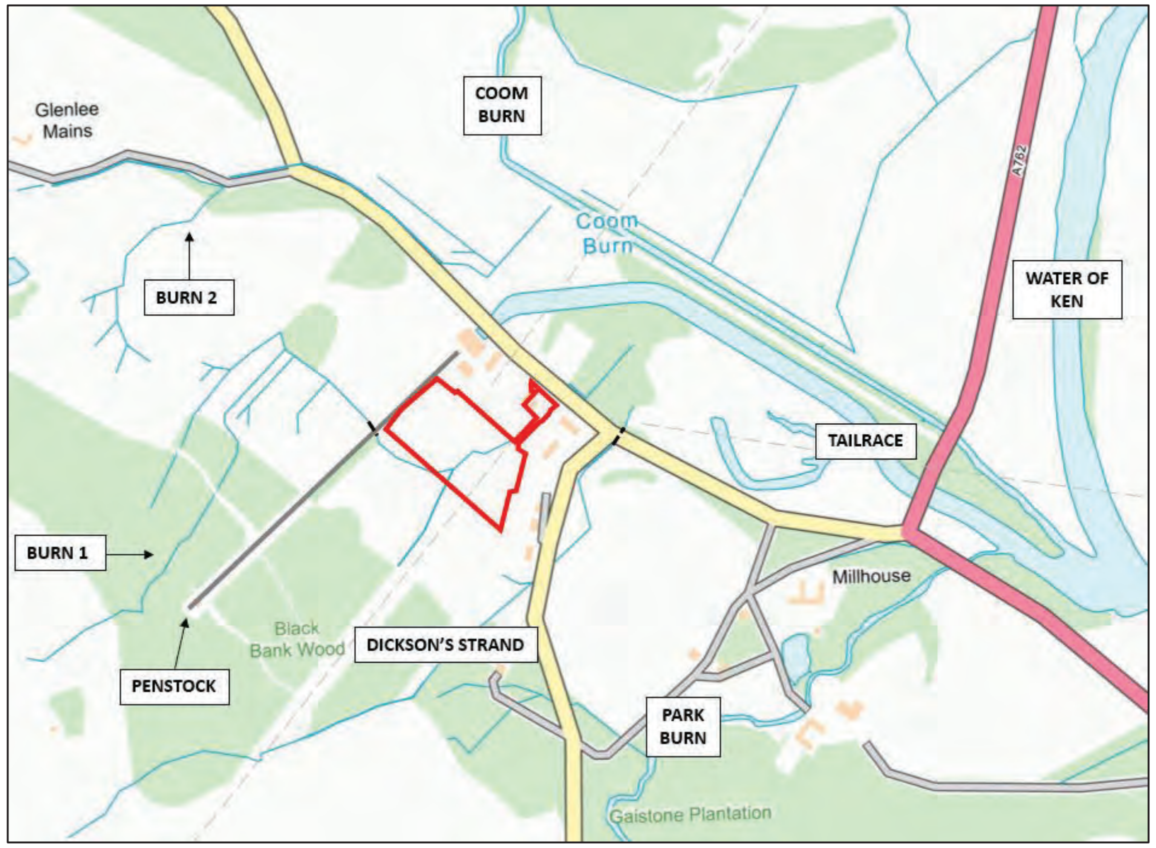

Photo 1 shows the site looking to the west taken from close to the eastern site boundary. Photo 2 shows the site looking south taken from close to the eastern site boundary.

Development proposals are for the extension of the existing Glenlee substation including associated infrastructure and landscaping and changes to the existing substation. This will require the extension of the existing culvert under the substation.

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Photo 1: Image of site looking to the west taken from the eastern site boundary

Photo 2: Image of the site looking south to Glenlee Hill taken from close to eastern boundary

3.2 Topography

The general site topography was derived from the topographic survey and 1m resolution LiDAR DTM data obtained for this assessment.

Levels within the site range between highs of approximately 72.5m AOD (metres Above Ordnance Datum) at the south-western site corner to approximately 54m AOD at the very northern part of the site adjacent to the local road. Ground levels generally slope in a north-easterly direction within the site.

Glenlee Hill to the south-west of the site has a peak elevation of approximately 270m which slopes steeply in a north-easterly direction towards the site, levelling out close to the site. This is shown in Photo 3. Areas to the north and north-east of the site and local road are relatively flat and vary in elevation from approximately 53m AOD to 50m AOD. This low-lying area likely represents the historic floodplain of the Coom Burn prior to its realignment and the construction of the power station (Photo 4). Gradients in this area generally slope to the east, in line with the trajectory of the Coom Burn.

The site generally lies at a higher elevation than areas to the north-east of the site close to the local road. However, the site generally lies at a lower elevation than areas flanking the site to the north-west, south-east and north-east. This is clearly shown in Figures 3 through to 7. This may suggest a risk of surface water flooding. Section 5.4 provides additional information on flood risk from surface water.

Figure 3 shows the general topography of the site and the surrounding area with contours and spot heights. Figure 4 shows a section through the site from south-west to north-east. Figure 5 shows a section through the site from north-west to south-east. Figure 6 displays the location of the sections. Figure 7 shows a 3D representation of the site.

Photo 3: Photo looking south towards Glenlee Hill

Photo 4: Tailrace and low-lying area to north of site, photo looking east

Figure 3: General topography of the site and surrounding area with contours and spot heights

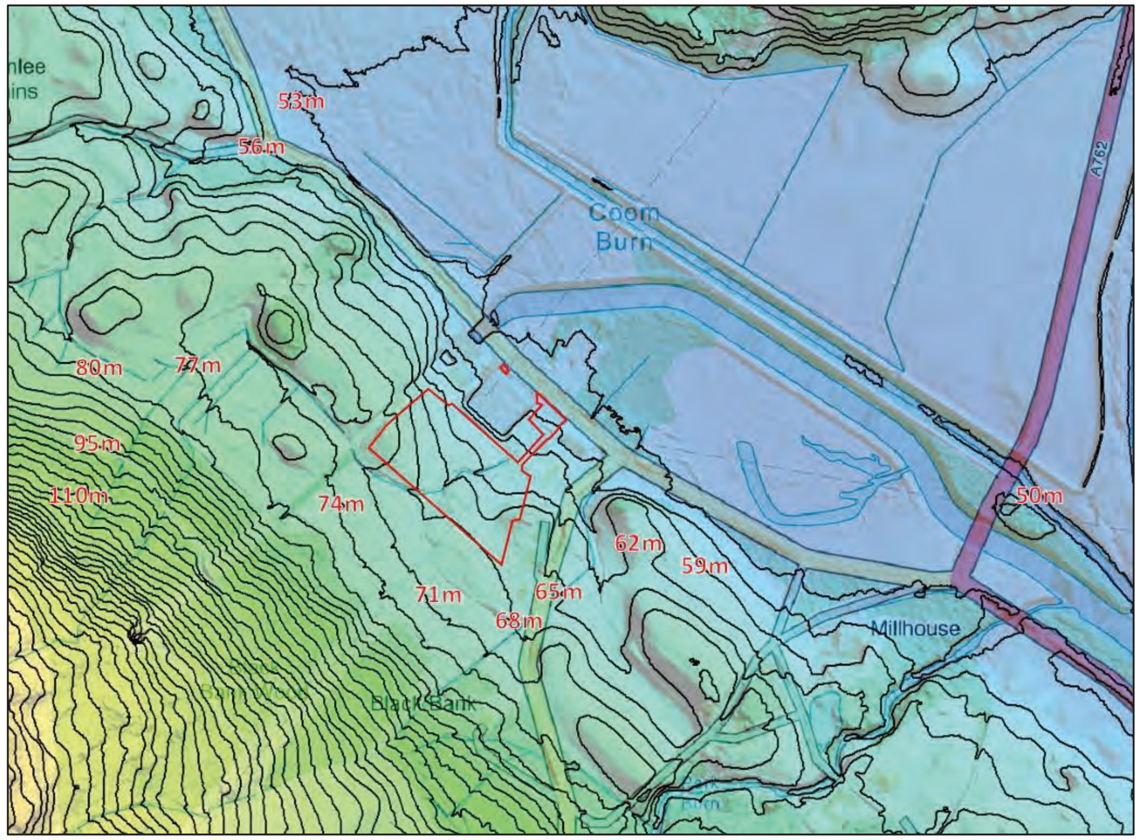


Figure 4: Section 1 through site from south-west to north-east

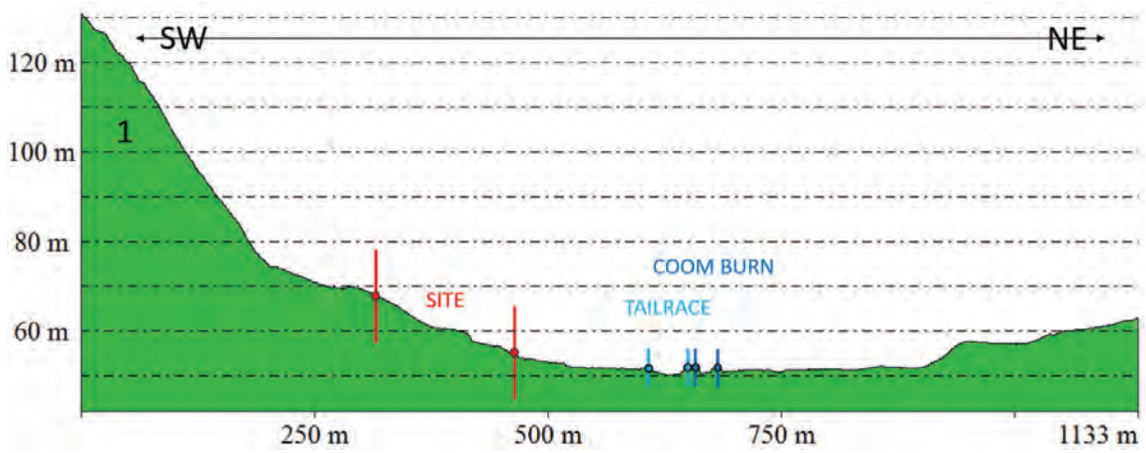


Figure 5: Section 2 through the site from north-west to south-east

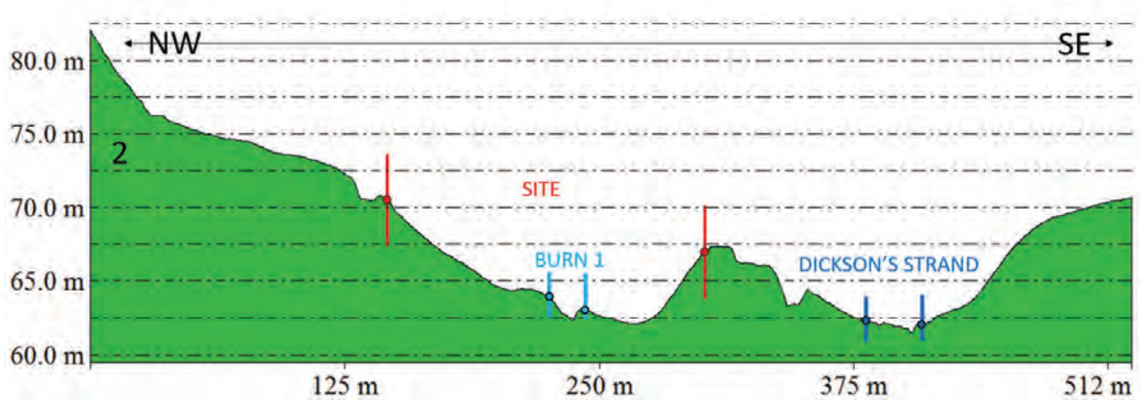


Figure 6: Plan showing location of sections through the site

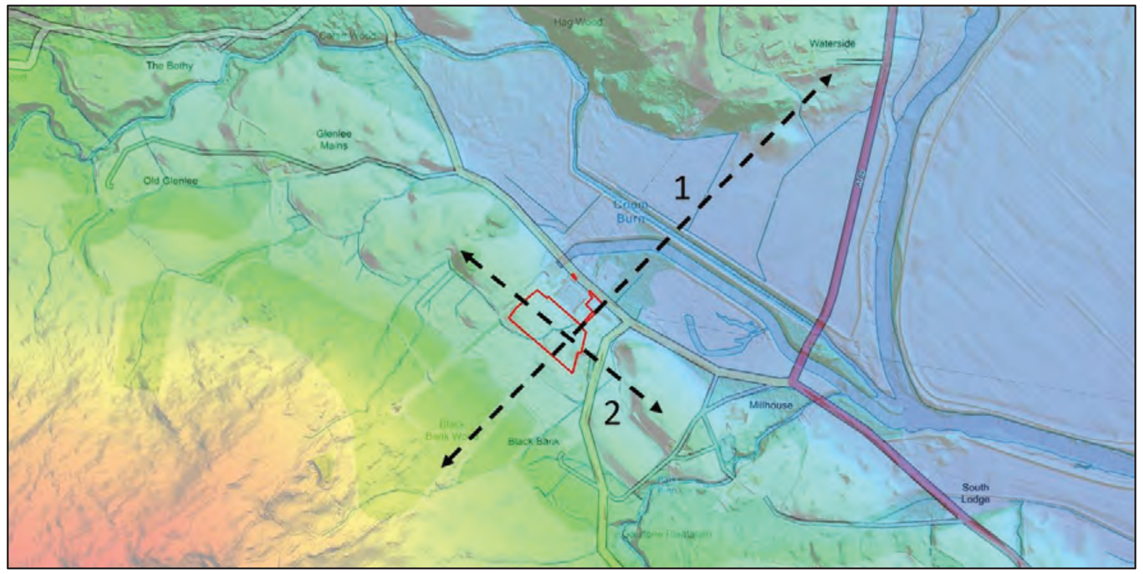
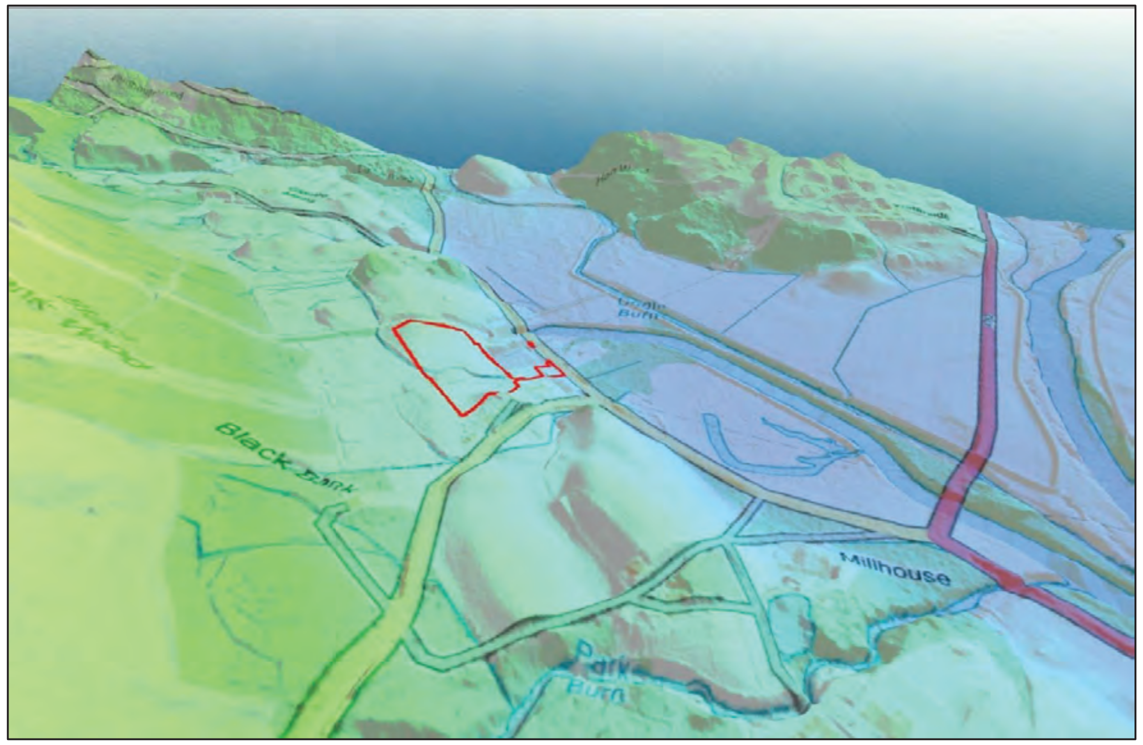


Figure 7: 3D representation of the site and surrounding topography looking north-west



3.3 Watercourses & Water Features

There are numerous watercourses within the vicinity of the site and surrounding area. Watercourses are marked on Figure 8.

The Water of Ken is a large watercourse that lies 550m to the east of the site. This watercourse flows in a southerly direction before turning towards the east at its confluence with the Coom Burn. The Water of Ken has a catchment area of approximately 373 km² close to its confluence with the Coom Burn and drains a number of large reservoirs including the Kendoon Loch and Earlstoun Loch. The Water of Ken has a channel width of approximately 45m within the vicinity of the site. Photo 5 shows the Water of Ken at its confluence with the Tailrace looking downstream.

The Coom Burn flows in a south-easterly direction some 200m to the north of the site. The watercourse is also marked on Ordnance Survey (OS) maps as the Garroch Burn. This watercourse has its confluence with the Water of Ken some 600m to the east of the site. This watercourse drains an area of approximately 21 km² and has its source close to the Rig of Clenrie. For the majority of its trajectory the upstream tributaries of the Coom Burn flow naturally through the Garroch and Glenlee Valleys. However, the watercourse has been realigned for its final reach adjacent to the site, likely to maximise agricultural production. Photo 6 shows the Coom Burn looking upstream from Coom Bridge.

The Glenlee Power Station generates energy through hydropower and so has a Tailrace via which flows are discharged. The Tailrace exits the power station flowing in a north-easterly direction before turning south-east, flowing parallel to the Coom Burn, and discharging into the Water of Ken just downstream of the confluence of the Coom Burn and the Water of Ken, at Coom Bridge. Flows that feed the Glenlee Power Station are abstracted from the Clatteringshaws reservoir and conveyed down the penstock to generate electricity. Photo 7 shows the Tailrace looking upstream from Coom Bridge.

The Park Burn flows in a north-easterly direction to the south and south-east of the site. This watercourse is also known as the Craigshinnie Burn or Lane on some mapping. This watercourse has its confluence with the Water of Ken just downstream of Coom Bridge close to that of the Tailrace and the Coom Burn. The Park Burn has its source close to the Backhill of Glenlee.

Dickson's Strand flows in a north-easterly direction approximately 50m to the east of the site at its closest. It has its source at Glenlee Hill and drains a small catchment of less than 1 km². This watercourse discharges into the low-lying, wetland area close to the Tailrace and will ultimately make its way into the Tailrace. Photo 8 shows the Dickson's Strand just downstream of where it flows under a local road to the east of the site, looking downstream.

Burn 1 is an unnamed watercourse that drains from Glenlee Hill and traverses the site in a north-easterly direction. This watercourse appears to retain its historic route and flows in a south-easterly direction north of Glenlee Hill before turning north-east, passing under the penstock, and flowing into the site. The watercourse leaves the site and passes under the local road and is conveyed eastwards and then again in a north-easterly direction discharging into the low-lying, wetland area close to the Tailrace. It is thought likely that the watercourse ultimately discharges into the Tailrace. The watercourse was culverted through the Glenlee substation when the power station was constructed. The culvert at its inlet is of 0.45m diameter, however plans of the culvert show that the culvert is restricted by a smaller section of 0.375m diameter. There is a small wooden, span footbridge immediately upstream of the culvert. Photo 9 shows Burn 1 upstream of the site; Photo 10 shows the burn as it passes under the penstock; Photo 11 shows the burn within the site; Photo 12 shows the culvert inlet and Photo 13 the outlet.

Burn 2 is an unnamed watercourse that flows in a northerly direction approximately 130m to the west of the site, at is closest. This watercourse flows towards and under the local road where it is conveyed in a south-easterly direction, parallel to the road, before turning in a north-easterly direction. Here the watercourse has been realigned prior to discharging into the Coom Burn. This watercourse is thought to have a catchment of less than 1 km². This burn is shown in Photo 14.

There is a low-lying, wetland area located between the local road and the Tailrace. OS maps show a pond and marshland vegetation. While relatively dry during the site visit this area has some vegetation typical of a marsh or a wetland area and is likely part of the historic Coom Burn floodplain.

While the site itself is relatively dry, areas to the south of the site between the site and the steep slopes of Glenlee Hill are marshy. This is also true for areas to the west of the site to the west of the penstock. Marsh areas are marked on Figure 9. Photo 3, in Section 3.2, shows marsh to the south of the site.

A penstock that feeds the power station runs down Glenlee hill in a north-easterly direction. This is a large structure with a steep gradient. This structure is shown in Photos 15 and 16.

Figure 8: Watercourses and water features close to the site. Culverts are marked with a dotted black line.

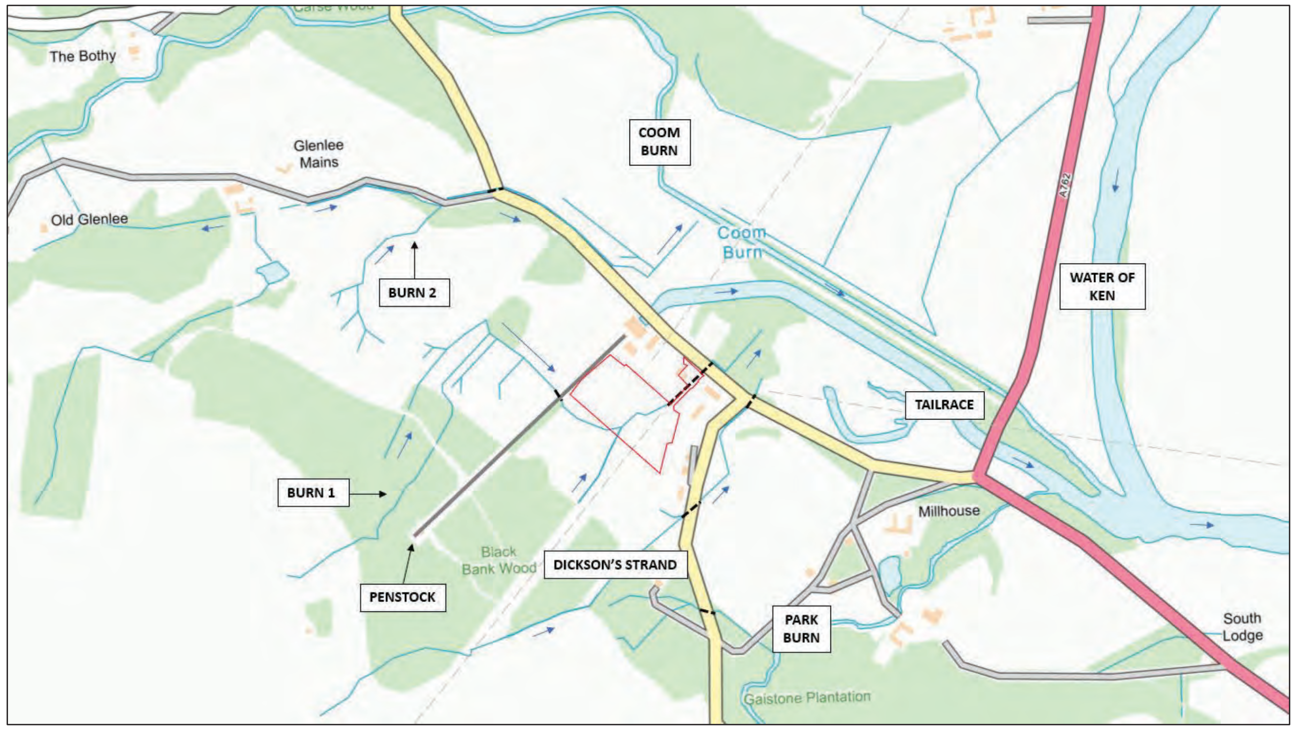


Figure 9: Identified areas of Wetland and Marsh

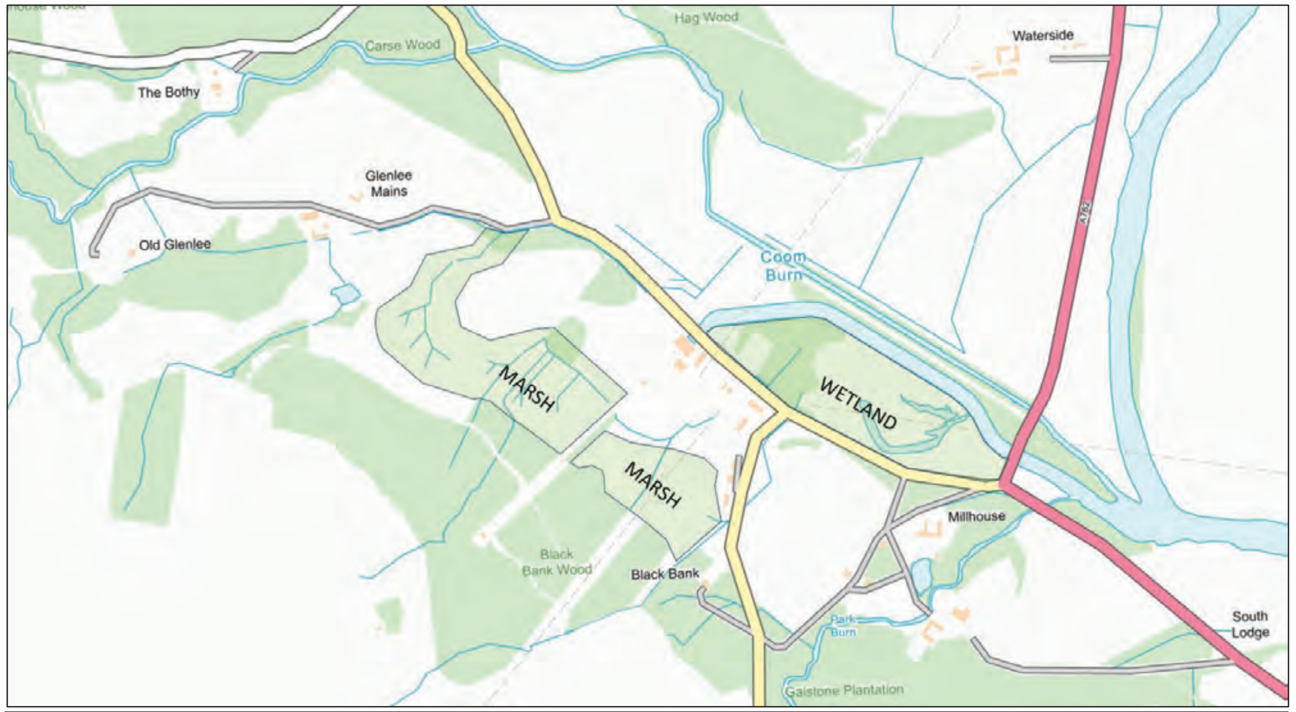


Photo 5: Water of Ken at its confluence with the Tailrace looking downstream

Photo 6: Coom Burn looking upstream from Coom Bridge

Photo 7: Tailrace looking upstream from Coom Bridge

Photo 8: Dickson's Strand looking downstream of the culvert under the local road

Photo 9: Burn 1 to the west of the site prior to passing under the penstock looking upstream

Photo 10: Burn 1 looking upstream as it passes under the penstock from within the site

Photo 11: Burn 1 looking downstream towards the north-east and existing substation

Photo 12: Burn 1 looking downstream at the culvert inlet with wingwalls and trash screen

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Photo 13: Burn 1 culvert outlet north of the local access road

Photo 14: Burn 2 looking downstream as it flows under the local road and towards the Coom Burn

Photo 15: Penstock looking up Glenlee Hill towards the south-west

Photo 16: Penstock looking in a southerly direction. Marsh also shown

3.4 Historic Flood Search & Consultation

A review of the British Hydrological Society (BHS) Chronology of British Hydrological Events website was undertaken searching for the following keywords: “Glenlee”, “Knockensee”, “Court Hill”, “Coom Bridge”, “Garnoch”, “Tannoch”, “Water of Ken”, “Park Burn”, “Craigshinnie Burn”, “Coom Burn” and “Dickson’s Strand”. Searched keywords refer to nearby locations.

This review did not uncover any relevant search results.

A thorough internet search, including social media, was conducted to highlight any history of flooding in and around the surrounding area and the site.

The SEPA Flood Risk Management Strategy for the Solway Local Plan District refers to flooding of the Water of Ken in December 2006 that caused “substantial damage to the A762 and road surface.” This likely refers to the part of the A762 that closely follows the Water of Ken between Glenlee and New Galloway.

A Youtube video posted on the 31st December 2013 shows flooding at Boat Knowe to the south of St John’s Town of Dalry, presumably from the Water of Ken. A screenshot is shown in Photo 17 looking towards the property at Boat Knowe and towards the Water of Ken.

Photo 17: Flooding of the Water of Ken at Boat Knowe, Dec 2013 (Source: Youtube)

Additional photos were posted on the “Dumfries and Galloway – What’s going on” Facebook page on the 20th of December 2013. Two photos show flooding of the footbridge that crosses the Water of Ken (Photo 18) and another photo shows flooding on the A713 between Dundeugh and St John’s Town of Dalry, again presumably caused by flooding of the Water of Ken.

Photo 18: Flooding at the footbridge in St John's Town of Dalry, Dec 2013 (source: Facebook)

Photo 19: Flooding of the A713 between Dundeugh and St John's Town of Dalry, Dec 2013 (source: Facebook)

Dumfries and Galloway Council were consulted with respect to flood risk within the vicinity of the site. The council responded and provided their Joint FRA for Castle Douglas that was undertaken with Scottish Power. This document does not cover the power station at Glenlee but instead covers areas further downstream.

The council also provided records of historical flooding at Court Hill in November 2009 and Dickson's Strand in October 2010, although little additional information was available. Court Hill is located to the east of the Water of Ken and is not considered to be relevant to the site. Dickson's Strand lies closer to the site and so additional assessment has been undertaken in Section 5.2.

3.5 Review of Previous Flood Risk Assessments

A Flood Risk Assessment for the Glenlee Power Station has previously been undertaken by Halcrow to support the design of flood mitigation measures (2011).

This assessment included a hydrological analysis, to estimate design flows; the development of a 1D mathematical model; to estimate peak flood levels; and the development of flood mitigation measures.

This assessment estimated design flows for the main watercourses within the area up to the 1 in 1000 year flood event with a 30% allowance for climate change. A 1D mathematical model of the Coom Burn, Tailrace and Water of Ken was developed using ISIS (now Flood Modeller Pro) software. Mitigation measures included options for perimeter defences and the flood proofing of equipment. The assessment also considered flood risk from Burn 1 that is culverted under the existing substation.

As part of this assessment some of the work carried out by Halcrow has been reassessed using current methods. This has been compared to the results provided in the Halcrow report, where deemed necessary, in the following sections of the report.

3.6 Pre-Application Consultation with SEPA

An earlier version (Version 2.1, March 2019) of this FRA was submitted to SEPA as part of a pre-application consultation.

In their response, SEPA indicated that they would be unlikely to object on flood risk grounds if formally consulted through the planning process. SEPA reviewed the content of the FRA and agreed with the conclusions of the report. SEPA highlighted that certain details of the 2D model had not been confirmed but that given that the 2D modelling showed similar results to the previously undertaken 1D model that they would not request this additional information. SEPA accepted that "The modelling exercise undertaken has (therefore) confirmed that the use of the model results from the previously undertaken FRA can be used to support this assessment. No further detailed review of the modelling is therefore required in this case."

SEPA indicated in their response that "Climate change has been considered in line with good practice". It should be noted that since the initial submission of the FRA, SEPA have changed their guidance with respect to climate change uplifts. This updated version of the FRA has given due consideration to the new climate change uplift of 44% for the Solway Basin.

4 Hydrological Analysis

A hydrological assessment was undertaken to estimate the design flows that could reach the Water of Ken, Coom Burn, Park Burn, Dickson's Strand, Burn 1 and Burn 2. A comparison has been made between the design flows estimated as part of this assessment and in the previous report by Halcrow (2011).

It should be noted that a 30% allowance for climate change was considered in earlier versions of this FRA. This was to permit comparison with a previous assessment undertaken by Halcrow. SEPA have since revised their guidance on climate change uplifts and now recommend a climate change allowance of 44% for the Solway basin for catchments in excess of 50km². The uplift is 55% (rainfall intensity) for catchments smaller in area than 25km². These flows have been estimated for this version of the FRA for the 1 in 200-year event.

4.1 Estimation of Design Flows for the Water of Ken

The catchment area of the Water of Ken, close to its confluence with the Coom Burn to the east of the site, was estimated to be approximately 372.75 km². The catchment was extracted from the FEH Web-service. The catchment descriptors for catchment are shown in Table 1. The FEH catchment is shown in Figure 10.

Table 1: Catchment descriptors for the Water of Ken

Parameter	Value
EASTING (m)	261300
NORTHING (m)	580450
AREA (km²)	372.7475
ALTBAR (m)	322
ASPBAR (°)	175
ASPVAR	0.1
BFIHOST	0.34
DPLBAR (km)	21.9
DPSBAR (m/km)	138.1
FARL	0.926
LDP	45.61
PROPWET	0.65
SAAR (mm)	1777
SAAR4170 (mm)	1729
SPRHOST	50.73
URBCONC1990	-999999
URBEXT1990	0
URBLOC1990	-999999
URBCONC2000	-999999
URBEXT2000	0.0003
URBLOC2000	-999999

Given the large size of the catchment and presence of numerous reservoirs upstream the FEH Statistical Method (Pooling Group) was used to estimate design flows. Rainfall-Runoff methods do not provide good flow estimates for large catchments with reservoirs in the headwaters.

Numerous variations of this assessment were undertaken using different growth curves and QMED values. While the Generalised Logistic (GL) growth curve is normally recommended for use, this gave a poor "goodness-of-fit" of 3.94 compared to that of the Generalised Extreme Values curve (GEV) of 1.02 and the Pearson Type III curve (P3) of 0.4. Two different QMED values were used in the assessment: one using catchment descriptors (CD) and another based on the donor adjustment options in WINFAP (donor) using the 6 most representative catchments. Theoretically the latter should provide a more accurate estimate of QMED as it is based on gauged data from the donor catchments.

The estimated design flows for the 1 in 200-year event vary between 476 m^3/s and 565 m^3/s. The estimations made by Halcrow in their assessment for the Water of Ken are also provided for comparison purposes.

The results are shown in Table 2.

Table 2: Design flows for the Water of Ken (Return Period - m^3/s)

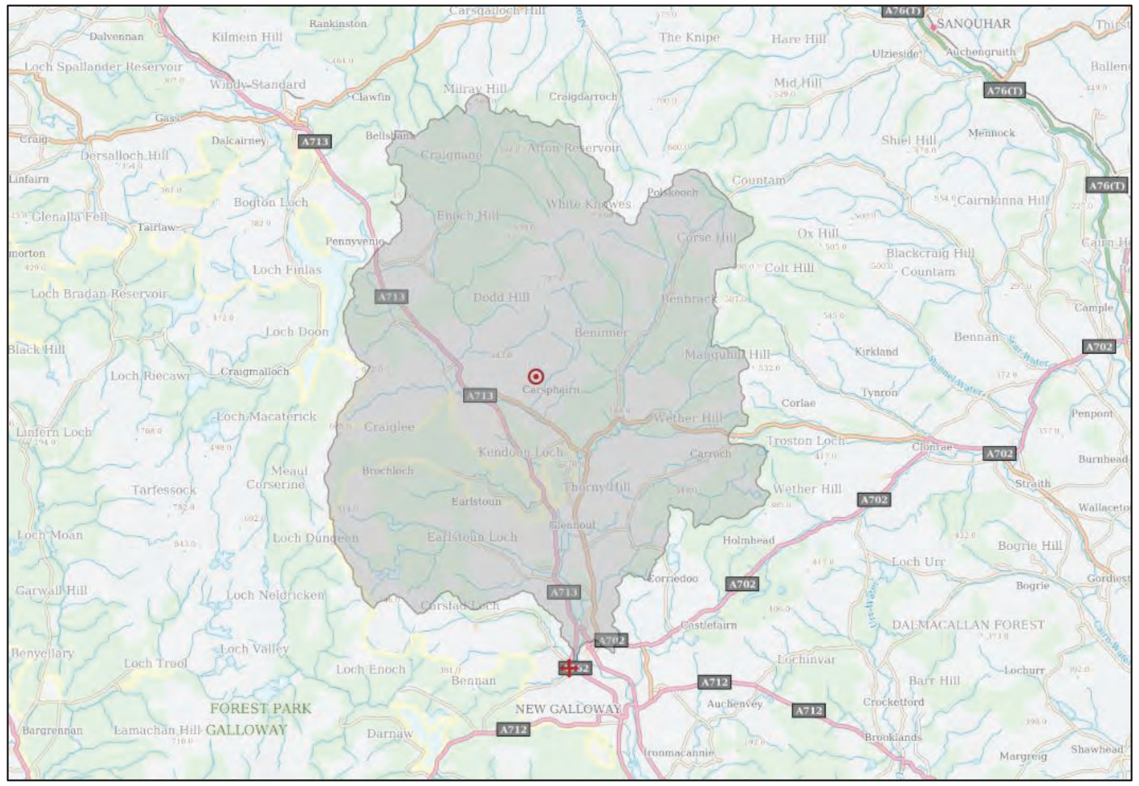
Estimation Method (FEH Statistical Method)	1 in 200	1 in 500	1 in 1000	1 in 200 + 30% CC	1 in 200 + 44% CC	1 in 1000 + 30% CC
QMED CD - GL	565.4	649.7	720.7	735.1	814.2	936.9
QMED CD - GEV	519.4	563.5	565.7	675.2	747.9	774.4
QMED CD - P3	513.6	556.6	588.2	667.7	739.6	764.7
QMED Donor - GL	524.6	602.8	668.7	682.0	755.4	869.3
QMED Donor - GEV	481.8	522.8	552.7	626.4	693.8	718.5
QMED Donor - P3	476.5	516.4	545.8	619.5	686.2	709.5
Previous estimate	498.5	568.2	626.6	648.05	NA	814.58

QMED CD: *QMED based on Catchment Descriptors.*
QMED Donor: *QMED based on the donor adjustment options in WINFAP using the 6 most representative catchments.*
GL: *Generalised Logistic growth curve*
GEV: *Generalised Extreme Value growth curve*
P3*: Pearson Type III growth curve*

The most conservative design flow was calculated using the QMED estimated with catchment descriptors and using a Generalised Logistic growth curve. For this reason, this flow estimate was used in this assessment. The most conservative flows are shown in red in Table 2.

A comparison of the design flows estimated here and as part of the previous assessment suggests that the previous flows are generally in line with the estimates in this report. The mean of the flows estimated for the 1 in 500-year event as part of this assessment, for example, is very similar to the 1 in 500-year estimate in the previous report. It should also be noted that the P3 growth curve, which offered the best "goodness-of-fit", provides the lowest design flow estimates which are closest to those estimated in the previous assessment.

Figure 10: FEH Catchment area of Water of Ken



4.2 Estimation of Design Flows for the Coom Burn

The catchment area of the Coom Burn, close to its confluence with the Water of Ken, was estimated to be approximately 21.48 km². The catchment was extracted from the FEH Web-service. The catchment descriptors for the catchment are shown in Table 3. The FEH catchment area is shown in Figure 11.

Table 3: Catchment descriptors for the Coom Burn

Parameter	Value
EASTING (m)	261250
NORTHING (m)	580350
AREA (km^2)	21.475
ALTBAR (m)	215
ASPBAR (°)	84
ASPVAR	0.23
BFIHOST	0.409
DPLBAR (km)	5.86
DPSBAR (m/km)	124.4
FARL	0.992
LDP	11.37

PROPWET	0.68
SAAR (mm)	1889
SAAR4170 (mm)	1781
SPRHOST	45.66
URBCONC1990	-999999
URBEXT1990	0
URBLOC1990	-999999
URBCONC2000	-999999
URBEXT2000	0
URBLOC2000	-999999

Given the size of the catchment the design flows were estimated based on a selection of methods: the FEH Rainfall-Runoff method, the Revitalised FEH Rainfall-Runoff method (ReFH2) for the "Winter" rainfall profile and the FEH Statistical Method (Pooling Group).

The estimated flows from the three methods are tabulated in Table 4.

Table 4: Design flows for the Coom Burn (Return Period - m^3/s)

Estimation Method	1 in 200	1 in 500	1 in 1000	1 in 200 + 30% CC	1 in 200 + 55% CC[1]	1 in 1000 + 30% CC
FEH Rainfall-Runoff [a]	62.7	73.9	84.9	81.5	104.6	110.3
ReFH2 Winter [b]	65.6	82.5	97.8	85.3	113.4	127.1
FEH Statistical Method	75.0	91.5	106.5	97.5	116.3	138.4
Previous estimate	89.7	105.6	119.3	116.6	NA	155.1

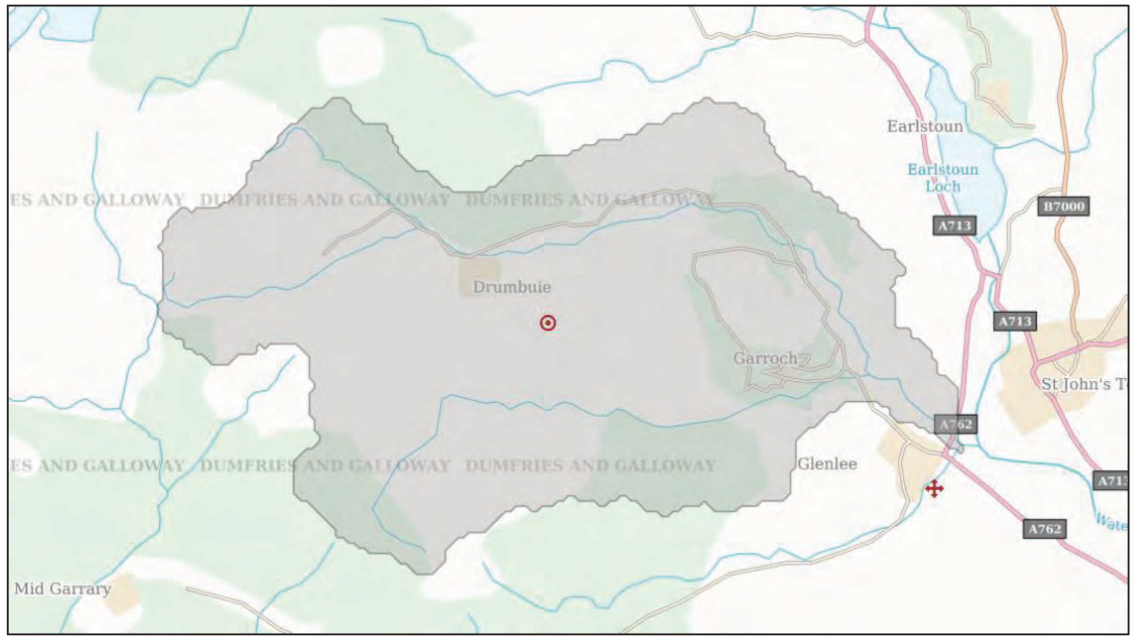
a Design Storm Duration = 8.1 hours
b Design Storm Duration = 5.25 hours
1 Uplift of 55% rainfall intensity for Rainfall-Runoff methods and increase of 55% peak flow for Statistical Method.

The estimated design flows for the 1 in 200-year event vary between 62.7 m^3/s and 75 m^3/s. The estimations made by Halcrow in their assessment are also provided for comparison purposes.

The most conservative design flow was calculated using the FEH Statistical Method. For this reason, this flow estimate was used in this assessment. The most conservative flows are shown in red.

A comparison of the design flows estimated here and as part of the previous assessment suggests that the previous flows are generally in line with the estimates in this report. However, the previous estimates are higher than the estimates made as part of this assessment. This may be due to the updated Rainfall data for 2013 provided lower rainfall depth estimates than the 1999 data.

Figure 11: FEH Catchment for the Coom Burn



4.3 Estimation of Design Flows for the Park Burn

The catchment area of the Park Burn, at its confluence with the Tailrace, was estimated to be approximately 7.2km². The catchment was extracted from the FEH Web-service. The catchment descriptors for catchment are shown in Table 5. The FEH catchment area is shown in Figure 12.

Table 5: Catchment descriptors for the Park Burn

Parameter	Value
EASTING (m)	261150
NORTHING (m)	580300
AREA (km²)	7.165
ALTBAR (m)	213
ASPBAR (°)	54
ASPVAR	0.25
BFIHOST	0.397
DPLBAR (km)	3.94
DPSBAR (m/km)	127
FARL	0.994
LDP	6.65
PROPWET	0.68
SAAR (mm)	1831
SAAR4170 (mm)	1717

SPRHOST	51.21
URBCONC1990	-999999
URBEXT1990	0
URBLOC1990	-999999
URBCONC2000	-999999
URBEXT2000	0.0028
URBLOC2000	-999999

Given the size of the catchment the design flows were estimated based on a selection of methods: the FEH Rainfall-Runoff method, the Institute of Hydrology (IH) Small Catchment Equation (IH124), and the Revitalised FEH Rainfall-Runoff method (ReFH2) for the "Winter" rainfall profile.

The estimated flows from the three methods are tabulated in Table 6.

Table 6: Design flows for the Park Burn (Return Period - m^3/s)

Estimation Method	1 in 200	1 in 500	1 in 1000	1 in 200 + 30% CC	1 in 200 + 55% CC[1]	1 in 1000 + 30% CC
FEH Rainfall-Runoff [a]	27.0	31.9	36.6	35.1	44.7	47.6
ReFH2 Winter [b]	24.8	31.3	37.0	32.2	42.4	48.1
IH124	29.1	32.3	37.6	37.8	45.1	48.8
Previous estimate	31.3	38.0	45.1	40.7	NA	58.6

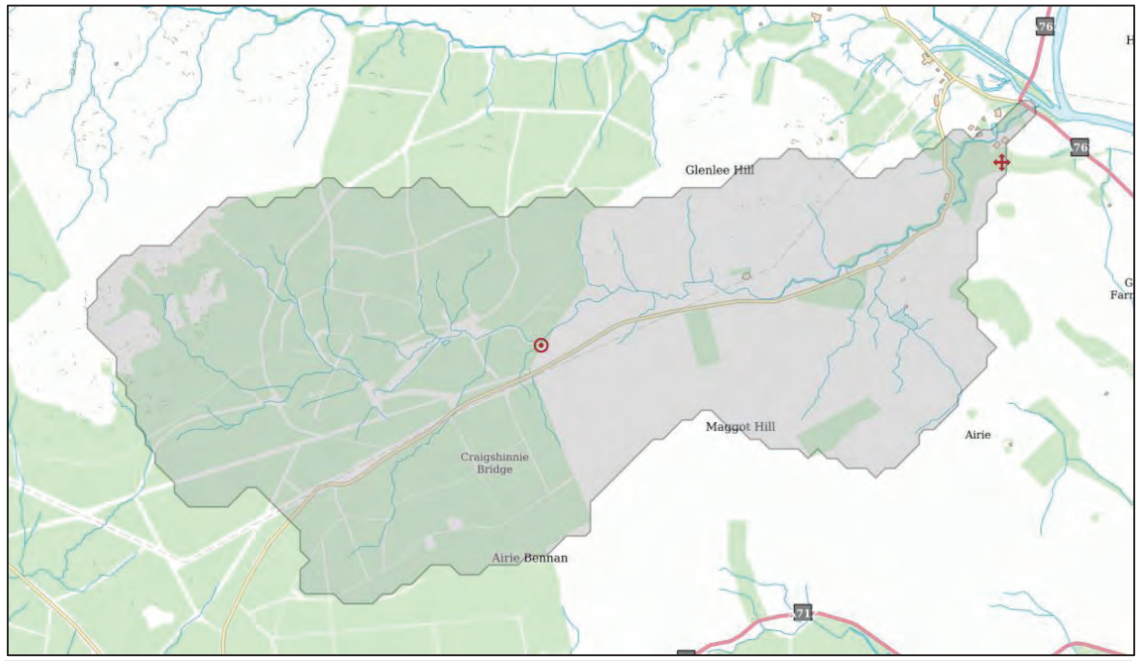
a Critical Storm Duration = 6.3 hours
b Critical Storm Duration = 4.25 hours
1 Uplift of 55% rainfall intensity for Rainfall-Runoff methods and increase of 55% SAAR for IH124.

The estimated design flows for the 1 in 200-year event vary between 27.0 m^3/s and 29.1 m^3/s. The estimations made by Halcrow in their assessment are also provided for comparison purposes.

The most conservative design flow was calculated using the IH124. For this reason, this flow estimate was used in this assessment. The most conservative flows are shown in red.

A comparison of the design flows estimated here and as part of the previous assessment suggests that the previous flows are generally in line with the estimates in this report. However, the previous estimates are higher than the estimates made as part of this assessment. This may be due to the updated Rainfall data for 2013 provided lower rainfall depth estimates than the 1999 data.

Figure 12: FEH catchment area for the Park Burn



4.4 Estimation of Design Flows for the Dickson's Strand

The catchment area of the Dickson's Strand, close to its confluence with the Tailrace, was estimated to be approximately 0.2 km² using a combination of LiDAR DTM data and a comparison of FEH catchments to estimate the catchment area.

Due to its small size the catchment descriptors for the burn were not available from the FEH web-service. To undertake the hydrological analysis the catchment descriptors for the closest catchment, a larger catchment was obtained. This catchment has an area of 0.6 km². Details of this catchment area provided in Section 4.1.5. The larger catchment was considered to be representative of the Dickson's Strand and so the majority of catchment descriptors were not adjusted. The catchment descriptors for the catchment are shown in Table 7.

Table 7: Catchment descriptors for the Dickson's Strand

Parameter	Value
EASTING (m)	260672
NORTHING (m)	580218
AREA (km²)	0.18
ALTBAR (m)	121
ASPBAR (°)	36
ASPVAR	0.76
BFIHOST	0.53
DPLBAR (km)	0.9
DPSBAR (m/km)	180.7
FARL	1
LDP	1.83
PROPWET	0.65
SAAR (mm)	1638
SAAR4170 (mm)	1531
SPRHOST	42.5
URBCONC1990	-999999
URBEXT1990	0
URBLOC1990	-999999
URBCONC2000	0.333
URBEXT2000	0.0125
URBLOC2000	0.299

Given the size of the catchment the design flows were estimated based on a selection of methods: the FEH Rainfall-Runoff method, the Institute of Hydrology (IH) Small Catchment Equation (IH124), and the Revitalised FEH Rainfall-Runoff method (ReFH2) for the "Summer" rainfall profile. The "Summer" profile was chosen over the "Winter" profile due to the steep catchment gradient.

The estimated flows from the three methods are tabulated in Table 8.

Table 8: Design flows for Dickson's Strand (Return Period - m³/s)

Estimation Method	1 in 200	1 in 500	1 in 1000	1 in 200 + 30% CC	1 in 200 + 55% CC[1]	1 in 1000 + 30% CC
FEH Rainfall-Runoff 2013 Rainfall [a]	1.2	1.5	1.7	1.6	2.1	2.2
ReFH2 Summer [b]	0.5	0.7	0.8	0.7	0.7	1.1
IH124	0.9	1.0	1.1	1.1	1.4	1.5
Previous estimate	-	-	-	-	-	-

a Design Storm Duration = 2.1 hours
b Design Storm Duration = 2.45 hours
1 Uplift of 55% rainfall intensity for Rainfall-Runoff methods and increase of 55% SAAR for IH124.

The estimated design flows for the 1 in 200-year event vary between 0.5 m³/s and 1.2 m³/s. In their previous Flood Risk Assessment, Halcrow did not provide design flows for this watercourse.

The most conservative design flow was calculated using the FEH Rainfall-Runoff method. For this reason, this flow estimate was used in this assessment. The most conservative flows are shown in red.

4.5 Estimation of Design Flows for Burn 1

Design flows for the Burn 1 were estimated by Kaya Consulting Limited to support the design of the culvert extension under the substation extension.