Chapter 6

Hydrology, Hydrogeology, Geology and Soils

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Chapter 6

6 Hydrology, Hydrogeology, Geology and Soils

6.1 Introduction

1. This chapter considers the likely significant environmental effects of the Proposed Development on hydrology, hydrogeology, geology and soils receptors. For each of these topics it details the baseline description, identifies and assesses the effects on each receptor and, where relevant, identifies proposed mitigation.

2. This assessment considers the likely significant environmental effects of the Proposed Development on the following:

- Geomorphology and geology – geomorphological characteristics of the Site and changes to geological structures or effects on designated sites;
- Soils and peat – changes to soil and peat characteristics related to erosion, compaction and soil quality, changes to peat stability within and immediately adjacent to the Site;
- Hydrogeology – changes to groundwater infiltration and groundwater levels, water quality and wetland characteristics; and
- Hydrology – changes to drainage regime and associated alteration to surface water runoff rates and volumes, erosion/sedimentation and water quality characteristics across the Site and the catchment as a whole, including designated sites. Also, changes to water resources such as public and private water supplies.

6.2 Legislation, Policy and Guidance

6.2.1 Legislation

3. This assessment is carried out in accordance with the principles contained within the following legislation:

- The Water Environment and Water Services (Scotland) Act 2003;
- The Water Environment (Controlled Activities) (Scotland) Regulations 2011, as amended; and
- The Water Intended for Human Consumption (Private Supplies) (Scotland) Regulations 2017.

6.2.2 Policy

4. This assessment is carried out in accordance with the principles contained within the following documents:

- Scottish Planning Policy (SPP) 2014. The Scottish Government;
- Scottish Environment Protection Agency Environmental Policy Number 19, Groundwater Protection Policy for Scotland v3; and
- Dumfries and Galloway Council Local Development Plan 2 October 2019.

6.2.3 Guidance

5. This assessment is carried out in accordance with the principles contained within the following documents:

- Construction Industry Research and Information Association (CIRIA) (2001) Report C532, Control of water pollution from construction sites: Guidance for consultants and contractors;
- CIRIA (2006) Report C648, Control of water pollution from linear construction projects: Technical guidance;
- CIRIA (2006) Report C649, Control of water pollution from linear construction sites: Site guide;
- CIRIA (2018) Report C753, The SUDS Manual;
- Forestry Commission (2019) Managing forest operations to protect the water environment. Practice Guide;
- Scottish Executive (2012) River crossings & migratory fish: Design guidance;
- Scottish Government (2017) Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, 2nd Edition;
- Scottish Natural Heritage (SNH) (2017) Siting and designing wind farms in the landscape, Version 3a;
- SNH (2018) Environmental Impact Assessment Handbook, Version 5;
- SNH (2001) Guidelines on the environmental impacts of windfarms and small-scale hydroelectric schemes;
- SNH and Forestry Commission (2010) Floating roads on peat;
- Scottish Environment Protection Agency (SEPA) (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR) A Practical Guide;
- SEPA (2009) Policy No. 19, Groundwater protection policy for Scotland Version 3;
- SEPA (2015) Position Statement WAT-PS-06-02, Culverting of watercourses;
- SEPA (2010) WAT-SG-25, Engineering in the water environment: good practice guide;
- SEPA (2006) WAT-SG-31, Prevention of Pollution from Civil Engineering Contracts: Special Requirements;
- SEPA (2010) Regulatory Position Statement – Developments on Peat;
- SEPA (2017) Land Use Planning System SEPA Guidance Note 31, Guidance on assessing the impacts of development proposals on groundwater abstractions and groundwater dependent terrestrial ecosystems, Version 3;
- Scottish Renewables / SEPA (2012) Developments on Peatland: Guidance on the assessment of peat volumes, reuse of excavated peat and the minimisation of waste; and
- Scottish Renewables (2019) Good Practice during Wind Farm Construction (joint publication by Scottish Renewables, SNH, SEPA, Forestry Commission Scotland, Historic Environment Scotland, Marine Scotland Science and AEECoW), 4th Edition

6. The following SEPA (jointly with the Environment Agency and the Northern Ireland Environment Agency) Pollution Prevention Guidelines (PPG) and Guidance for Pollution Prevention (GPP) will also be considered:

- PPG1 Understanding your environmental responsibilities – good environmental practices (July 2013);
- GPP2 Above ground oil storage tanks (January 2018);
- PPG3 Use and design of oil separators in surface water drainage systems (April 2006);

- GPP4 Treatment and disposal of wastewater where there is no connection to the public foul sewer (November 2017);
- GPP5 Works and maintenance in or near water (January 2017);
- PPG6 Working at construction and demolition sites (2012);
- PPG7 Safe storage – the safe operation of refuelling facilities (July 2011);
- GPP8 Safe storage and disposal of used oils (July 2017);
- GPP13 Vehicle washing and cleaning (April 2017);
- PPG18 Managing fire water and major spillages (June 2000);
- GPP21 Pollution incident response planning (July 2017);
- GPP22 Dealing with spills; (October 2018); and
- GPP26 Safe storage – drums and intermediate bulk containers (February 2019).

6.3 Consultation

7. **Table 6.1** summarises the consultation undertaken as part of the assessment. The response/action taken to the points raised by consultees is provided within the table, showing where the issues raised have been assessed, or where the Proposed Development has been altered in relation to the issue.

Consultee	Response	Action
Dumfries and Galloway Council	The Council provided Private Water Supply (PWS) information within a 10km area surrounding the Site centre point.	This information is considered further within Water Supplies section of this report, including details of appropriate mitigation measures proposed.
SEPA	SEPA provided authorisations under the Controlled Activities Regulations (CAR) found within a 10km radius of the Site centre point.	This information is considered further within Water Supplies section of this report, including details of appropriate mitigation measures proposed.
	Phase 1 Peat probing methodology was agreed with SEPA. The method targets peat surveys within the identified developable area on Site, focussing particularly on provisional turbine locations, open ground and forest rides.	Peat probing was undertaken in accordance with agreed methodology and is presented in **Appendix 6.2 Soil and Peat Management Plan** and in **Figure 6.5 Peat Overview**.
	Requested a detailed map of peat depths and table detailing quantities of acrotelmic, catotelmic and amorphous peat that would be excavated.	This information is presented in **Appendix 6.1 Peat Stability Assessment** and **6.2 Soil and Peat Management Plan,** and shown in **Figure 6.5 Peat Overview**.
	Map and assessment sought for all engineering activities in or impacting on the water environment including proposed buffers, details of any flood risk assessment and details of any related CAR applications.	This information is provided in **Appendix 6.4 Watercourse Crossings Report** and shown in **Figure 6.7 Hydrology Overview**.
	Requested a map detailing Groundwater Dependent Terrestrial Ecosystems (GWDTE) within 100m radius of all excavations shallower than 1m and within 250m of all excavations deeper than 1m.	This is presented in **Figure 6.6 Groundwater Dependent Terrestrial Ecosystem - Overview**.
	The assessment should consider surface water flows and potential impacts upon this and downstream receptors associated with the infrastructure layout and outline potential mitigation.	This is considered further in the Construction Impacts Section and **Appendix 6.4 Watercourse Crossings Report**.
	Provide some more detail of mitigation where infrastructure encroaches within 50m water body buffers.	This is considered further in the Construction Impacts Section and **Appendix 6.4 Watercourse Crossings Report**
	Information and plans sought showing borrow pits, pollution prevention measures, water abstractions and restoration measures.	This is provided in **Appendix 6.5 Borrow Pit Assessment**.
Scottish Water	Scoping Response received on 22 April 2020. Scottish Water confirmed there are no Drinking Water Protected Areas or water abstraction sources within 10km of the centre point of the Site Boundary.	This information is considered further within Water Supplies section of this report, including details of appropriate mitigation measures proposed.
Galloway Fisheries Trust	Water quality and fisheries impacts were associated with the construction of the operational Harestanes Windfarm. Information sought regarding watercourse crossings, peat depths and mitigation measures to protect watercourses, fish and their habitats.	This is provided in the Potential Effects Section, in **Appendix 6.4 Watercourse Crossings Report** and shown in **Figure 6.7 Hydrology Overview**.
NatureScot	Noted that impacts on peat are being considered. Scoping Response received on 13 May 2020.	This is provided in **Appendix 6.2 Soil and Peat Management Plan**, which includes details of appropriate mitigation measures proposed.

Table 6.1: Consultation Responses

6.4 Assessment Methodology and Significance Criteria

6.4.1 Study Area

8. The Study Area proposed is based on the land within the Site Boundary (otherwise referred to as Application Boundary), with a wider study area of 5km downstream of the Site Boundary for hydrologically relevant designations and surface water receptors (following watercourse pathways). A Study Area of 1km beyond the Site Boundary has been used to assess the effects on groundwater receptors. All other surveys related to this assessment have been conducted within the Site. It is considered that at distances in excess of 5km, the Proposed Development is unlikely to have a hydrological or water quality effect, as attenuation and dilution of substances is likely to occur. In addition, areas down-catchment from the

Proposed Development have been included in the Study Area, whereby there is potential for cumulative effects to occur. The Study Area is based upon professional judgement and experience of assessing similar developments in similar environments.

9. The Site layout is shown in **Figures 4.1 Site Layout Plan** and an aerial photograph is provided in **Figure 6.1.4 Aerial Photography** within **Appendix 6.1 Peat Stability Assessment**.

6.4.2 Desk Study

10. The following sources of information have been reviewed during the desk-based research:

- Ordnance Survey (OS) (2017) digital mapping, 1:10,000, 1:25,000 and 1:50,000 scales;
- SEPA Water Classification Hub (2018a) (River Basin Management Plan interactive web map);
- Scotland's Environment Main river and coastal catchments (2019) (interactive web map);
- SEPA Flood Maps (2020) (interactive web map);
- British Geological Survey (BGS) Hydrogeological Map of Scotland (2019), 1:625,000 scale;
- BGS Geoindex Onshore Bedrock and Superficial Deposits geology (2019) 1:50,000 scale (interactive web map);
- BGS Groundwater Vulnerability (Scotland) User Guide: GIS dataset (2011), Version 2.
- NatureScot SiteLink (2020) (interactive web map);
- James Hutton Institute Soil mapping 1:250,000 scale (2013) (interactive web map);
- Drinking Water Quality Regulator for Scotland (DWQR) Private Water Supplies (2019) mapping;
- Email correspondence with the Dumfries and Galloway Environmental Health Officer regarding Private Water Supplies information; and
- Email correspondence with SEPA regarding CAR authorised groundwater abstractions.

6.4.3 Field Surveys

11. The following field surveys were carried out to inform the assessment:

- Phase 1 Peat Probing between March and May 2020;
- Phase 2 Peat Probing between 20 and 24 July 2020; and
- Phase 2a Peat Probing and Coring on 23 September 2020.

6.4.4 Assessment Methodology

12. The general methodology used to assess the effect of the Proposed Development on the hydrology, hydrogeology, geology and soils receptors of the Site is as follows:

- Desktop study to obtain baseline and historical data;
- Consultation with SEPA and Dumfries and Galloway Council to identify water abstractions and private water supplies;
- Field surveys to obtain watercourse crossings baseline data and confirm PWS data;
- Identification of the likely significant environmental effects of the Proposed Development on sensitive receptors; and
- Identification of options for the mitigation of likely significant environmental effects, taking account of Good Practice measures.

13. The likely significance of environmental effect was determined through a standard method of assessment based on SNH (2018), taking account of three key factors:

- sensitivity of the receiving receptor;
- likely magnitude of the effect; and
- probability of the effect occurring.

6.4.4.1 Sensitivity

14. Sensitivity has been determined on the basis of the receptor's ability to absorb the anticipated effect without perceptible change resulting. Three levels of sensitivity have been used, as shown in **Table 6.2**. Evaluation of sensitivity of hydrology, hydrogeology, geology and soils requires a considerable degree of judgement, based on defined characteristics and values and calling on professional experience, which is accordingly applied during evaluation.

Sensitivity	Definition
High	• Receptor has 'High' or 'Good' Water Framework Directive (WFD) overall status and/or water quality status for surface water or groundwater body. • Receptor is a designated site protected under national or international legislation, such as Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC), and Special Protection Areas (SPA), for the disciplines assessed in this chapter. • Receptor contains Geological Conservation Review (GCR) sites designated as SSSIs or Candidate SSSIs. • Receptor contains areas of regionally important economic mineral deposits. • Receptor supports key species and habitats sensitive to changes in suspended sediment concentrations and turbidity, such as salmon or freshwater pearl mussels. • Receptor supports GWDTE confirmed as highly groundwater dependent. • Receptor contains a range of hydromorphological features with very little modification. • Receptor is a watercourse or floodplain, with a possibility of direct flood risk to populated areas, which are sensitive to increased flood risk by the possible increase in water levels. • Receptor provides clear flood alleviation benefits. • Receptor used for abstraction or storage for public water supply or large private water supply serving ≥10 properties. • Receptor is classed as a high productivity aquifer. • Receptor groundwater vulnerability contains classes 5, 4a and 4b.
Medium	• Receptor has 'Moderate' WFD overall status and/or water quality status for surface water or groundwater body. • Receptor contains GCR sites with Local Geodiversity Site (LGS) status. • Receptor contains areas of locally important economic mineral deposits. • Receptor supports GWDTE confirmed as moderately groundwater dependent. • Receptor contains limited hydromorphological features and a limited range of fluvial processes, such areas may have been subject to past modification such as straightening, bank protection and culverting or other anthropogenic pressures. • Receptor is a watercourse or floodplain, with a possibility of direct flood risk to high value agricultural areas, which are moderately sensitive to increased flood risk by the possible increase in water levels. • Receptor provides limited flood alleviation benefits. • Receptor used for abstraction or storage for private water supply serving <10 properties or for agricultural/industrial use. • Receptor is classed as a moderate or low productivity aquifer. • Receptor groundwater vulnerability contains classes 2 and 3.

Sensitivity	Definition
Low	• Receptor has 'Poor' or 'Bad' WFD overall status and/or water quality status for surface water or groundwater body. • Receptor contains GCR sites without SSSI (or Candidate SSSI) designation or LGS status, and non GCR sites with potential geodiversity interest. • Receptor supports no key species and habitats sensitive to changes in suspended sediment concentrations and turbidity. • Receptor supports GWDTE based on NVC mapping, with local water sources not considered as predominantly groundwater. • Receptor contains no hydromorphological diversity and/or are identified as 'heavily modified water bodies' or 'artificial water bodies'. • Receptor is a watercourse or floodplain which passes through low value agricultural areas, which are less sensitive to increased flood risk by the possible increase in water levels. • Receptor provides limited flood alleviation benefits. • Receptor does not support any water abstractions. • Receptor is classed as a very low productivity aquifer. • Receptor groundwater vulnerability contains classes 0 and 1.

Table 6.2: Sensitivity of Receptors

6.4.4.2 Magnitude

15. The magnitude of change has been assessed taking account of the timing, scale, size, duration and reversibility of the likely effect. Four levels of magnitude have been used in this assessment, as shown in **Table 6.3**.

Magnitude	Definition
Major	• Long-term (≥12 months) or permanent change in surface water quality, resulting in a permanent change in WFD status and/or prevention of attainment of target status of 'Good'. • Loss of feature(s) and failure of hydromorphological elements (morphology, quantity and dynamics of flow), loss or damage to existing habitats, replacement of natural bed and/or banks with artificial materials, extensive change to channel planform. • Loss of floodplain due to construction within flood risk area. • Permanent loss of water supply. • Major or total loss of a geological site or mineral deposit, where the value of the site would be severely affected. • Major or total loss of soils or where the value of the site would be severely affected. • Long-term (≥12 months) or permanent change in groundwater quality, resulting in a permanent change in WFD status and/or prevention of attainment of target status of 'Good'. • Major loss of an aquifer in terms of water level or yield, with total loss of or major changes to dependent abstractions/habitats. • Major change or total loss of a GWDTE, where the value of the site would be severely affected.
Moderate	• Mid-term (≥6 months) change in local surface water quality, potentially resulting in a temporary change of WFD status (or equivalent status at local scale) or preventing attainment of target overall status of 'Good' during this period. • Adverse change to the integrity of hydrological feature(s) or loss of part of feature / moderate shift away from baseline conditions, failure of one or more hydromorphological elements (morphology, quantity and dynamics of flow), some damage or loss to habitat due to modifications., replacement of the natural bed and/or banks with artificial material. • Floodplain reduction due to extensive increases in impermeable area within catchment and/or drainage design which would result in an increase in peak flood level. • Temporary loss of water supply. • Partial loss of a geological site or mineral deposit, with major change to the settings, or where the value of the site would be affected. • Partial loss of soils or where the value of the site would be affected. • Mid-term (≥6 months) change in local groundwater quality, not affecting overall WFD status. • Changes to an aquifer in terms of water level or yield, with small changes to nearby dependent abstractions/habitats. • Partial change or loss of a GWDTE, where the value of the site would be affected.
Minor	• Short-term (≥1 month) change in local surface water quality, resulting in minor temporary changes such that ecology is affected for short-term. Equivalent to a temporary minor, but measurable, change within WFD status class. • Potential failure of one of the hydromorphological elements (morphology, quantity and dynamics of flow), minimal shift away from baseline conditions or partial loss or damage to habitat due to modifications. • Floodplain changes due to limited increases in impermeable area within catchment and/or drainage design which would result in a minor increase in peak flood level. • Temporarily reduced quality and quantity of water supply. • Small loss to a geological site or mineral deposit, such that the value of the site would not be affected; • Small loss of soils or where soils will be disturbed but the value not affected. • Short-term (0-6 months) change in local groundwater quality. • Small change to an aquifer in terms of water level or yield, with little discernible change to dependent abstractions/habitats. • Small change to or loss of a GWDTE, where the value of the site would not be affected.
Negligible	• Negligible change to surface water quality, very slight temporary change in water quality with no discernible change to watercourse ecology. • No alteration to hydromorphological elements, some change to feature(s), but of insufficient level to affect the use / integrity, approximating to a 'no change' situation. • Floodplain variations of negligible change. • No anticipated change to water supply. • Minimal or no change to a geological site or mineral deposit. • Minimal or no change to soils. • Negligible change to groundwater quality, very slight temporary change in local water quality. • Minimal or no change to an aquifer in terms of water level or yield, with no discernible change to dependent abstractions/habitats. • Minimal or no change to or loss of a GWDTE.

Table 6.3: Magnitude of Change

6.4.4.3 Probability

16. The probability of occurrence of an effect has been evaluated as being high (≥50%), medium (<50% and ≥20%) or low (<20%) during the phase of work being assessed.

17. The application of good practice and mitigation measures predominantly reduce the probability of an effect occurring.

6.4.5 Significance Criteria

18. The findings of the three criteria considered in the evaluation of an effect has been evaluated via a matrix for each potential effect (see **Table 6.4**) to assess the likely significance of an effect.

19. Through the assessment, potential effects are concluded to be of likely **major, moderate, minor** or **negligible** significance (before and after applicable proposed mitigation measures have been taken account of). For the purpose of this assessment, **moderate** and **major** effects are considered significant and **minor** and **negligible** effects are considered not significant.

20. Effects are considered adverse, unless stated otherwise.

Sensitivity	Magnitude	Probability	Significance of Effect
High	Major	High	Major
		Medium	Major
		Low	Moderate
	Moderate	High	Moderate
		Medium	Moderate
		Low	Minor
	Minor	High	Minor
		Medium	Minor
		Low	Minor
	Negligible	High	Minor
		Medium	Negligible
		Low	Negligible
Medium	Major	High	Major
		Medium	Moderate
		Low	Minor
	Moderate	High	Moderate
		Medium	Minor
		Low	Minor
	Minor	High	Minor
		Medium	Minor
		Low	Negligible
	Negligible	High	Negligible
		Medium	Negligible
		Low	Negligible
Low	Major	High	Moderate
		Medium	Minor
		Low	Negligible
	Moderate	High	Minor
		Medium	Minor
		Low	Minor
	Minor	High	Minor
		Medium	Negligible
		Low	Negligible
	Negligible	High	Negligible
		Medium	Negligible
		Low	Negligible

Table 6.4: Significance Matrix

6.4.6 Limitations to Assessment

21. The fieldwork followed standard 'reconnaissance' field methods in which watercourses were visited close to planned access routes and peat probing was completed on a representative sampling basis initially, following a targeted approach within a refined 'Developable Area'. Following the provision of the infrastructure design, specific infrastructure locations were visited for peat probe survey and stability assessment.

22. It is recognised that the equipment employed to determine peat depth will also pass through other soil types before 'refusal depth', thus peat depth results incorporate all soil through which probing rods pass, such as podzols, gleys and brown soils at this site. This is a conservative approach to ensure soil depths are accurately gauged but is anticipated to provide an overestimate of peat depths, given visual evidence from the site and the fact that the mapping indicates peat overlying other soil types.

23. PWS information was provided by Dumfries and Galloway Council. It is recognised that council information may be incomplete and that information on supplies serving abandoned properties and livestock welfare may not be available. However, it is considered unlikely that such types of supply exist at the Site.

24. Whilst some information gaps have been identified above, it is considered that there is sufficient information to enable an informed decision to be taken in relation to the identification and assessment of likely significant environmental effects on hydrology, hydrogeology, geology and soils.

6.5 Baseline Conditions

6.5.1 Site Description

25. The Proposed Development is located approximately 13km north of Dumfries, entirely within the Dumfries and Galloway Council area. There are a number of existing tracks within the Site due to current forestry activities and the operational Harestanes Windfarm.

26. The Site consists mainly of commercial conifer plantation, with clear-felled areas predominantly in the north east. Peat is notable in open areas, such as forestry rides, clearings and in the vicinity of surface water bodies.

27. Elevation of the Site undulates, reaching a peak at Pumro Fell, 393m AOD. The majority of the Site spans across the Water of Ae catchment. There are a number of watercourses which are situated within or border the Site.

6.5.2 Designated Sites

28. NatureScot (2020) indicates there is one designated site within 5km of the Site, Black Loch Site of Special Scientific Interest (SSSI).

29. Black Loch SSSI lies approximately 3.2km south west of the Site and is designated for its basin fen. It is cited as being the best example of a basin fen within Nithsdale District, showing a transition from a central fen to drier moorland, with a variety of vegetation types.

30. The Proposed Development is located 5.72km upstream of the SSSI therefore the SSSI is not hydrologically connected to the Proposed Development.

6.5.3 Climate

31. This section details:

- the climate characteristics for the Proposed Development and the surrounding region; and
- the historic rainfall data for the surrounding region.

32. The Site is recognised by the Met Office (2016) as lying within the Western Scotland climatic region. Much of Western Scotland's climate is influence by westerly winds from the Atlantic Ocean and the Gulf Stream. Coastal areas of the region are milder than the east of Scotland with temperatures falling inland and with altitude.

33. The Site is likely to experience a higher level of precipitation compared with lower areas nearby, with air cooling at altitude causing more cloud and precipitation.

34. The long-term average monthly rainfall is shown in **Diagram 6.1** using details from the Eskdalemuir Met Office station (242m AOD and located approximately 22km north east of the Site). The upper area of the Site is at approximately 400m AOD, with the lower site area on the east, at around 115m AOD.

35. This precipitation data provides an understanding of seasonal variations that is anticipated in the region, but the higher altitude of the Site will lead to an expectation of greater rainfall than these station records.

36. Longer-term trends for Scotland indicate that weather may become more variable leading to hotter and drier summers and milder and wetter autumn/winters. It is also anticipated that there will be an increase in extreme temperatures and drought in summer and an increase in frequency and intensity of precipitation events.

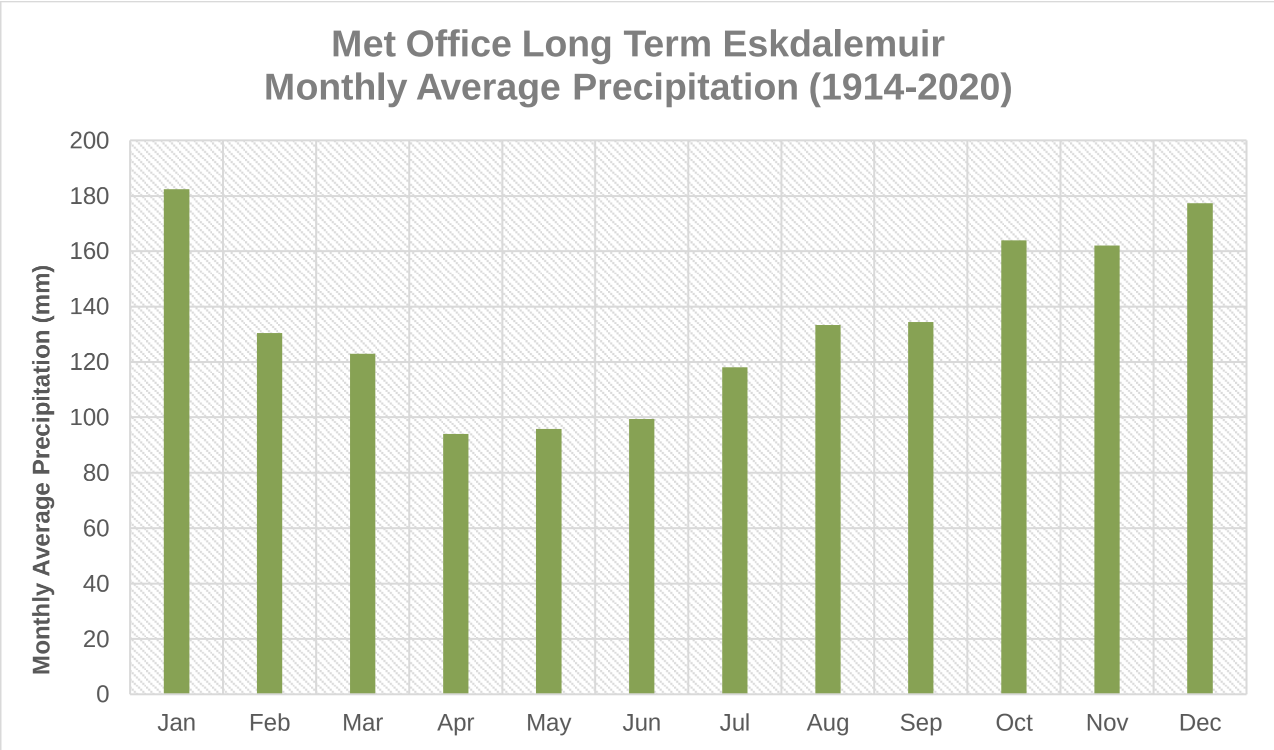

Diagram 6.1: Long Term Monthly Average Rainfall Data at the Eskdalemuir Met Office Station

6.5.4 Geomorphology

37. This section details:

- the geomorphological characteristics of the Site; and
- topographic cross-sections of the Site.

6.5.4.1 Geomorphological Characteristics

38. There are a number of identified hill peaks within and surrounding the site, with the undulating terrain typically gently sloping. The steeper slopes within the Site are generally related to incised watercourse valleys, some of which have extremely steep slopes, such as the Garrel Water Tributary, Glenkiln Burn and Clachanbirnie Burn.

39. The Site is largely afforested peatland and till, including the hills of Holehouse Hill, 401mAOD, Pumro Fell, 393mAOD, Kirkland Hill, 343mAOD, Muir Hill, 333mAOD, Whitefaul Hill, 351mAOD, and Brownmoor Hill, 350mAOD. The majority of the Site is drained by tributaries of the Water of Ae, including the Clachanbirnie Burn, Clatterstanes Burn, Wreaths Burn, Davie's Burn and Kirkland Burn. A small area to the north east of the Site is located within the Kinnel Water Catchment, comprising the Kinnel Water, Broadshaw Water and Mollin Burn. The north of the site is located within the River Annan catchment, which includes the Auchendowal Sike, Glenkiln Burn, Auchencaigroch Burn, Blenoch Burn, Deer Burn and Ox Cleuch.

40. Elevation data is provided in **Figure 6.1 Elevation**. Transect locations of cross-sections are detailed in **Diagrams 6.1** and **6.2** alongside photographs of site features.

41. **Photographs 6.1**, **6.2** and **6.3** show the Site from two viewpoints, giving a good impression of current site conditions.

42. Topographic cross sections of the site taken from north east to south west, and south east to north west across the main site are provided in **Diagram 6.2** and **Diagram 6.3**, respectively. They were generated using digital terrain model data.

43. The slope angles exhibited on the Site are very steep in localised places, with slope angles in excess of 30˚ found along the valleys of Garrel Water Tributary, Glenkiln Burn, Clachanbirnie Burn and their tributaries.

44. Where steeper slopes and watercourse channels are coincident, some accelerated bankside erosion was noted on both sides.

Photograph 6.1: Looking north, towards the Glenkiln Burn from lower slopes of Whitefauld Hill, taken at NGR 302172, 593616

Photograph 6.2: Looking west, across the Site from lower slopes of Pumro Fell, taken at NGR 301247, 592088

Photograph 6.3: View south west towards Whitefauld Hill, taken above existing quarry at NGR 302484, 593948

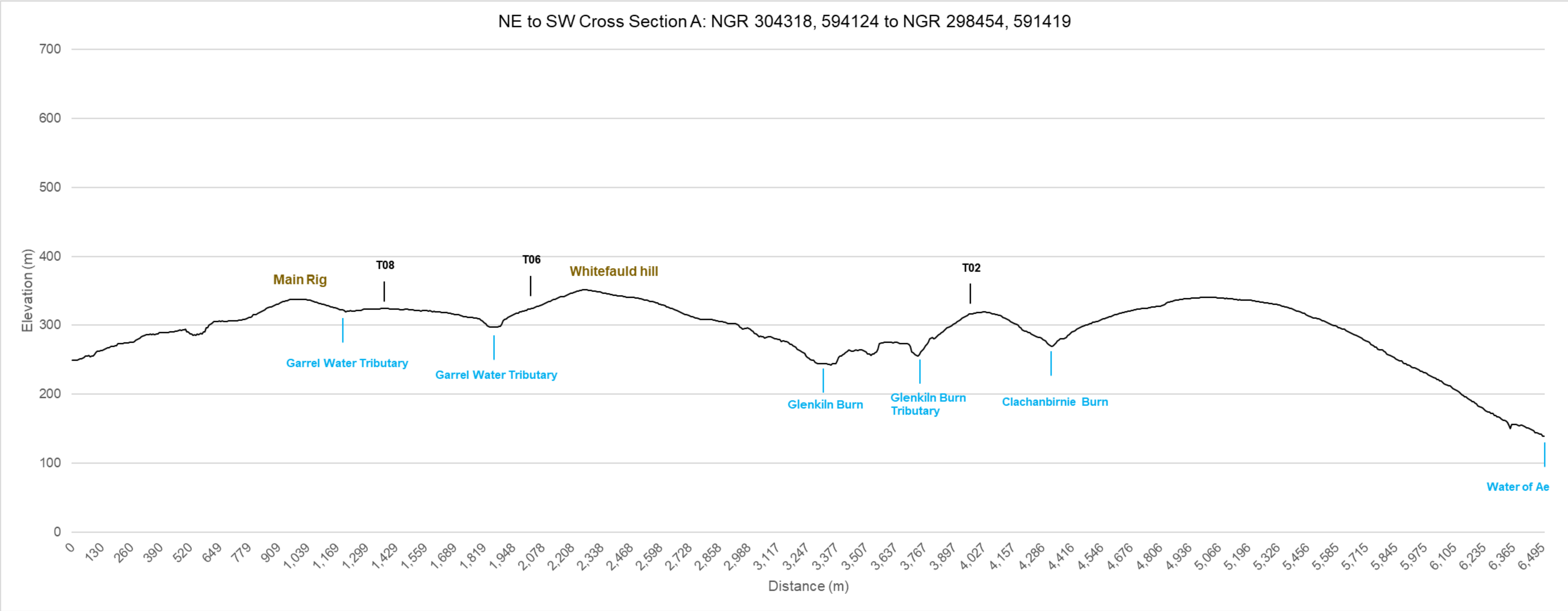

Diagram 6.2: Cross Section A: NGR 304318, 594124 to NGR 298454, 591419, showing landforms from north east to south west extents

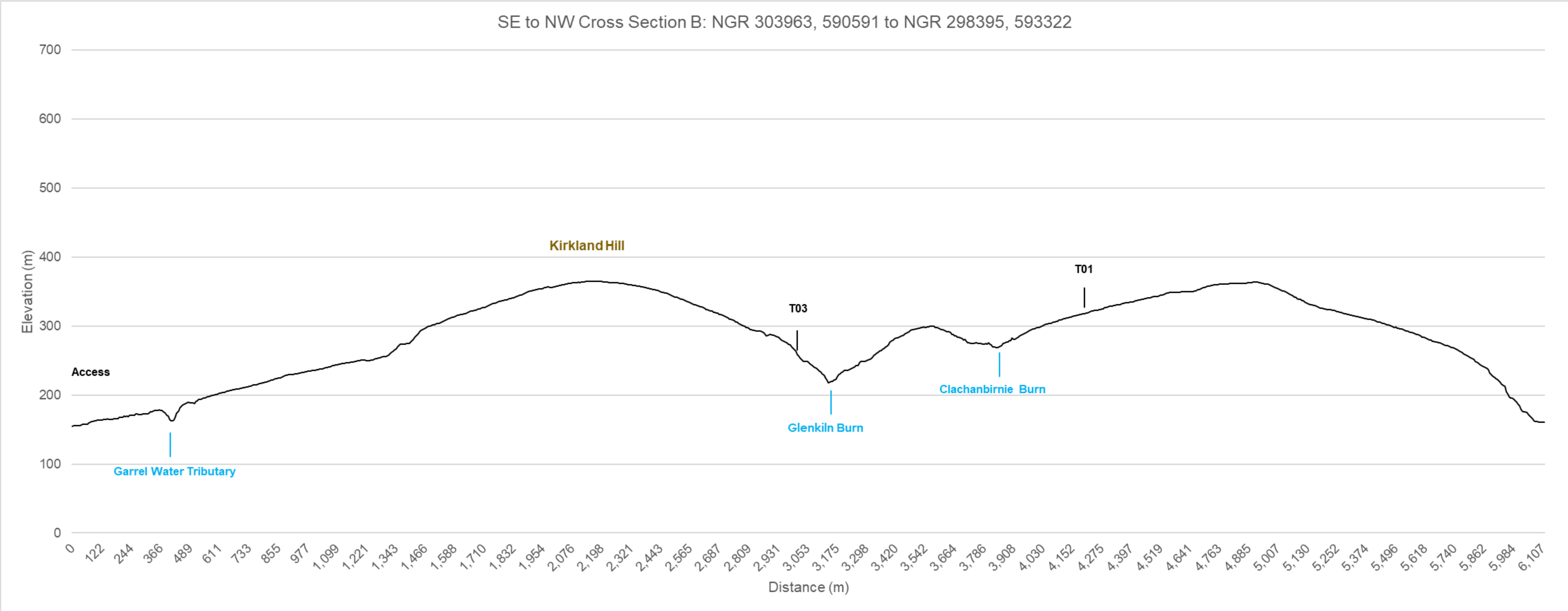

Diagram 6.3: Cross Section B: NGR 303963, 590591 to NGR 298395, 593322, showing landforms from south east to north west extents

6.5.5 Geology

45. This section details:

- bedrock geology (**Figure 6.2 Bedrock Geology**);
- superficial geology (**Figure 6.3 Superficial Geology**); and
- other geological faults or features found within and immediately surrounding the Site.

6.5.5.1 Bedrock Geology

46. The Site is largely formed from sedimentary rocks of the Gala and Ettrick Groups. The northern access route, the main body and part of the southern access route of the Site is underlain by sedimentary rocks from the Silurian age Queensberry, Selcoth and Glendearg formations of the Gala and Ettrick Groups. These formations comprise interbedded turbidite (wacke) sandstone and mudstone/siltstone in variable proportions.

47. The southern section of the southern access route is underlain by the Permian age Hartfield and Corncockle Sandstone formations of the Stewartry Group. The Hartfield Formation comprises sandstone interbedded with pebbly sandstone and angular pebble grade conglomerate, while the Corncockle Sandstone Formation comprises fine- to medium-grained, well sorted, red quartz sandstone.

48. BGS Geological mapping (2019) (**Figure 6.2 Bedrock Geology**) indicates the formations noted within the Site from north to south east:

- Queensberry Formation - sandstone, typically medium to coarse-grained, but ranging from fine to very coarse-grained, locally pebbly. Generally medium- to very thick-bedded or massive over thicknesses of tens of metres, units up to few metres thin-bedded;
- Selcoth Formation - sandstone, typically fine to medium-grained but ranging from very fine to coarse-grained. Generally medium- to thick-bedded over thicknesses of tens of metres interspersed with units up to few metres very thin to thin-bedded;
- North Britain Siluro-Devonian Calc-Alkaline Dyke Suite – small area south of Whitefauld Hill;
- Glendearg Formation - sandstone, typically fine- to medium-grained but ranging from very fine- to coarse-grained. Generally medium- to thick-bedded over thicknesses of tens of metres interspersed with units up to few metres very thin to thin-bedded;
- Hartfield Formation - Red, laminated and cross-laminated silty sandstone interbedded with pebbly sandstone and lenses of breccio-conglomerate. The sandstone is medium- to thick-bedded, silty, medium- to fine-grained with small [<0.5mm] detrital mica flakes and including many frosted and rounded quartz grains; and
- Corncockle Sandstone Formation - fine to medium-grained, well sorted, red quartz sandstone with large scale aeolian cross-bedding.

6.5.5.2 Superficial Geology

49. BGS Superficial geology mapping (**Figure 6.3 Superficial Geology**) indicates the higher ground in the vicinity of turbines 3, 5 and 7 are largely free of superficial deposits. The lower slopes are dominated by Langholm Till Formation, a stoney, sandy silty clay diamicton, with some Kirkbean Sand and Gravel Formation to the north of the Site, and small pockets of peat and alluvium (silt and clay). River terrace deposits are noted adjacent to the larger watercourses, such as the Water of Ae.

50. Glacial meltwater channels are present in the headwaters of the Garrel Water.

6.5.5.3 Other Structural Geological Features

51. BGS Geology mapping, shown in **Figure 6.3 Superficial Geology**, indicates that in the wider region, the noted geological Formations are heavily faulted. The faults follow the same orientation as the bedrock geology, from north east to south west. A fault is noted 20m to the east of Turbine 6 and 160m to the east of Turbine 8.

6.5.6 Soils and Peat

52. This section details:

- soils and soil characteristics;
- carbon-rich soil, deep peat and priority peatland habitats;
- peat characteristics and depth; and
- peat stability.

53. The following information is summarised from The James Hutton Institute soil mapping, using the National soil map of Scotland (1:250,000 scale), with reference to information gathered on the Site.

6.5.6.1 Soils and Soil Characteristics

54. The distribution of soils within the Study Area is dependent on the geology, topography and drainage regime of the area.

55. The Site soils consist of peaty podzols, brown forest soils and noncalcareous gleys, units of the Ettrick and Holywood Soils Association, associated with drifts derived from Lower Paleozoic greywackes and shales. The soil units present are detailed in **Table 6.5**.

Soil Association Parent Materials	Soil Unit	Component Soils	Landforms	Typical Associated Vegetation	Site Presence
Ettrick Drifts derived from Lower Paleozoic greywackes and shales	209	Brown forest soils with gleying; some noncalcareous gleys.	Highly variable, drumlins and undulating terrain within lowland areas, hill or valley sides, with gentle or moderate slopes and upland hill summits.	Permanent pasture, forestry and recreation.	Most dominant soil type, predominantly covering the Forest of Ae and the north eastern extent.
	218 220	Peaty podzols, peaty gleys, peat.	Hills with gentle and strong slopes.		
	233	Noncalcareous gleys, brown forest soils Peaty gleys, noncalcareous gleys	Hills and valley sides, generally concave with strong and steep slopes.		
Holywood Drifts derived from sandstones and conglomerates of Permian age	303	Brown forest soils with gleying, brown forest soils.	Undulating lowlands with gentle and strong slopes.	Pasture but some arable crops are grown.	Presence of this soil type between Burrenrig and Wester Parkgate, at the south eastern extent.

Table 6.5: Soil units with associated landforms, in order of dominance onsite

56. A brief description of the characteristics and formation of component soil groupings is included below.

- Brown forest soils: Fertile, often deep soils, rich in nutrients and organic matter. Soil is free draining and often not very distinctive visually, although usually lightens in colour with depth as organic content decreases. Texture and level of fertility depend on parent material and degree of alteration that the soil has undergone.
- Noncalcareous gleys: naturally poorly drained soils that develop under conditions of intermittent or permanent waterlogging. Soils are typically greyish or blue-grey with orange mottling. Humic gleys are loamy or clayey with a surface horizon of decomposed organic material, while peaty gleys have a peat-rich surface horizon.
- Podzols: these typically form in acid, coarse textured, well drained materials. Surface vegetation is usually coniferous woodland or heather moorland. Podzols are generally nutrient deficient and heavily leached in the upper horizons resulting in a bleached appearance, with an accumulation of thin layers of iron/aluminium oxides ('ironpan') or organic material at lower levels within the soil profile, with an orange-brown or black colour, respectively. Humus-iron podzols have a surface horizon of humified (or decomposed) organic material. In areas with low slope angles, waterlogging may occur above the ironpan; this can produce a soil intermediate between a podzol and a gley.

6.5.6.2 Carbon-rich Soil, Deep Peat and Priority Peatland Habitats

57. The Carbon and Peatland Map (SNH, 2016), a GIS vector dataset covering Scotland, presents the importance of environmental interests. They have been derived using a matrix of soil carbon categories (derived from Soil Survey of Scotland maps) and peatland habitat types (derived from Land Cover of Scotland 1988 map).

58. With regard to Scottish Planning Policy (2014), carbon-rich soils, deep peat and priority peatland habitat importance Classes 1 and 2 from the Carbon and Peatland Map are within Group 2 ('areas of significant protection'), where development should demonstrate that effects can be substantially overcome by siting, design or other mitigation. No Class 1 or Class 2 have been identified within the Site (as shown within **Figure 6.4 Soils**).

59. A summary description of the classes (SNH, 2016) present within the site is provided in **Table 6.6**, with 91.3% within Class 5 and 1.3% within Class 0. These classes do not indicate peatland habitat. Class 5 predominates within the Forest of Ae and Class 0 around the perimeter, typically where steeper slopes occur.

Class	Area (km^2)	%	Description	Site Presence
5	9.46	91.3	Soil information takes precedence over vegetation data. No peatland habitat recorded. May also include areas of bare soil. Soils are carbon-rich and deep peat.	Predominant class across the Site.
0	0.76	1.3	Mineral soil - Peatland habitats are not typically found on such soils.	Spread throughout the site, in the south east and south west alongside some small isolated areas.
3	0.007	0.1	Dominant vegetation cover is not priority peatland habitat but is associated with wet and acidic type. Occasional peatland habitats can be found. Most soils are carbon-rich soils, with some areas of deep peat.	Area on the north eastern extent.
4	0.14	7.4	Area unlikely to be associated with peatland habitats or wet and acidic type. Area unlikely to include carbon-rich soils.	Small areas located to the south and west of the Site.

Table 6.6: Summary of Carbon and Peatland Classes Present within the Site in order of Dominance

60. Outcomes of the peat survey summarised below and fully detailed in **Appendix 6.2 Soil and Peat Management Plan**, provide site-specific peat depth information which supersedes the higher-level characterisation from the NatureScot Carbon and Peatland 2016 Map dataset.

6.5.6.3 Peat Characteristics and Depth

61. Peat is a soft to very soft, highly compressible, highly porous organic material which can consist of up to 90% water by volume. Unmodified peat typically has two layers, a surface layer or acrotelm which is often around 0.3m thick (but can vary widely in depth depending on local conditions), highly permeable

and receptive to rainfall. The acrotelm layer generally has a high proportion of fibrous material and often forms a crust under dry conditions. The second layer, or catotelm, lies beneath the acrotelm and forms a stable colloidal substance which is generally impermeable. As a result, the catotelm usually remains saturated with little groundwater flow. Peat is thixotropic, meaning that its viscosity decreases under applied stress. This property may be considered less important where the peat has been modified through artificial drainage and is drier but will be significant when the peat body is saturated.

62. Given the presence of peat, as mentioned on Section 6.5.6.2, further peat-specific work was undertaken, including peat probing for use in a site-specific peat stability assessment, soil and peat management plan and carbon emission evaluation. Soil and peat depths were sampled at representative locations across the site, with latter focus upon infrastructure locations.

63. The Scottish Government guidance document on peat landslide hazard and risk assessments defines peat as a soil greater than 0.5m in depth, with an organic matter content of more than 60%. It is noted that, approximately 65% of the measured depths are less than 0.5m and are not therefore not formally considered as peat.

64. **Table 6.7** shows the range of results gathered during peat depth surveys. A total of 1,207 soil and peat depth records were gathered at the site and the surrounding areas, with measured depths averaging 0.48m.

65. Of the measured peat depths, 89% were less than 1.0m and 95% less than 1.5m. Peat or organic soil deposits were generally located in the central site area, with deeper deposits typically on the lower altitude and shallow gradient ground.

Peat/Soil Depth Range (m)	Number of locations surveyed	Percentage of locations surveyed	Average depth in range (m)
0.0 to <0.5	779	65%	0.22
≥0.5 to <1.0	294	24%	0.65
≥1.0 to <1.5	65	6%	1.18
≥1.5 to <2.0	28	2%	1.70
≥2.0 to <2.5	19	1%	2.20
≥2.5 to <4.0	22	2%	2.75
≥4.0	0	0%	N/A
Total / Aggregate	1,207	100%	0.48

Table 6.7: Peat / Soil Depths

66. The results of the peat depth survey were extrapolated to produce an indicative peat depth map as a 50m x 50m grid for the Site. This map and the results of the peat depth survey are shown in **Figure 6.5 Peat Overview**.

6.5.6.4 Peat Stability

67. Due to the presence of areas of peat on the site, a peat landslide hazard and risk assessment has been undertaken and a soil and peat management plan prepared.

68. The peat landslide hazard and risk assessment applies a combined qualitative (contributory factor) and quantitative (factor of safety) approach to determine the likelihood of peat landslides and then compares areas with the highest likelihoods with receptors to identify risks and determine appropriate mitigation measures. Further details on the methodology, interpretation and results are provided in **Appendix 6.1 Peat Stability Assessment**.

69. A draft peat management plan has been prepared that uses peat depth data to calculate likely excavation volumes during construction, identifies pragmatic options for reuse of excavated material, including in restoration of degraded areas across the site, and provides guidance on good practice storage and management of excavated material. Further details are provided in **Appendix 6.2 Soil and Peat Management Plan**.

6.5.7 Hydrogeology

70. This section details:

- hydrogeological features present at the Site and their characteristics;
- groundwater vulnerability;
- groundwater body characterisation and water quality; and
- GWDTE.

6.5.7.1 Hydrogeological features

71. The sandstones of the Queensberry, Selcoth and Glendearg Formations (Gala Group) which underlie the majority of the Site are classified as Low productivity aquifers, with highly indurated greywackes with limited groundwater in the near surface weathered zone and secondary fractures. These formations may support small private water supplies.

72. The sandstones of the Hartfield and Corncockle (Stewartry Group) in the south east of the Site forms a Highly productive aquifer, which can be up to 1500m thick with sandstones and breccias yielding up to 40l/s.

6.5.7.2 Groundwater Vulnerability

73. Groundwater vulnerability to pollution is Class 5 in the western part of the Site and south of Turbine 5, with the rest of the Site within Class 4. Class 5 is defined as ‘Vulnerable to most pollutants, with rapid impact in many scenarios’, and Class 4 ‘Vulnerable to those pollutants not readily adsorbed or transformed’.

74. The groundwater vulnerability increases as altitude increases. This increasing vulnerability is likely to be due to the generally decreasing depth of drift material protecting the underlying bedrock towards the top of the hill.

6.5.7.3 Groundwater Body Characterisation and Water Quality

75. The WFD came into force in December 2003 and is implemented in Scotland through the Water Environment and Water Services (Scotland) Act 2003. A key objective of this Directive is the achievement of 'good condition' (as a minimum) of all natural water bodies by 2027.

76. Under the terms of the WFD, all river basin districts require to be characterised. The characterisation process required SEPA to produce an initial assessment of the impact of all significant pressures acting on the water environment. Groundwater bodies have been identified to reflect the main aquifer types (bedrock and superficial). For areas above low productivity aquifers, groundwater bodies have been defined by SEPA using surface water sub-catchments as a surrogate. Areas above high productivity aquifers have been defined using geological and major catchment boundaries. The main purpose of identifying water bodies is to enable their status to be described accurately and compared with environmental objectives.

77. SEPA classify groundwater bodies using two classes: 'Good' and 'Poor'. The classifications take into account pressures and their potential effects, compared to near natural conditions for the respective water body (SEPA, 2018a). This risk-based system highlights groundwater issues such as over abstraction, in addition to chemical groundwater quality.

78. There are three groundwater bodies within the Site; East Dumfrieshire (ID:150690), Annandale Sand and Gravel (ID: 150739), Lochmaben (ID: 150582). The classification results of these water bodies are summarised in **Table 6.8**.

Name (WFD SEPA ID)	Area (km^2)	Classification (2018)	Anticipated Classification (2021)	Summary of Pressures
East Dumfriesshire 150690	1,184.3	Overall: Good Quantitative status: Good Chemical status: Good	Overall: Good Quantitative status: Good Chemical status: Good	No existing pressures
Annandale Sand and Gravel 150739	175.8	Overall: Good Quantitative status: Good Chemical status: Good	Overall: Good Quantitative status: Good Chemical status: Good	No existing pressures
Lochmaben 150582	102.4	Overall: Good Quantitative status: Good Chemical status: Good	Overall: Good Quantitative status: Good Chemical status: Good	No existing pressures

Table 6.8: Water Framework Directive Groundwater Classification

6.5.7.4 Groundwater Dependent Terrestrial Ecosystems

79. Regions of the Site have been surveyed using the National Vegetation Classification (NVC) system and an associated map produced, see **Chapter 7: Ecology and Biodiversity**. This map was reviewed for GWDTE, using SEPA guidance (2017). This was used to determine which NVC areas could potentially be GWDTE-applicable.

80. The NVC surveys across targeted areas at the Site (see **Appendix 7.2 Habitats Baseline Report**). The result is a matrix of species including those which are identified as GWDTE, including NVC M5, M6, M9, M15, M23, MG9, MG10, U6 and W7. Further details of each community are detailed below.

- M5 *Carex rostrata-Sphagnum squarrosum* mire is a community of loch-sides, pools and fens where there is mild base enrichment, either from the underlying rock or from irrigating water. It occurs where the pH is a little higher than in the *Carex rostrata-Sphagnum fallax* mire, but where conditions are not as base-rich as they are in the *Carex-Calliergonella* mire (JNCC, 2004).
- M6 *Carex echinate-Sphagnum fallax/denticulatum* mire and M6c sub-community dominated by *J. effusus* appear in wet hollows, gullies and along streams (JNCC, 2004).
- M9 *Carex rostrata-Calliergonella cuspidata/Calliergon giganteum* mire is confined to places where base-rich water seeps through deep, wet peat. It occurs in hollows and seepage lines in blanket bogs, in calcareous fens, in topogenous mires, and around lochans, springs and raised mires (JNCC, 2004).
- M15 *Trichophorum-Erica* wet heath is a community of shallow, wet or intermittently waterlogged, acid peat or peaty mineral soils on hillsides, over moraines, and within tracts of blanket mire (JNCC, 2004).
- M23 *Juncus effuses / acutiflorus-Galium palustre* rush-pasture is a community of gently-sloping ground around the margins of soligenous flushes, as a zone around topogenous mires and wet heaths, and especially widespread in ill-drained, comparatively unimproved or reverted pasture (JNCC, 2001).
- MG9 *Holcus lanatus - Deschampsia cespitosa* grasslands is characteristic of permanently moist and periodically inundated soils (JNCC, 2014).
- MG10 *Holcus lanatus-Juncus effusus* rush-pasture is a vegetation type of damp acid to neutral soils on level to gently sloping ground in enclosed pastures, and in neglected situations such as ditches, pond sides and roadside verges (JNCC, 2004).
- U6 *Juncus squarrosus-Festuca ovina* grassland is a vegetation type of damp peaty soils or gleyed podsols on flat or gently sloping ground. The soils are moist and can be waterlogged (JNCC, 2004).
- W7 *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* are woodlands of flushed slopes, valleys and streamsides throughout the upland fringes (JNCC, 2004).

81. The majority of these communities, where present, are associated with surface water moving from the surrounding hills downslope to eventually form or join surface water channels. As a result, surface water and hill runoff are likely to be the dominant soil water factors and the groundwater dependency of these habitats is considered Low. Further details are included in **Figure 6.6 GWDTE Overview** and **Appendix 6.3 Groundwater Dependent Terrestrial Ecosystems**.

6.5.8 Hydrology

82. This section details:

- hydrological characteristics of the Site and downstream area;
- surface water flows and flooding;

- water quality;
- water supplies; and
- fisheries.

83. By evaluating the hydrology of the Site using a catchment-based system, judgements can be made regarding potential influences that site activities may have downstream and on other water bodies within the catchment. Figures displaying the hydrological overview and more detailed site-specific hydrology are provided in **Figure 6.7 Hydrology Overview**.

6.5.8.1 Hydrological Characteristics

84. The Site is located entirely within the Kinnel Water catchment, with a total catchment area of 229.0km^2 and spans the catchments of two of its tributaries, the Water of Ae (143.1km^2 catchment area) and Mollin Burn 6.9km^2 catchment area).

85. The northern extent of the Site is drained by the Deer Burn (5.0km^2 catchment area) (shown in **Photograph 6.4**) which flows in a south-westerly direction to join the Water of Ae, 1.7km from the existing crossing where the burn is channelled beneath the existing forestry track, east of Muir Hill.

86. The central part of the Site is drained by the Glenkiln Burn (shown in **Photograph 6.5**) (9.9km^2 catchment area), which flows in a south-westerly direction to join the Water of Ae, 7.8km from the existing crossing where the Ox Cleuch (Glenkiln Burn tributary) is channelled beneath the existing forestry track, north of Whitefauld Hill.

87. The eastern extent of the Site is drained mainly by the Garrel Water (2.4km^2 catchment area), which flows in a south-easterly direction to join the Kirkland Burn, 5.9km from where Garrel Water crosses the Site Boundary. The far eastern extent is drained by WhiteKnowe Head Burn (0.5km^2 catchment area), which flows in a south-easterly direction to join the Mollin Burn, 3.3km from where it crosses the Site Boundary.

88. The Kirkland Burn drains part of the southern extent of the Site and flows south adjacent to the existing Harestanes Windfarm access track, then flows in a south-easterly direction to join the Water of Ae, 7.0km from where Kirkland Burn crosses the Site Boundary.

89. The western extent of the Site is drained by the Clachanbirnie Burn (1.7km^2 catchment area) which flows in a south-easterly direction to join the Glenkiln Burn, 1.8km from where the burn crosses the existing forestry track north of Brownmoor Hill.

90. The narrow extension of the Site Boundary in the north incorporates a proposed cable route which would cross numerous watercourses, including Glenkiln Burn (9.9km^2 catchment area), Auchendowal Sike (1.0km^2 catchment area), Ox Cleuch (4.2km^2 catchment area), Auchencaigroch Burn (0.9km^2 catchment area), an unnamed tributary of Water of Ae (2.9km^2 catchment area), Blenoch Burn (0.6km^2 catchment area), Deer Burn (5.0km^2 catchment area) and Water of Ae (u/s Goukstane Burn).

Photograph 6.4: Looking downstream on Deer Burn, towards the existing forestry track crossing, taken at NGR 300819, 596590

Photograph 6.5: Looking downstream on Glenkiln Burn, from the existing track crossing, taken at NGR 302162, 593968

91. Numerous smaller unmapped watercourses and flush zones are also present within the Site. These form more distinct channels on the lower slopes closer to the larger watercourses. During fieldwork it was noted that areas of the Site were wet underfoot, particularly on the lower slopes and in relatively wide flush zones adjacent to some headwater channels.

92. No standing water bodies are present within the Site Boundary. Minister's Moss is a small water body located 10m south of the Site Boundary in the southern extent. The moss is located upstream of the Site and is therefore not hydrologically connected to it. Cran Loch is located 700m north of the Site Boundary.

6.5.8.2 Surface Water Flows and Flooding

93. Theoretical runoff rates have been estimated for a selection of representative Site watercourses, at proposed watercourse crossing locations. Peak flows have been estimated using the Flood Estimation Handbook catchment characteristics, with the 'FEH Rainfall-Runoff' method used to derive a range of peak flow return periods. Low flow measurements have been determined by the 'Low Flow' method and are quoted as Q_{95} (i.e. the flow exceeded 95% of the time). These data are shown in **Table 6.9**.

Catchment (Upstream of Grid Reference)	Area (km^2)	Mean Annual Flow (m^3/s)	Low Flow Q_{95} (m^3/s)	Estimated Peak Runoff (m^3/s) for each return period (years)				
				5	10	25	50	100
Glenkiln Burn tributary, Water of Ae Catchment NGR 302150, 593950	3.30	0.12	0.01	4.98	6.04	7.88	9.45	11.02
Auchencaigroch Burn (Glenkiln Burn Tributary), Water of Ae Catchment NGR 302100, 594300	0.84	0.03	0.01	1.55	1.89	2.45	2.96	3.45
Deer Burn, Tributary of Water of Ae NGR 300850, 596600	2.81	0.11	0.01	4.76	5.77	7.57	9.09	10.61

Table 6.9: Estimated Surface Water Flow Characteristics

94. The Hydrology of Soil Types (HOST) is a hydrologically-based classification of soils on the basis of their physical properties and their effects on the storage and transmission of water. It makes use of the fact that the physical properties of soils have a major influence on the hydrological response of a catchment. Other parameters can then be derived from the HOST classification (Institute of Hydrology, 1995). For the purposes of hydrological assessment, the Baseflow Index (BFI) and Standard Percentage Runoff (SPR) are the most useful parameters.

95. BFI is the long-term ratio of baseflow to total stream flow, where baseflow represents the contribution to total flow from groundwater (University of Newcastle, 2008). BFI values range from 0.1 in relatively impermeable clay catchments to 0.99 in highly permeable chalk catchments. A very low BFI of 0.15 represents a flashy catchment with minimal storage, low BFI values (e.g. 0.3) indicate a catchment with little storage and active runoff, a BFI of 0.7 (or greater) indicates a significant contribution to flow from a major aquifer.

96. SPR is the average percentage of rainfall that causes the short-term increase in flow seen at a catchment outflow following a storm event (NSRI, 2008).

97. Using FEH to derive catchment descriptors, watercourse reaches relevant to the site have BFI-HOST values ranging from 0.30 to 0.32, indicating catchments with little storage and active runoff. These values would be expected given the low aquifer productivity across the majority of the Site. Local watercourses would quickly respond to rainfall events, with a short lag time between rainfall occurring and increased stream flow values. The SPR values range between 53-54%, indicating a moderately flashy response to rainfall, attenuated by local conditions. Additionally, the steep characteristics of Site valleys would further contribute to this high level of runoff.

98. Flood risk data provided by SEPA (2018b) shows flooding risk limited to the immediate area adjacent to the Glenkiln Burn and Garrel Water, which runs across the main Site between Turbines 8 and 10, and along the eastern edge of the Site Boundary, respectively. Discrete small locations of surface water flooding are noted adjacent to the small tributaries of the Water of Ae and forestry rides.

99. Downstream of the Site, there is a wider area of high risk river flooding noted at Ae Brigend (NGR 301130, 586711), where the watercourse is channelled beneath the A701.

6.5.8.3 Surface Water Quality

100. As discussed in the Groundwater Body Characterisation and Water Quality section, the WFD is a risk-based classification system. This highlights such issues as watercourse morphology (hydromorphology) and existing artificial structures in addition to chemical water quality and ecological diversity.

101. As for the Groundwater Body Characterisation and Water Quality section, SEPA has characterised surface water quality under the WFD.

102. The WFD applies to all surface waters, but for practical purposes, SEPA has defined a size threshold above which a river or loch qualifies automatically for characterisation. For lochs, the threshold is a surface area of $0.5km^2$ and rivers must have a catchment area of $10km^2$ or more. In addition to these larger water bodies, smaller waters have been characterised where there is justification by conservation interests and to meet the requirements of regulatory legislation, such as for drinking water supplies. **Table 6.10** summarises the WFD classification for the Glenkiln Burn, Kirkland Burn and Garrel Water.

Catchment	Name (WFD SEPA ID)	Overall Classification (2018)	Anticipated Classification (2021)	Summary of Pressures
River Annan	Glenkiln Burn 10662	Poor	Good	Barrier to fish migration
River Annan	Kirkland Burn 10660	Poor	Poor	Barrier to fish migration
River Annan	Garrel Water (u/s Kirkland Burn) 10659	Poor	Poor	Barrier to fish migration

Table 6.10: WFD Surface Water Classification

103. For water bodies that have not been classified, the normal convention is to assume a classification based on downstream or adjacent water bodies unless there are specific indications to the contrary.

104. In relation to this assessment it is considered that the higher the WFD status, the higher the sensitivity of the water body. To prevent any deviation from 'good status' for receiving watercourses, the objective is to keep construction phase and post-development runoff to pre-development levels, in terms of both quality and quantity, whilst recognising that natural variability in flow values and water quality do occur. Measures to ensure this are discussed in the assessment sections below.

6.5.8.4 Water Supplies

105. Information on public water supplies was sought from Scottish Water. This confirmed that the Site is not located within a Drinking Water Protected Area (Surface Water) and no public water supply assets are within 10km of the Site.

106. Private water supply information was obtained from Dumfries and Galloway Council, who provided a record of identified properties and supplies within 10km of the Site Boundary. Further information was obtained from the DWQR (2019) online map and all the sources were then refined to properties within a 1km radius of the Site. The screening exercise was based on the sources' hydrological linkage to the Proposed Development and/or their location within SEPA (2017) construction buffers. For further details, please refer to **Appendix 6.6 Private Water Supply Assessment**.

107. **Figure 6.7 Hydrology Overview** shows the location of local private water supply sources that were identified within the 1km buffer.

108. There are two categories of private water supply provided within the data:

- Type A supplies: supply more than 10m^3 per day or serve at least 50 people, or supply a commercial or public activity (regardless of volume).
- Type B supplies: categorise the remaining supplies which do not meet the Type A criteria.

109. There are 2 Type B supplies within the 1km buffer. These supplies generally supply individual properties, which are either residential or farms. These have been considered in more detail, taking account of source type and location, distance from Site and intervening topography, and water features to determine if there are potential pollutant source-pathway-receptor relationships.

110. Further details are covered in **Appendix 6.6 Private Water Supply Assessment**. Information on those considered to be potentially affected by the Proposed Development is also available in this Section 6.6.1 Mitigation by Design and Embedded Mitigation.

6.5.8.5 Fisheries

111. The Water of Ae, Glenkiln Burn, Clachanbirnie Burn, Clatterstanes Burn, Wreaths Burn, Davies Burn, Kirkland Burns and Kinnel Water are recognised as having the potential to support fish populations (including salmonids). Fish populations could also be present in minor watercourses, tributaries of the noted watercourses. Further details and species information are available in the River Annan Trust & District Salmon Fishery Board Annual Report (2017) and **Appendix 7.4 Aquatic Ecology Report**. This supports to the requirements of Schedule 9 of the Electricity Act 1989 as described in **Chapter 3: Site Selection and Design.**

6.6 Potential Effects

112. The assessment of effects is based on the project description as outlined in **Chapter 4: Development Description**. Unless otherwise stated, potential effects identified are considered to be negative and adverse. The assessments are based on the criteria for sensitivity, magnitude, probability and significance provided in the Significance Criteria section of this chapter, including **Tables 6.2** to **6.4**.

113. The assessment assumes the integral good practice measures described in **Appendix 4.1 Outline Construction Environmental Management Plan** have been incorporated into the scheme design and these do not form mitigation measures.

114. Mitigation is considered as additional measures beyond the design principles and good practice, the application of such measures is separately noted and residual effects evaluated.

6.6.1 Mitigation by Design and Embedded Mitigation

115. Detailed constraints advice was provided during the iterative layout design process for the turbines and associated infrastructure features. At various stages during the determination of the design, fieldwork was undertaken to provide feedback to the design team. This approach identified Site constraints in order to minimise a number of potential effects (such as minimising development infrastructure close to or crossing water features and undertaking initial peat depth and stability studies to avoid deeper peat areas). These are discussed further in **Chapter 3: Site Selection and Design**.

116. Forestry felling, extraction and associated activities would require specific management and control measures in order to reduce environmental impact. However, although the baseline condition is that the existing plantation forests will require harvesting in due course, this activity may be hastened by the Proposed Development. Felling contractors would be expected to conduct felling, harvesting and associated activities in accordance with forestry good practice measures, provided in **Appendix 13.1 Forestry Report**.

117. During the detailed design and construction phases, sections of track would be surveyed and microsited, within 50m, to optimise the distances from the waterbodies, taking into account local topography and local characteristics.

118. Sustainable drainage strategy that minimises disturbance of natural groundwater systems to reduce adverse effect on groundwater levels and flows would be implemented.

119. As part of the layout design strategy, watercourse crossings were minimised. Where access necessitates watercourse crossings, construction features have been limited in these buffers as far as possible, for example minimising tracks running parallel to streams and trying to avoid track junctions being constructed in these zones. This approach has resulted in seven watercourse crossing locations for the proposed track upgrades; two cable route crossing using an extended culvert and one cable crossing utilising an existing bridge structure not requiring watercourse engineering works. These crossings are mapped on OS 1:50,000 scale map and therefore subject to CAR. It has been assumed that nine of these existing locations have a structure in place that requires upgrading. The upgrading will be required if the crossing falls within a track section that requires upgrading. This will be investigated further during detailed design stage.

120. Hydromorphological processes such as erosion and deposition have been identified and presented in a watercourse crossings guidance report (**Appendix 6.4 Watercourse Crossings Report**), with recommendations made to minimise adverse effects relating to construction of crossing structures.

Water Crossing	Easting	Northing	Description
WC01	302926	590995	Black Linn (Garrel Water tributary), Water of Ae Catchment
WC02	302162	593969	Glenkiln Burn tributary, Water of Ae Catchment
WC03	301660	593821	Ox Cleuch (Glenkiln Burn tributary), Water of Ae Catchment
WC04	301004	594116	Auchendowal Sike (Glenkiln Burn tributary), Water of Ae Catchment
WC05	300481	593384	Rough Cleuch (Glenkiln Burn tributary), Water of Ae Catchment
WC06	300076	593011	Clachanbirnie Burn (Glenkiln Burn tributary), Water of Ae Catchment

Water Crossing	Easting	Northing	Description
WC07	303225	593362	Yellowtree Grain (Garrel Water tributary), Water of Ae Catchment
WC08	302115	594317	Auchencaigroch Burn (Glenkiln Burn Tributary), Water of Ae Catchment
WC09	300819	596590	Deer Burn, Tributary of Water of Ae
WC10	300366	597297	Unnamed Tributary of the Water of Ae

Table 6.11: Summary of CAR Applicable Watercourse Crossings Location

Infrastructure	Crossing Type	Watercourse Size			
		Large	Medium	Small	Total
Track Upgrades	Bridge	-	WC02	-	1
	Rectangular culvert / arch	-	-	-	-
	Open base arch structure	-	-	-	-
	Circular culvert	-	WC03, WC06, WC07	WC01, WC04, WC05	6
	Drainage layer	-	-	-	-
Cable crossings at existing track crossing locations	Extended culvert – circular pipe	-	-	WC10, WC08	2
	Suspended to bridge	-	WC09	-	1
Total		-	5	5	10

Table 6.12: Summary of Types and Sizes of CAR-Applicable Watercourse Crossings

121. All engineering activities in such locations are subject to CAR, and subject to SEPA approval. Post-consent, detailed design information would be provided to support this process.

122. A number of additional, smaller watercourse crossings have also been identified during fieldwork, these watercourses are not mapped on OS 1:50,000 scale mapping and comprise crossings of flush zones and small headwater channels. These crossings would have structures installed appropriate to local conditions and would be anticipated to be designed as over-sized circular culverts or layers of pipes for flush zones. **Table 6.11** and **Table 6.12** summarise the CAR watercourse crossings, with further details and a full inventory of crossings in **Appendix 6.4 Watercourse crossings** and shown in **Figure 6.7 Hydrology - Overview.**

123. The following mitigation measures are proposed to reduce potential alterations to sub-surface flows and groundwater levels by the works and, as result, reduce potential effects on GWDTE:

- Development and implementation of a drainage system, encouraging the infiltration of surface water runoff via SuDS arising from the infrastructure.
- The tracks will be micro-sited, where possible, to avoid areas of potential GWDTE.
- Use of permeable fill in the construction of the access tracks to maintain flow and inclusion of cross-formation drains to maintain groundwater flows, where practicable.
- Consideration shall be given to peat storage and reuse in areas of GWDTE, to avoid causing long-term alterations in local hydrological conditions.

6.6.2 Receptor Sensitivity

124. Receptor sensitivity has been determined using the criteria provided in **Table 6.2**.

125. All watercourses and groundwater bodies have been rated as of High sensitivity, given water quality, groundwater vulnerability classifications and direct hydrological linkage to the Water of Ae.

126. Local Private Water Supply identified of concern are generally considered of Medium sensitivity value, based on the number of properties they serve. It is recognised that these receptors would be an important issue for the residents of each specific property.

127. No Class 1 or Class 2 from the Carbon and Peatland Map (SNH, 2016) have been identified within the site. An extensive peat depth survey was undertaken, with an average peat depth of 0.48m and 89% of peat depth records less than 1.00m. Although peat depths and peatland characteristics did vary across the Site, a high degree of soil modification due to widespread forestry practices was generally evident, with soils and peat rated as of Medium sensitivity, based on soil characteristics and carbon-rich status across the Site.

128. Groundwater levels and sub-surface flows have a relationship with the peatland habitats present and the associated sensitivity for this Site is considered as high. GWDTE have been assessed and are not considered as predominantly groundwater fed, therefore are rated as Low sensitivity.

6.6.3 Construction

6.6.3.1 Private Water Supplies

129. PWS locations were evaluated based on their position relative to the Site and on the potential of the Proposed Development to affect the PWS, in order to determine if there could be potential pollutant source-pathway-receptor relationships. This took into account source type and location, distance from Proposed Development infrastructure, groundwater pathways, intervening topography, and other surface water features. Potential effects on water supply and on infrastructure of the PWS were also considered.

130. Dumfries and Galloway Council provided data of PWS within 10km of the Application Boundary. This data specifies whether each supply represents a small domestic supply (known as Type B) or a supply to a larger population and/or for commercial purposes (known as Type A).

131. Groundwater sources within a 1km buffer zone and surface water sources within a 5km buffer zone of the Application Boundary were considered. In addition, sources within a 100m buffer around tracks and other ancillary infrastructure, and those within a 250m buffer around Turbines and Borrow Pits, were considered further as per SEPA (2017) Land Use Planning System Guidance Note 31 (LUPS-GU31) with regards to potential groundwater monitoring. All other PWS were scoped out, as were judged unlikely to be hydrologically connected to the Proposed Development.

132. Following review of PWS, one supply has been identified as having potential for adverse effects from the Proposed Development. Burrance (PWS01) has been confirmed on-site and information, including grid reference, is presented in **Appendix 6.6 Private Water Supply Assessment** and **Figure 6.7 Hydrology Overview**.

6.6.3.2 Pollution Incidents

133. During the construction phase a number of potential pollutants would be present onsite to facilitate forestry clearance and civil engineering activities, including oil, fuels, chemicals, unset cement and concrete, waste / wastewater from construction activities, and nutrient release from logging residues. With chemicals and oil being stored and used onsite, along with concrete batching, there is the potential for an incident. Any pollution incident occurring on the Site could have a detrimental effect on the water quality of the nearby surface waters, groundwater and/or soil, thereby also indirectly affecting ecology.

134. The adoption of the applicable good practice measures as summarised in the Outline CEMP (provided in **Appendix 4.1 Outline CEMP**) would reduce the probability of an incident occurring and also reduce the magnitude of any incident due to a combination of good site environmental management procedures, including minimised storage volumes, staff training, contingency equipment and emergency plans. Key measures identified to reduce potential for pollution include:

- application of a 50m buffer zone from OS 1:10,000 watercourses, except where access is required;
- secure oil and chemical storage in over-ground bunded areas, limited to the minimum volume required to serve immediate needs with specified delivery and refuelling areas;
- emergency spill kits retained onsite at sensitive locations;
- special measures at concrete batching plants with pre-cast structures used where appropriate;
- cessation of work and development of measures to contain and/or remove pollutant should an incident be identified; and
- a surface water quality monitoring programme is recommended, to commence 12 months prior to construction and continue into early operational period. During construction, this would include an adaptive monitoring system enabling early investigation of parameters outwith expected ranges, with prompt alerts to the construction team to amend any work activities causing an adverse effect.

135. In addition, the substantial dilution factor when comparing site watercourse flows with downstream flow characteristics, taking account of enlarged catchment areas and confluences, would be expected to further reduce any potential effect downstream. This would be particularly notable for the large hydrological systems of the Water of Ae.

136. Taking into account the design and embedded mitigation, the effects are assessed as follows:

- the magnitude of pollution effect on surface waters is considered Moderate and of Low probability to occur, giving an overall significance of **Minor**;
- the magnitude of pollution effect on groundwater is considered Minor and of Low probability to occur, giving an overall significance of **Minor**;
- the magnitude of pollution effect on groundwater PWS is considered Minor and of Low probability to occur, giving an overall significance of **Negligible**; and
- the magnitude of pollution effect on soil is considered Minor and of Low probability to occur, giving an overall significance of **Minor**.

6.6.3.3 Erosion and Sedimentation

137. Soil erosion, loss of soil and sediment generation may occur in areas where the ground has been disturbed during construction including in situations where: engineering activities occur close to watercourses, such as at watercourse crossings; where higher velocity surface water flows may occur due to local slopes and drainage design; and where forestry felling is occurring. Surface water passing through the drainage network, efficiently draining the new infrastructure, could exhibit high localised flows, increasing the potential for bank erosion.

138. Sediment transport in watercourses can result in high turbidity levels which affect the ecology, particularly fish stocks, by reducing the light and oxygen levels in the water. Sediment deposition can further effect watercourses by potentially smothering plant life, invertebrates and spawning grounds and can reduce the flood storage capacity of channels and block culverts, resulting in an increased flood risk. It is recognised that extensive felling of forestry can lead to long-term increases in run-off from previously afforested slopes and shorter term increases in sediment loading.

139. Requirements for soil excavation, transport and storage may lead to additional sedimentation issues at locations where new track, widened existing track, crane hardstandings or foundation construction activities are necessary. Borrow pits have the potential to release sediment-laden runoff if measures are not taken to minimise surface water input into such areas and to adequately treat flows from the borrow pits.

140. The adoption of the applicable good practice measures as summarised in the **Appendix 4.1 Outline CEMP** and **Appendix 6.5 Borrow Pit Assessment** would reduce the probability of an incident occurring and also reduce the magnitude of any incident due to a combination of good site environmental management procedures, including additional precautions when operating machinery close to watercourses, soil management, staff training, contingency equipment and emergency plans. Key measures identified to reduce erosion and sedimentation include:

- existing tracks would be used where applicable to reduce earthworks;
- vegetation clearance would be scheduled only as needed, buffer strips would be retained as vegetated features and revegetation encouraged with native species;
- silt traps would be employed and maintained in appropriate locations;
- temporary interception bunds and drainage ditches would be constructed upslope of excavations such as borrow pits to minimise surface runoff ingress and in advance of excavation activities;
- borrow pits would have appropriate and specific drainage, likely to include a series of settlement lagoons to reduce sediment load and would be monitored prior to discharge;
- excavation and earthworks would be suspended during and immediately following periods of heavy rainfall in order to minimise sediment generation and soil damage; and
- a surface water quality monitoring programme is recommended, to commence 12 months prior to construction and continue into early operational period. During construction, this would include an adaptive monitoring system enabling early investigation of parameters outwith expected ranges, with prompt alerts to the construction team to amend any work activities causing an adverse effect.

141. In the case of pollution incident effects, good practice site environmental management measures and the dilution factor involved would be expected to reduce any potential sedimentation effect downstream.

142. Taking into account the design and embedded mitigation, the effects are assessed as follows:

- the magnitude of the effect of erosion or loss of soil is considered to be Minor and of Medium probability to occur, giving an overall significance of **Minor**;
- the magnitude of sedimentation effect on surface water is considered to be Minor and of Medium probability to occur, giving an overall significance of **Minor**; and
- the magnitude of sedimentation effect on groundwater PWS is considered Minor and of Low probability to occur, giving an overall significance of **Negligible**.

6.6.3.4 Modification of Surface Water Drainage Patterns

143. Surface flows could be impeded by construction activity in or adjacent to stream channels, poor choice of watercourse crossing locations or inadequately designed crossing structures. Blockages could be caused by inadequate control of earthmoving plant, sedimentation and poor waste management, all of which could lead to flooding upstream. There are a number of flood-sensitive locations such as Glenkiln Burn and Garrel Water, which run across the Site, as discussed in the Baseline Conditions.

144. Turbine bases and other constructed impermeable surfaces would restrict the infiltration of rainfall into the soil and underlying superficial deposits, resulting in localised increased volumes of surface runoff. The interception of diffuse overland flow by new tracks and their drains could disrupt the natural drainage regime of the site by concentrating flows and influencing drainage in soils.

145. Local watercourses have been identified as having a moderately flashy response to rainfall events, as demonstrated by rapid response times and peak flows. Forestry felling may lead to increased surface water flows due to less interception and uptake from trees. The increases in flows could have a detrimental effect on the populations of fish, freshwater invertebrates and species dependent on the water environment.

146. The track design includes an upgrade to nine existing crossing structures, for watercourses that are subject to CAR regulation (as shown on OS 1:50,000 mapping). **Table 6.11** summarises these watercourse crossings, with further details in **Appendix 6.4 Watercourse Crossings Report**.

147. There would be a requirement for minor watercourse crossings (i.e. representing minor watercourses not shown on OS 1:50,000 mapping), typical crossing locations and suggested structures are also provided in **Appendix 6.4 Watercourse Crossings Report**.

148. The adoption of the applicable good practice measures summarised in the Outline CEMP would reduce the impact of modification to surface water drainage patterns, with artificial drainage installed only where necessary and would, wherever practical, be installed in advance of ground being cleared of vegetation. All structures would be designed and constructed following good practice techniques and would be of sufficient capacity to receive storm flows with an allowance for increased flows due to climate change. Key measures identified to minimise alterations to surface water drainage patterns include:

- minimising the number of watercourse crossings, using and upgrading existing structures where applicable;
- application of sustainable drainage techniques to increase peak lag time and implementation of cross-drains at appropriate intervals and frequent discharge points to reduce scour potential;
- minimising the size and duration of in-channel works; and
- appropriate design of crossing structures to ensure sufficient capacity to convey 1:200-year storm flows and enable mammal and fish passage.

149. The area of impermeable surface created would be very small in comparison with sub-catchment areas, as only the turbine, hardstandings and control building bases would be designed as impermeable, with the unbound tracks likely to act as semi-permeable features with limited infiltration potential.

150. Taking into account the design and embedded mitigation, the effect is assessed as follows:

- the magnitude of effect on surface water drainage patterns is considered Minor and of Medium probability to occur, giving an overall significance of **Minor**.

6.6.3.5 Modification of Groundwater Levels and Flows

151. Deep excavations, such as those required for the turbine foundations and borrow pits could disrupt shallow groundwater systems. Groundwater controls, such as physical cut-offs or dewatering, would be utilised to prevent the excavations filling with water. This would result in the lowering of groundwater levels in the immediate vicinity of the excavations and alterations to flow paths during dewatering activities. Access tracks could interrupt shallow groundwater flow. There may be some infiltration of water through the access tracks, but the majority of the water would enter the surface water drainage system and would be discharged downslope of the access track at discrete points.

152. Cable trenches, particularly if backfilled with more permeable material than surrounding soil, can create preferential pathways for groundwater flow, resulting in local lowering of groundwater level.

153. Soil water conditions at the Site are likely to be primarily influenced by surface water and direct rainfall, with groundwater having minimal influence, and this influence decreasing at higher altitude.

154. It is possible that there would be local lowering of the water table close to track corridors, resulting in a localised corridor of altered vegetation and ecology. Turbine foundations and borrow pit excavations would permanently alter groundwater flows at the coincident locations, however it would be expected that natural conditions of groundwater level and flow would recur close to these locations. In contrast, forestry felling could result in a rise in groundwater levels in the short term until restocked trees are established.

155. The adoption of the applicable good practice measures as summarised in the Outline CEMP would reduce potential for lowering effects upon groundwater systems, with the effects of dewatering likely to be local and temporary, with groundwater expected to return to former levels quickly following cessation of construction activities. The key concerns for good groundwater management involve careful decisions involving locations of drainage and dewatering activity and ensuring such activities are undertaken sympathetically and minimised in terms of extent and time to avoid excessive influence on groundwater levels and flows. Key measures identified to minimise alterations to groundwater levels and flows include:

- drainage systems, typically consisting of french drains (using a gravel layer as water conduit, rather than pipework, running downhill to a soakaway zone designed to enable water to percolate back into soil), would be installed at hardstanding locations where applicable;
- dewatering activity would be limited to the minimum necessary duration; and
- tracks crossing GWDTE would have appropriate drainage measures applied to maintain current groundwater conditions.

156. Taking into account the design and embedded mitigation, the effect is assessed as follows:

- the magnitude of effect on groundwater levels and flows is considered Minor and of Medium probability to occur, giving an overall significance of **Minor**;
- the magnitude of effect of alterations to groundwater levels and flows on PWS is considered Moderate and of Medium probability to occur, giving an overall significance of **Minor**; and
- the magnitude of effect on GWDTE is considered Minor and of Medium probability to occur, giving an overall significance of **Negligible**.

6.6.3.6 Loss and Compaction of Soils and Peat

157. In its regulatory position statement, SEPA (2010) states that "developments on peat should seek to minimise peat excavation and disturbance to prevent the unnecessary production of waste soils and peat". The key items of infrastructure which influence this effect are the dimensions, location and type of new access tracks, turbine base foundations and crane hardstandings. Other features which would also be considered for excavation requirements include borrow pits, substation and temporary construction compound facilities.

158. Modifications made during the layout design process has led to an avoidance of areas where deeper peat has been identified, the volume of excavated material for site infrastructure results in 58,300m^3 of material requiring to be excavated. **Appendix 6.2 Soil and Peat Management Plan** evaluates the likely volumes of soil and peat excavated during construction and opportunities for reuse of this material. It also identifies measures for the management of peat throughout the construction process. It is recognised that the initial priority is to reduce the volume of peat excavated, followed by appropriate reuse of any peat and soil excavated, as per the principle of the 'waste hierarchy'. The extensive dataset of peat depth data collected for the peat stability study has been used to inform this assessment.

159. With peat excavation and reuse opportunities refined, based on pragmatic good practice measures, the revised reuse potential exceeds the estimated excavated volume by 1,500m^3, demonstrating that it is reasonably practicable to anticipate the reuse of all excavated material onsite (**Appendix 6.2 Soil and Peat Management Plan**). No material is planned to be transported into the Site for restoration purposes.

160. Locally excavated peaty podzols, peaty gleys, brown forest soils and alluvial soils could be used to aid habitat management and landscaping of the Site, in particular those areas where coniferous forestry would be removed. This potential re-use option has not been quantified within the assessment but it is considered in **Appendix 7.7 Outline Habitat Management Plan**.

161. Compaction may also damage the vegetation and result in a reduction in soil permeability and rainfall infiltration, particularly on peat, thereby increasing the potential for longer-term erosion from surface water runoff. This would be most likely caused by tracking of heavy plant machinery.

162. Stockpiled and unvegetated/exposed areas of soils are also at risk of desiccation and wind and water erosion, also potentially causing soil loss.

163. The design principles and adoption of the applicable good practice measures summarised in **Appendix 4.1 Outline CEMP** would reduce the soil losses and compaction of soil effects, with the combination of planning infrastructure on very shallow soils, minimising excavation, promoting local reuse of suitable material, identifying catotelmic/amorphous peat in-situ and the majority of vehicle movements being restricted to existing or new site tracks or clearly demarcated construction areas. This combination of measures resulting in any notable effect being very localised and temporary in nature. Site monitoring would identify any areas where soil effects are noted and enable a fast response to minimise effect. Key measures identified to minimise loss and compaction of soils and peat include:

- limiting movements to specific corridors avoiding sensitive receptors such as deep peat;
- reducing excavation depth for site infrastructure by careful placement; and
- limiting storage and restoration of soil and peat to a maximum height of 2m;

164. Taking into account the design and embedded mitigation, the effect on loss and compaction of soils is assessed as follows:

- the magnitude of effect of soil loss is considered Minor and of High probability to occur, giving an overall significance of **Minor**; and
- the magnitude of effect of compaction of soil is considered Minor and of Medium probability to occur, giving an overall significance of **Minor**.

6.6.3.7 Peat Stability

165. Peat slides are a natural occurrence that can occur without human interference, but issues such as removal of slope support or increased loading upon slopes can either increase the likelihood of an event occurring or can increase the scale of any failure that does occur.

166. Peat slides affect soil (and associated habitats) and potentially downstream surface water systems where soil inundation can lead to sedimentation reducing water quality and modification to drainage patterns. The various receptors of a peat stability failure have been separated for this evaluation.

167. The Proposed Development area is underlain by peat of varying depths and shallower peaty soil, with an average depth across the Study Area of 0.48m. **Appendix 6.1 Peat Stability Assessment** has highlighted two localised areas of stability concern (initial Moderate risk) in relation to the infrastructure proposed, with the methodology, data, location maps and interpretation of individual locations provided within this report. Areas identified as of higher likelihood for instability based on the factor of safety approach, were primarily related to locations at or below convex breaks of slope and where isolated deeper peat deposits were recorded, with such locations then considered in relation to potential receptors to evaluate initial risk. The methods involved in this initial risk assessment are purposefully cautious, in order to highlight areas of concern, with the expectation that additional data collated as part of the revised risk assessment and pre-construction investigations would reduce concern.

168. The peat instability process identified occurrences of other slope instability within the Site, with these locations typically within or above incised stream valleys, such as the Glenkiln Burn, where fluvial erosion is considered the causal factor of such peaty debris slides. Although this instability is not caused by peat conditions, it has been recommended that these locations are also included in the Geotechnical Risk Register.

169. The inherent design principles and adoption of the applicable good practice measures summarised in the Outline CEMP would reduce the effect of peat instability. Key measures identified to minimise peat stability risk include:

- avoidance of removal of slope support;
- avoidance of heavy loading on slopes;
- forestry clearance activities to follow good practice and take account of slope stability;
- good drainage practice to ensure flows not concentrated onto slopes or into excavations;

- restricting earthmoving activities during and immediately after intense and prolonged rainfall events; and
- creating and managing of geotechnical risk register or similar management system throughout the detailed design and construction phases.

170. Taking into account the design and embedded mitigation, the effect on peat stability is assessed as follows (with peat stability risk value considered broadly equivalent to probability in EIA Report):

- the magnitude of effect of a peat stability failure on soil loss is considered Minor and of Medium probability to occur, giving an overall significance of **Minor**;
- the magnitude of effect of a peat stability failure on surface water sedimentation is considered Moderate and of Medium probability to occur, giving an overall significance of **Moderate**; and
- the magnitude of effect of a peat stability failure on surface water drainage patterns is considered to be Minor and of Medium probability to occur, giving an overall significance of **Minor**.

171. As there is a significant effect identified, appropriate mitigation measures have been provided in the Mitigation section.

6.6.4 Operation

172. Many of the effects identified during construction would not be expected to lead to significant effects during the operational phase. Furthermore, good practice design and construction management would be anticipated to reduce potential operational adverse effects.

173. This section sets out the likely operational effects of the Proposed Development.

6.6.4.1 Modification of Groundwater Levels and Flows

174. Groundwater levels may be influenced by the drainage features of the Proposed Development and may also be influenced by local alterations in groundwater regime, such as where foundations or track construction leads to changes in level or flow. Such issues are more likely to become apparent in the operation phase than during construction, where corridors of altered vegetation may occur adjacent to tracks and other locations where the natural regime has changed.

175. However, the adoption of the applicable good practice measures would incorporate a sustainable drainage strategy that minimises disturbance of natural groundwater systems to reduce adverse effect on groundwater levels and flows. Good practice sustainable drainage measures would minimise any effect upon GWDTE.

- Taking into account the design and embedded mitigation, the effect is assessed as follows: the magnitude of effect on groundwater levels and flows is considered Minor and of Medium probability to occur, giving an overall significance of **Minor**.

6.7 Mitigation

176. Mitigation is considered as additional measures beyond the design principles and good practice, the application of such measures are separately noted and residual effects evaluated.

177. The majority of effects have been assessed as Not Significant, with the exception of peat stability.

6.7.1 Peat Stability

178. Two locations were identified as at initial Moderate risk in **Appendix 6.1 Peat Stability Assessment**, which required further investigation, known as ‘Detailed Assessment’. Following a visit and interpretation of the additional site data, location-specific peat stability measures were identified, including:

- additional site investigation pre-construction, including post-felling surveys, with any additional areas of concern identified and assessed (and specific mitigation implemented, as applicable);
- slope management measures for particular slopes; and
- specific drainage designs including routes, scour prevention and discharge locations to be implemented to reduce potential adverse effect on slope stability during construction.

179. On the basis of the additional information and application of the identified mitigation, both of these locations were re-evaluated as at revised Low risk in **Appendix 6.1 Peat Stability Assessment**.

6.8 Residual Effects

180. As specific mitigation is only proposed for peat stability effects, all other construction phase effects would remain as per the above section.

181. Following the application of mitigation measures that have been identified for peat stability failures, primarily in relation to surface water sedimentation but which also influence the assessment of other potential peat stability effects, as detailed in **Appendix 6.1 Peat Stability Assessment**:

- the magnitude of effect of a peat stability failure on soil loss is considered to remain Minor but reduced to a Low probability to occur, giving an overall significance of **Negligible**;
- the magnitude of effect of a peat stability failure on surface water sedimentation is considered to remain Moderate but reduced to a Low probability to occur, giving an overall significance of **Minor**; and
- the magnitude of effect of a peat stability failure on surface water drainage patterns is considered to remain Minor but reduced to a Low probability to occur, giving an overall significance of **Minor**.

Description of Effect	Pre-mitigation Effect		Mitigation Measure	Residual Effect	
	Magnitude	Significance		Magnitude	Significance
During Construction					
Pollution of surface waters	Moderate	Minor Adverse	N/A	Moderate	Minor Adverse
Pollution of groundwater	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Pollution of groundwater PWS	Minor	Negligible	N/A	Minor	Negligible
Pollution effect on soil	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Erosion causing loss of soil	Minor	Minor Adverse	N/A	Minor	Minor Adverse

Description of Effect	Pre-mitigation Effect		Mitigation Measure	Residual Effect	
	Magnitude	Significance		Magnitude	Significance
Sedimentation of surface water	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Sedimentation of groundwater PWS	Minor	Negligible	N/A	Minor	Negligible
Surface water drainage patterns	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Modification of groundwater levels and flows	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Modification of groundwater levels and flows on PWS	Moderate	Minor Adverse	N/A	Moderate	Minor Adverse
Modification of groundwater levels and flows on groundwater and GWDTE	Minor	Negligible	N/A	Minor	Negligible
Loss of soil	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Compaction of soil	Minor	Minor Adverse	N/A	Minor	Minor Adverse
Peat stability failure on soil loss	Minor	Minor Adverse	Additional site investigation, including post-felling Slope management Specific drainage design	Minor	Negligible
Peat stability failure causing surface water sedimentation	Moderate	Moderate Adverse	Additional site investigation, including post-felling Slope management Specific drainage design	Moderate	Minor Adverse
Peat stability failure modifying surface water drainage patterns	Moderate	Moderate Adverse	Additional site investigation, including post-felling assessment Slope management Specific drainage design	Minor	Minor Adverse
During Operation					
Modification of Groundwater Levels and Flows	Minor	Minor Adverse	N/A	Minor	Minor Adverse

Table 6.13. Summary of Significant and Residual Effects.

6.9 Cumulative Assessment

182. Cumulative effects are additional effects as a result of the Proposed Development in combination with other developments currently at the planning, consented, or construction stages.

183. Soil and geology cumulative effects are considered to be limited to the Site; however, surface water and groundwater pathways have the potential to cause or exacerbate a wider cumulative effect.

184. Other windfarms, e.g. Whitelaw Brae, Little Hart Fell, Crookedstane, etc. were identified and have been considered for the assessment of cumulative effects. Within these catchments there may be development activities further afield and in alternative sectors, such as forestry and agriculture, all of which have the potential to cause similar effects to the Proposed Development, particularly in relation to surface water quality and surface water flow patterns.

185. As the Proposed Development sits within headwaters of a number of watercourses, there would not be expected to be any cumulative effect from upstream development. However, runoff from the Proposed Development in combination with other developments could contribute to effects on overall water quality and flow within the channels. There is the potential for flow levels or sediment to be elevated downstream due to cumulative construction activities, particularly if there were coincident construction phases. However, effective 'source' controls would limit each individual development's effects on respective catchments, and it would be anticipated that other sites or activities involving groundworks would follow a similar good practice methodology to that for this proposed development. Furthermore, the differing construction programming and activities that would be anticipated to occur across various developments reduces the probability that water quality and flow issues would be coincident across a number of intra-catchment sites in a manner that would lead to a notable cumulative effect downstream, particularly when taking account of the higher flow/dilution available within the downstream channels.

186. Taking account of the above factors cumulative effects during construction on pollution of surface water and groundwater, sedimentation of surface water and modifications to surface water drainage patterns are not considered likely to be significant. This is outcome has resulted on the basis of large intervening distances, substantial dilution factor, effective 'source' controls and differing construction programmes at various sites to manage water quality and drainage patterns.

6.10 Summary

187. The effects detailed in **Table 6.13** are with reference to the criteria identified in **Tables 6.2**, **6.3** and **6.4** and the mitigation measures from the applicable sections of text above. Following the implementation of good practice measures and specific mitigation measures outlined, no significant effects are predicted for the hydrology, hydrogeology, geology and soils receptors.

6.11 References

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