12. Geology, Hydrogeology and Hydrology

Introduction

12.1 This chapter presents the findings of the assessment of the potential geological, hydrogeological and hydrological effects of the proposed wind farm.

12.2 The assessment provides baseline information, identifies potential effects, assesses the significance of the potential effects, identifies mitigation measures where required, and assesses the residual effects of the proposed wind farm.

12.3 The majority of potential effects are considered likely to arise from construction activities, including the proposed felling operations, therefore reference should be made to **Chapter 5: Construction and Decommissioning** and **Chapter 6: Forestry**. Hydrological effects may also result in secondary effects on ecology, therefore reference should also be made to **Chapter 9: Ecology**.

12.4 Effects on peat are considered in relation to hydrology. A summary assessment of peat in relation to peat slide risk is also highlighted. Further information on peat stability is considered in **Appendix 12.1: Peat Landslide Hazard Risk Assessment (PLHRA)**.

Legislation and Policy Context

12.5 There is a range of environmental legislation that any development must be guided by throughout the development life cycle. Key legislative and planning policy drivers relating to the water environment which have been considered within this assessment are listed below:

International Legislation and Policy

12.6 Key international legislation includes:

- EC Fisheries Directive[1] (78/659/EEC);
- EC Water Framework Directive[2](2000/60/EC); and
- EC Assessment and Management of Flood Risk Directive[3](2007/60/EC).

National Legislation and Policy

12.7 Key national legislation relating to the water environment includes:

- Scottish Planning Policy (SPP); Flooding and Drainage4;
- PAN 61 – Planning and Sustainable Urban Drainage Systems
- The Water Environment and Water Services (Scotland) Act 2003 (WEWS)
- The Water Environment (Controlled Activities (Scotland) Regulations 2005 (which replaces the Groundwater Regulations 1998 and the Control of Pollution Act 1974(COPA))
- Environmental Impact Assessment (Water Management) (Scotland) Regulations 2003
- The Flood Risk Management (Scotland) Act 2009

[1] European Commission (1978) Fisheries Directive (78/659/EEC)

[2] European Commission (2000) Water Framework Directive (2000/60/EC)

[3] European Commission (2007) Floods Directive (2007/60/EC)

[4]Scottish Executive (2010), Scottish Planning Policy

Regional/Local Policy

12.8 The Dumfries and Galloway Council (DGC) Structure Plan and Annandale & Eskdale Local Plan contain a number of relevant environmental policies. These are detailed in **Chapter 2: Planning Policy Context.**

Effects Assessed in Full

12.9 This chapter assesses the following effects in full:

- pollution risk, including potential effects on surface water and groundwater quality and public and private water supplies;
- erosion and sedimentation which could give rise to potential effects on surface water and groundwater quality and public and private water supplies (such as culvert blocking, reduction in watercourse capacity and impacts upon salmon habitat);
- flood risk resulting from changes to runoff volumes and rates and modifications to natural and man-made drainage patterns;
- effects on groundwater levels and recharge;
- reductions in baseline flows arising from any temporary or permanent abstractions; and
- potential cumulative hydrological or hydrogeological effects.

12.10 In addition to the effects of the proposed wind farm upon hydrology and hydrogeology, a PLHRA report was prepared by Mott MacDonald Ltd to ascertain baseline ground conditions to investigate and assess potential peat instability at the proposed wind farm. The PLHRA report also evaluates the potential effects upon the peat stability during construction and operation of the wind farm. The findings of the PLHRA report are summarised in this chapter, the full report is included in **Appendix 12.1**.

Effects Scoped Out

12.11 On the basis of the desk-based study and survey work, the professional judgement of the EIA team, experience from other relevant projects and policy guidance, the following aspects have been 'scoped out' and only given brief treatment within the ES:

- potential effects on solid geology during the construction and operation of the proposed wind farm. This is due to the limited exposed solid geology on site and the lack of any geological designations either within the site or near it; and
- designated sites; as it has been identified that there are no sites within, or near the site, at risk of being affected. Table 12.1 highlights water-related designated areas within 3 km of the site.
- reductions in runoff volumes due to: the distance of private water supplies from site infrastructure; the nature of the development; and the small overall proportion of the catchment areas affected by development.

Table 12.1: Designated Sites within 3 km of the Proposed Wind farm

Designated Site	Approximate Distance	Reason for Designation
Bell's Flow SSSI	1 km to the south of the proposed access	Intermediate raised bog and peatland habitats
Bigholm Burn SSSI	2.4 km north-east	Geological SSSI
Ancient Woodland, Semi-Natural Woodland Inventory	Palling Wood (NY 313 782), the woodland adjacent to the Woodside Burn immediately north of Solwaybank Farm (NY 306 775), and the woodland immediately south of the unclassified road where access is gained to Woodside Farm (NY 316 777).	Woodland Type

12.12 The Bells Flow SSSI site contains habitat which is predominantly rainfall fed. Given this, and due to the separation distance, the SSSI is not in hydraulic connectivity with the site and will not be affected by the proposed wind farm. Given the underlying reason for Bigholm Burn SSSI designation i.e. geological, this designation will not be affected by the proposed wind farm.

12.13 Three areas of semi-natural ancient woodland (SNAW) occur immediately to the south of the site, 400-500 m to the south of the proposed access track. However, these will not be directly or indirectly affected by the proposed wind farm and therefore will not be considered further in this assessment.

Issues Identified during Consultation

12.14 A range of consultation has been undertaken for the site. A summary of the consultation responses is provided in Table 12.2 and includes consultation responses on the previous ES submitted in 2009, as well as recent information requests.

Table 12.2:Issues Identified during Consultation

Consultee	Scoping/Other Consultation	Issue Raised	Response/Action Taken
SEPA	ES 2009 Consultation	No objection in principal. Key issues included: The construction method statements should address pollution prevention issues and drainage. Foul drainage for the control building to be treated via a septic tank with soakaway. Any floating roads to be fit for purpose	Considered in the assessment and mitigation sections of this chapter.
DGC	Scoping Consultation	Concerns about location of proposed works in relation to the ground conditions, proximity to watercourses and overland drainage routes. Concerns about hydrological conditions being disrupted and resultant effects on migratory fish and juvenile salmonids. Concerns about general effects on migratory and resident species of salmonids and other species in catchment areas on site.	Layout takes account of these concerns, mitigation with regards to watercrossings discussed in more detail in the Wind Farm Layout Considerations section of this chapter. Generic hydrological impacts such as effects on water quantity and quality are considered in this chapter. Effects on ecological receptors are considered in **Chapter 9: Ecology**.
Scottish Natural Heritage (SNH)	Scoping Consultation	No statutory designations on site. Highlighted the Bells Flow – raised bog (SSSI) SE of site; and Bigholm Burn – blanket bog (SSSI) to NE of site. Specific attention should be given to the impacts on surface waters, especially tributaries flowing into River Sark, Kirtle Water and Wauchope Water.	Noted. This assessment considers that both designated areas are of sufficient distance from the site for any effects to be negligible. The effects on designated sites are therefore scoped out. These are considered as principal receptors in the assessment. The River Esk is used, as Wauchope Water flows into it.
Scottish Environment Protection Agency (SEPA)	Scoping Consultation	Main concerns about construction activities and the creation of access roads. Mud, silt and concrete run-off should be prevented where possible. Suitable treatment and disposal facilities should be constructed on site. If site has clay soils then settlement ponds with chemical treatment are recommended. Construction work should be planned to avoid periods of heavy rainfall. Water pollution due to extraction of rock from borrow pits should be avoided through drainage being directed towards water	These aspects are considered within the hydrology assessment. Appropriate best practice measures recommended for specific activities. See paragraph 12.118 onwards. Mitigation considers this aspect in more detail. Considered within the Construction Method Statement (CMS). Construction works would be planned to avoid periods of heavy rainfall where possible. This commitment would be included within the CMS. No borrow pits on site therefore no action required.

Consultee	Scoping/Other Consultation	Issue Raised	Response/Action Taken
		treatment plant on site.	
		Opposed to the culverting of watercourses as a matter of principle. Where road crossing of burns is required bridge crossings are preferred to culverts.	For small, typically inactive field drains, culverts may be used; natural channels will either use half moon culverts or bridges. See Table 12.7
		Felling operations to be carried out in accordance with the Forestry Commission Forests and Water Guidelines[5].	Forests and Water Guidelines consulted as part of this ES.
		All private water supplies should be identified.	Private water supplies identified through consultation with Local Authority, identified on Figure 12.1 and verified as a part of the site visit (2/8/2011).
Scottish Water	Scoping Consultation	Scottish Water assets under the road on the boundary of the development may be at risk.	Noted. Not considered as a hydrological receptor. This issue is considered in **Chapter 5: Construction and Decommissioning.**
DGC	September 2011	Information provided regarding private water supplies.	Information on private water supplies considered in assessment below.

Assessment Methodology

Baseline Characterisation

12.15 Baseline characterisation considers the current hydrological and hydrogeological characteristics of the site to inform the assessment of the effects of construction and operation of the proposed wind farm on the existing conditions.

12.16 The baseline characterisation has been developed through a combination of a desk-study of data sources and a site walkover.

Study Area

12.17 The study area encompasses catchments draining the site. The downstream extent of this study area is determined through expert judgement and is shown on Figure 12.2. The study area extends 5 km from the centre of the site to include areas downstream of the watercourses on site. Outwith this boundary it is considered that any impact from the proposed wind farm would not be detectable due to the number of tributaries that join the assessed receptors. The extent of the hydrological study area takes a precautionary approach to ensure that all potential effects are identified. The cumulative assessment considers potential effects from the proposed wind farm in combination with other proposed developments likely to effect the hydrological environment. At distances greater than 10 km it is considered that schemes are unlikely to contribute to cumulative hydrological effects.

12.18 The peat landslide risk assessment study area encompasses the area within the 'site boundary' as shown in Figure 1.2.

Data Sources and Guidance

12.19 The following data sources have been consulted as part of the preparation of this assessment:

- Ordnance Survey (OS) Mapping at scales 1:10 000, 1:25,000 and 1:50 000 scale;
- British Geological Survey (BGS) Groundwater Vulnerability Map of Scotland 1995 at 1:625,000 scale;
- British Geological Survey (BGS) Hydrogeological Map of Scotland 1998 at 1:625,000 scale;
- Institute of Geological Sciences (IGS) Ecclefechan Drift Map at 1:50,000 Scotland Sheet 10 (E);
- Envirocheck Report (2011) Geology Data Extract at 1:50,000 scale;
- SEPA online River Basin Management Plans (RBMP). (http://gis.sepa.org.uk/rbmp), Accessed 05/08/2011;
- SEPA information on known local abstractions (by email);
- SNH website on designations. (http://www.snh.org.uk/snhi/), Accessed 05/08/2011;
- DGC on Private Water Supplies (reference email/letter); and
- The Flood Estimation Handbook CD-ROM Version 3.

12.20 The following pollution prevention guidance has been consulted as part of the preparation of this assessment:

- Control of water pollution from constructions sites. Guidance for consultants and contractors C532 (CIRIA 2001);
- Environmental good practice on site C650 (CIRIA);
- Report 168: Culvert Design Guide (CIRIA); and
- Pollution Prevention Guidance (PPG)61, 2, 4, 5, 6, 8, 21 and 26 (SEPA).

12.21 Other relevant guidance includes:

- Forests and Water Guidelines (Forestry Commission, 2003);
- WAT-RM-02, SEPA Regulatory Position Statement-Regulation of Engineering Activities, Version 4, February 2011;
- WAT-PS-06-02, SEPA Regulatory Position Statement-Culverting of Watercourses, Version 1.2, December 2006;

[5]Forests and Water Guidelines (4th Edition).Forestry Commission 2003.http://www.forestry.gov.uk/pdf/FCGL002.pdf/$FILE/FCGL002.pdf

[6]PPG1 General guide to the prevention of pollution
PPG2 Above ground oil storage tanks
PPG4 Treatment and Disposal of sewage where no foul sewer is available
PPG5 Works or maintenance in or near water
PPG6 Working at Construction or demolition sites
PPG8 Safe Storage and disposal of used oils
PPG21 Pollution incident response planning
PPG26 Safe Storage-drums and intermediate bulk containers

- WAT-SG-25 SEPA Good Practice Guide: River Crossings, Second Edition (SEPA, 2010); and
- SG-31 Special Requirements for Civil Engineering Contracts for the Prevention of Pollution (SEPA, 2006).

Significance Criteria

12.22 The significance of effects of the proposed wind farm on existing baseline conditions are assessed using professional judgement through a combination of the magnitude of the potential effect and the sensitivity of the receptor to determine the significance of that effect.

12.23 Magnitude, sensitivity and significance criteria were developed for the conditions and environments prevailing at the site. Magnitude criteria are presented in Table 12.3.

Table 12.3: Effect Magnitude Criteria

Magnitude of Potential Effect	Definition
Major	Total loss of, or alteration to, key features of the baseline environment such that post development characteristics or quality would be fundamentally or irreversibly changed.
Moderate	Loss of, or alteration to, key features of the baseline resource such that post development characteristics or quality would be partially changed.
Minor	Small changes to the baseline resource which are detectable, but the underlying characteristics or quality of the baseline situation would be similar to pre-development conditions.
Negligible	A very slight change from the baseline conditions, which is barely distinguishable, and approximates to the 'no-change situation'.

12.24 Where appropriate, the probability, duration and proximity to proposed infrastructure of any effect will be discussed in relation to the magnitude.

12.25 Sensitivity criteria can be based on the degree of environmental response to any particular effect. This is frequently indicated by the classification of the receptor (e.g. a watercourse with a 'High' ecological status should be considered more sensitive to an effect than a watercourse with 'Poor' status). Only one of the definitions of a particular sensitivity classification needs to be met for a receptor to be included within that classification. The sensitivity criteria developed for this site are presented in Table 12.4.

Table 12.4: Sensitivity Criteria

Sensitivity of Environment	Definition
Not Sensitive	Environment is insensitive to impact showing no discernable change. Receptor lies outside the sphere of influence of the proposed wind farm.
Low	Environment responds in a minimal way to effect such that only minor change(s) are detectable. Water body is classified by SEPA as being Poor or Bad. Receptor is at low risk from flooding (less than 0.1% AEP). Receptor not used for water supplies (private or public). Soil type and associated land use not sensitive to change in hydrological regime (e.g. intensive grazing of sheep and cattle).
Moderate	Environment clearly responds to effect(s) in quantifiable and/or qualifiable manner. Water body is classified by SEPA as being Moderate. Receptor is at moderate risk from flooding (0.1% Annual Exceedance Probability (AEP) to 0.5% AEP) but does not act as an active floodplain or flood defence. Moderate classification of groundwater aquifer vulnerability. Soil type and associated land use is moderately sensitive (e.g. arable, commercial forestry).
High	Environment is subject to major change(s) due to effect. Water body is classified by SEPA as being High-Good status or is close to the boundary of a classification: Moderate to Good or Good to High. Nationally designated sites such as SSSIs, or non-designated sites meeting SSSI selection criteria, National Nature Reserves (NNRs), Marine Nature Reserves, Nature Conservation Review Grade 1 sites (Ratcliffe 1977) which may depend upon the hydrology of the site. Receptor is at risk from flooding above the 0.5% Annual Exceedance Probability (AEP) and/or water body acts as an active floodplain or flood defence. Receptor is used for public and/or private water supply (including Drinking Water Protected Areas)[7]. Groundwater vulnerability classified as high. Presence of a GWDTE as defined by SEPA Land Use Planning Guidance[8]. Soil type and associated land use is highly sensitive (e.g. an impermeable soil with artificial drainage present).

12.26 The combination of magnitude and sensitivity combine to provide a matrix categorisation of significance. These are presented in Table 12.5. If the receptor is insensitive then there will not be a significant effect irrespective of the magnitude; therefore this level of sensitivity is excluded from Table 12.5

Table 12.5: Effect Significance Criteria

Magnitude of Potential Effect	Sensitivity		
	High	Moderate	Low
Major	Major	Major	Moderate
Moderate	Moderate	Moderate	Minor
Minor	Moderate	Minor	Negligible
Negligible	Minor	Negligible	Negligible

12.27 Effects which are judged to be moderate or major are considered significant in relation to the EIA Regulations. Mitigation/management is proposed to reduce the level of significance to negligible or minor.

[7] The potential impact of the development on private water supplies is therefore assessed by designating a receptor as highly sensitive (based upon the presence, or possible presence, of a private water supply).

[8] SEPA (2011) Land Use Planning System; Guidance Note 4; Planning Guidance on Wind farm Developments

Limitations

12.28 The site visit was undertaken during a period of particularly wet weather (both preceding the visit and during it). The conditions observed during this visit may not be typical of those usually observed on site. The conditions experienced give a useful indication of high flow and erosion issues, but miss aspects such as low-flow conditions although this does not change the assessment of effects.

12.29 The desk-survey has made use of several different data sources (see paragraph 12.19). Every effort has been made to verify the data used in the original assessment however, it should be acknowledged that these data sources may contain errors or omissions which the team cannot identify.

Baseline Conditions

Current Baseline

Site Walkover

12.30 A site walkover to assess hydrological features was undertaken on 2 August 2011 by Jamie Ledingham and Calum Duke of Mott MacDonald Ltd, between the hours of 0930 and 1630. Weather on the day of the site visit was damp and humid, with showers of rain. Watercourses showed evidence of flows being higher than usual.

12.31 The site walkover confirmed that watercourses shown on the OS 1:10000 scale mapping existed on the ground, as well as identifying areas of shallow groundwater and bog. The site visit also assessed the watercourse conditions and underfoot conditions (such as soil moisture) for the indicative access track routes and turbine locations. A number of photographs were taken to record proposed water crossings, and to identify receptors and any other hydrological features of note.

12.32 Site walkover surveys and peat probing were undertaken between 13 and 15 April 2011 by Gail Muir and Sarah Hollier of Mott MacDonald Ltd. The findings of the surveys have been used to determine the baseline ground conditions of the proposed wind farm. The assessment comprises a Qualitative Risk Assessment (QRA) based approach to determine the baseline (pre-construction) level of risks of peat landslides occurring within the site.

Topography

12.33 The proposed wind farm site has a complex topography with smooth, rounded hills covered with plantation forestry, grass or heather, wooded river valleys and peatland.

12.34 The site comprises an upland area forming part of a deeply incised plateau sloping gently south-westwards towards the Solway Firth. The highest point is Gowdmuir Hill (247 m AOD) with a topographic low in the south-west and south-east corners of around 150 m AOD. The ground slopes vary from very gentle with broad almost level watersheds to steep slopes on the banks of rivers and streams.

Land Cover and Land Use

12.35 The land cover of the plateau is dominated by coarse acid grassland with areas of rushes in poorly drained, low lying areas. Land use consists of mainly mixed dairy and hill farming. More information on vegetation types and classes can be found in **Chapter 9: Ecology**.

12.36 Around 40% of the site is covered by plantation forestry. Some of this has been recently felled and replanted, mainly in the vicinity of Gowdmuir Sike.

Meteorological Summary

12.37 The site is subject to high annual average precipitation from rainfall and snowfall. Solwaybank has an unsettled cool climate, with an unevenly distributed annual rainfall and strong winds. According to the Flood Estimation Handbook, total annual average rainfall is some 1289 mm over the site[9].

12.38 On average, snow lies at the site for around 48 days per year[10].

Geology

12.39 The solid geology at the proposed wind farm is underlain by the Ballagan Formation (Sandstone, Siltstone and Dolomitic Limestone) to the north-north-west of the site, the Border Group (Sandstone, Siltstone and Mudstones) in the centre of the site and the Yoredale Group (Mudstone, Sandstone and Limestone) to south-east of the site, all known to be Carboniferous in Age. Bedrock is recorded to be at, or near, the surface within the area around Collin Hags and west of Leaheads Hill.

12.40 Several faults are located within the vicinity of the proposed wind farm; the Waterbeck Fault to the north; the Kirtleton Fault to the south-west and an unnamed fault to the north-east.

12.41 The superficial geology of the site comprises predominately boulder clay (grey clayey to red-brown sandy deposits containing cobbles of greywacke, sandstone and locally granite) belonging to the Gretna Till Formation. Pockets of clay silt, sand and gravels belonging to the Kerr Moraine Formation are located along the valley bottom of the Palling Burn, across the south-east of the site. Glacial meltwater deposits (sand, gravels and boulders) belonging to the Kilblane Sand and Gravel Formation are also indicated to be present in the south-east of the site near the settlement of Pingle.

Peat

12.42 Peat was found to be predominantly shallow or absent within most of the site. However, peat accumulations are present locally within the site, located to the south of Gowdmuir and south-west and south of Collin Hags and around Allfornought Hill.

12.43 Peat probing in areas of shallow depressions between low rounded hillsides indicated that peat depths range between 0.5 m to 2.6 m, varying in depth according to local topographic conditions. Refer to Figure 12.4: Peat Landslide Hazard Map.

12.44 The peat at the site appeared severely degraded by grazing and burning as well as forestry and agricultural drainage schemes. Natural erosion of the peat gives rise to minor disruption of the

[9] Centre for Ecology and Hydrology (2009) Flood Estimation Handbook Version 3.

[10] http://www.meoweather.com/history/United%20Kingdom/na/55.15/-3/Langholm.html (accessed August 2011)

ground surface in a few places and an old turbary[11] exists on the south facing slope of Leaheads Hill. Peat landslide risk is considered in more detail in Appendix 12.1: Peat Landslide Hazard Risk Assessment.

Hydrogeology

12.45 The hydrogeological map for Scotland[12] shows that the majority of the site is situated in a region underlain by bedrock of Lower Carboniferous Fell Sandstone rocks and Late Pleistocene (Devensian) Glacial Till (boulder clay). These contain highly productive aquifers in which flow is dominated by fissures and discontinuities. The lower reaches of the site contain small areas of locally important aquifers and contained aquifers of limited potential made up of coastal and river alluvium.

12.46 The site visit confirmed a number of springs and discharges within the forested area and feeding downslope flushes before consolidating at times into small burns and tributaries feeding into the main surface watercourse on site (Palling Burn – see Hydrology below).

12.47 SEPA recognises one groundwater body on site. This is the Liddlesdale bedrock and localised sand and gravel aquifers. This groundwater body has a 'good' quantitative and chemical status under the RBMP classification, suggesting that it is both relatively unpolluted and has a good abstraction/recharge ratio. The Liddlesdale aquifers are protected by two designations; as a Drinking Water Protection Zone and as a Nitrate Vulnerable Zone.

12.48 As the Liddlesdale aquifer is the only groundwater body present on site, it is considered a receptor when assessing any potential effects of the proposed wind farm. Due to its 'good' quantitative and chemical classification this water body must be considered as a high sensitivity environment using the definitions of Table 12.3.

Groundwater: Vulnerability to Pollution

12.49 The soil layers in the northern region of the site are characterised as being made up of mainly low risk and weakly permeable geology. This means that pollutants from point sources are highly unlikely to penetrate through to the groundwater.

12.50 These low risk, weakly permeable soil layers gradually give way to a highly permeable geology with soils of higher leaching permeability in the southern region of the site. These highly vulnerable soils are coarse textured or moderately shallow and readily transmit non-adsorbed potential pollutants and liquid discharges, however some soils have the ability to reduce the effect of pollutants in the soil because of their clay or organic matter contents.

12.51 In terms of risk to groundwater quality, the southern end of the site therefore carries a high risk of potential pollutants penetrating through to groundwater. The flow of water from soils in the lower areas of the site may also contribute to groundwater recharge elsewhere within the catchment.

Private Water Supplies

12.52 All private water supplies in the vicinity of the site rely on sources originating from springs and wells, rather than surface water.

12.53 The Environmental Health Department of DGC provided details of households with private water supplies within 5 km of the site (letter dated 6 September 2011). These are detailed in Table 12.6 and are shown by location on Figure 12.1. Some private water supplies have been identified beyond 5 km of the site, however, they are either upstream, in a separate catchment or too far away forthe proposed wind farm to provide any potential risk to these supplies therefore these have not been included within the information presented below.

Table 12.6: Private Water Supplies within 5 km of the site

Figure 12.1 Reference Number	Location	Grid Reference	Distance from Site Boundary (approx. km)
1	Megsfield, Waterbeck,	NY 276809	1
2	Hotts, Waterbeck,	NY 261785	2
3	Cleuchfoot, 1 & 2 Cleuchfoot Cottages, Langholm	NY 314828	2.5
4	Westwater Farm, Langholm	NY 303826	1.5
5	Collins, Langholm,	NY 304815	1.5
6	Bloch, Langholm,	NY 328812	2.5
7	Solway Bank Cottage	NY 302778	0.2
8	Callisterhall, Waterbeck,	NY 289816	0.1
9	Bigholms	NY 311 581	2
10	Kirkleton Farm Cottage	NY 266 580	1
11	Westwater Cottage	NY 306 582	1.5

12.54 The above supplies in Table 12.6 are all located within the hydrological study area defined above, i.e. the three catchments which drain the site. However, only Solway Bank Cottage, Kirtleton Farm Cottage, Collins, Callisterhall and Bigholms supplies are sourced from water potentially originating from the site (see Figure 12.1). None of these supplies are sourced directly from watercourses (sources are springs or boreholes).

Hydrology

12.55 The site consists of a ridge that runs roughly from the north-west to the south-east and represents the divide between the Kirtle Water and the River Sark catchments. Surface water from the western side of the site flows westward towards the catchment of the Kirtle Water, whilst surface water from the eastern side of the site flows to the south-east towards the River Sark and River Esk.

12.56 The site contains the headwaters of a number of burns and sikes (e.g. Collin Burn, Palling Burn, Pokeskine Sike, Hallsike Burn, Woodside Burn and Gowdmuir Sike) which drain down towards the Kirtle water, River Sark and River Esk (through Collin Burn). The 'Palling Burn', a tributary of the River Sark runs through the centre of the site (see Figure 12.1 for location and Figure 12.3 for photograph).

12.57 In total, the site drains into three separate catchments; the Kirtle Water, River Sark and River Esk.

[11] A Turbary is an area of peatland from which fuel in the form of peat or turf is sourced.

[12] British Geological Survey (BGS) 1988, Hydrogeological Map of Scotland, 1:625,000.

12.58 The River Sark has a 'Moderate' status under SEPA's RBMP classification. This is due to diffuse pollution from agricultural activities. Despite this, the River Sark is classified as a salmonid watercourse by SEPA. Areas of elevated flood risk have been noted downstream (D&G Council Information). The River Sark can be considered a high sensitivity receptor as any salmon habitat may be highly sensitive to material such as fine sediment.

12.59 The Kirtle Water is classified as a salmonid watercourse by SEPA and is classified as a sensitive area under the Urban Waste Water Treatment Directive (UWWTD). This UWWTD classification is given to waterbodies that are sensitive to eutrophication. Given these designations, the Kirtle Water is considered a high sensitivity receptor, primarily due to it supporting salmonid habitat.

12.60 A small portion of the site is drained by Collin Burn, which flows north-east into the River Esk. The burn is unclassified by SEPA, but due to downstream RBMP designations it can be considered of 'good' status. Collin Burn drains an area in the northern portion of the site and is identified on Figure 12.1. The River Esk is used as a receptor in order to assess effects; this implicitly includes the Collin Burn as a tributary. The approximate catchment of the River Esk is shown on Figure 12.1.

12.61 Plantation forestry areas contain artificial drains and most of these were observed to be inactive during the site visit (see Figure 12.2 for an example). Newly excavated drains were present in replanted areas adjacent to Gowdmuir Sike and contained flowing water (see Figure 12.3). These replanted areas are thought to contribute to the high sediment loads observed in Gowdmuir Sike during the field visit (See Figure 12.3).

12.62 The plateau area and moorland north-west of Pingle Farm contain artificial drains running parallel to the slopes. These are likely to have been constructed to improve the land for agricultural purposes.

12.63 For the purposes of assessing the effect of the proposed wind farm on surface hydrology, the River Sark, Kirtle Water and River Esk watercourses are considered the principal receptors as they cover the entire site. Whilst other smaller streams are found on site, they are tributaries of the River Sark, River Esk and Kirtle Water and so are implicitly considered in the assessment. Due to their 'Moderate' RBMP classification, both watercourses can be considered of medium sensitivity under the classification given in Table 12.4.

Surface Water Abstractions

12.64 All private water supplies in the vicinity of the site rely on spring or borehole sources, rather than surface water (see Groundwater Abstractions in paragraph 12.47). However, as several supply users are within the vicinity of natural watercourses, as a precautionary approach, it is assumed that there is a direct connection, and therefore these watercourse receptors are considered highly sensitive as a result.

Surface Water Discharges

12.65 A list of six discharge consents within 5 km of the site was obtained from the Environmental Health Officer for Dumfries. These are predominantly for sheep dip and local septic tanks, and are all located downslope and off-site.

Flooding

12.66 D&G Council was consulted regarding flood risk of the Solwaybank area. The closest area to the site with elevated flood risk was within the lower reaches of the River Sark, about 16 km south of the site.

12.67 The SEPA indicative flood map was also examined regarding flood risk. This showed a minor extent of flooding from the 0.5% AEP flood event on the riparian areas of the River Sark downstream of the site. A minor extent for the same AEP is also present on the riparian areas of Kirtle Water, again, outside of the site. No modelled flood extent is present within the site boundary.

12.68 Given the above, the site would not be categorised as sensitive to flood risk. However, as the River Sark, River Esk and Kirtle Watershow some sensitivity to flooding, the effect of the wind farm on flood risk must be assessed.

Future Baseline ('Do-nothing Scenario)

12.69 In the absence of the proposed wind farm, it is likely that the hydrology of the site would vary on a year to year basis. The driver behind this is the natural variability of the earth's climate, which has consequential effects upon hydrology. However, over longer time-scales, subtle shifts in climate (i.e. climate change) and land-use have the potential to permanently alter hydrological regimes. It is important to understand that information on future changes to hydrology is not site-specific, and is generalised from current research findings.

12.70 Analysis of existing rainfall data suggests a seasonal change in rainfall distribution. Since 1961, there are clear upward trends in both winter rainfall and annual average rainfall. Summer rainfall for the same period shows no significant change. Analysis over a longer time period (since 1914) does not show such a strong trend, emphasising the importance of understanding natural variability.

12.71 Climate change effects upon hydrology are difficult to determine as the link between climate and river flow varies across Scotland due to the varying physical characteristics across the country. There is no clear trend in either peak flows or low flows across Scotland from observed flow data over longer time scales (1970-1996). However, within this period there are increases and decreases in both peak flows and low flows. This emphasises the importance of understanding natural variability as well as climate change[13].

12.72 Existing trends can be helpful to interpret current and historical changes. However, there is increasing evidence that it is not appropriate to assume these trends will continue at the same rate in the future. Current climate model predictions suggest a wide range of future changes to climate. There may be little change in annual rainfall; however, most climate models suggest a significant seasonal alteration of rainfall, with wetter winters and drier summers. These predictions apply to both surface hydrology and hydrogeology[14].

12.73 Changes in land-use may also affect the hydrological regime. In the absence of the wind farm, changes in forest cover have the potential to affect the site hydrology. The change in forestry cover is unlikely to have a potential significant effect upon hydrology on decadal timescales,

[13] Foundation For Water Research (2000). Hydroclimatic Variations in Scotland and Northern Ireland. Report No. SR97 (08) D

[14] Barnett, C., Hossell, J. Perry, M., Procter, C., and Hughes, G. (2006) A handbook of climate trends across Scotland; Presenting changes in the climate across Scotland over the last century. Scotland and Northern Ireland Forum for Environmental Research.

although short-term effects may arise post-felling. Short term effects upon water quality may also arise from activities such as felling[15].

Wind Farm Layout Considerations

Setback distances

12.74 The most effective way of avoiding adverse effects is the careful location of turbines and tracks through the use of a minimum buffer distance from water features. A set-back distance of 50 m from watercourses is routinely recommended as a preliminary best practice measure for wind farm sites, as it is in excess of the standard SEPA recommendations for buffer distances and the Forests and Water Guidelines, published by the Forestry Commission (2003). These Guidelines state that in terms of buffer strips for 'adequate protection for the aquatic zone, a width of 20 m on either side will generally suffice for larger watercourses with a channel more than 2 m wide'. Recommended buffer distances for headwater streams and smaller watercourses are less, and between 5 - 10 m. For the proposed wind farm, a 70 m buffer from watercourses has been applied as a minimum, however, in some cases, a greater distance has been applied to minimise potential effects on bats (see **Chapter 9: Ecology** for more detail**)**. The setback distance recommended also provides precautionary protection for private water supplies. While there are no known supplies within the site boundary, the 50 m buffer will provide a mechanism to reduce any potential for sediment and/or pollutants to enter a watercourse and therefore travel downstream.

Track Design

12.75 Tracks which are orientated near 90^{o} to the slope contours may act to create rapid surface flows, resulting in erosion of the tracks and providing a direct pathway for discharge to watercourses. The track leading from Turbine 1 to Turbine 2, from Turbine 3 to Turbine 4 and the track from running north-west from Pingle farm in the layout of the proposed wind farm require carefulconsideration as part of the detailed design stage to ensure that water flow and sedimentation are minimised through either orientation (e.g. serpentine design) or through cut off drains, use of spoon drains or water bars for example.

12.76 The track layout has avoided all areas of deep peat on steep slopes. The PLHRA report included in Appendix 12.1 indicates that the tracks are to be constructed in areas where risks from peat landslides have been assessed to be Very Low, Low or Negligible.

Water Crossing Design

12.77 As a basic layout consideration, the number of watercrossings has been kept to a minimum. The revised layout takes advantage of existing tracks on site. New track (including the access track from Pingle farm) has a layout that minimises crossings of natural drainage channels. In particular, the revised layout removes the need for a crossing across the main channel of the Palling Burn.

12.78 Photographs of proposed water crossings can be found in **Appendix 12.2: Watercourse Crossings**. Proposed watercourse crossings are also highlighted in Table 12.7 and Figure 12.1.

12.79 To determine the most appropriate water crossing, the basic design criteria as defined in by the Scottish Executive River Crossings and Migratory Fish: Design Guidance (2000) will be applied, to ensure the following:

- there will be no hanging culverts;
- pipe culverts and box culverts will not be used to cross any watercourses known to contain salmon spawning grounds upstream due to potential for causing a barrier to migration (as set out in the Design Guidance16);
- where possible, all works associated with crossings will be performed from the riverbank;
- due to the small size of the new crossings (<1 m wide and <1 m deep), half-moon culverting is normally considered appropriate. This is based on guidance that pipe culverts will not be used where the design flow in the watercourse exceeds 8 m3/s (for a 0.5% annual probability flood event), and a box culvert not used where this flow exceeds 15 m3/s. However, due to the need to consider weight-bearing capacity, alternative designs may be required; and
- all designs will ensure that the effect on flood risk and the ecological status of the watercourse is minimal.

12.80 The above guidance also requires that all watercourses where normal flow is 5 m^3/s and over will be bridged. However, as none of the watercourses on site were observed to contain flow exceeding 5 m^3/s (during a wet period), it is not anticipated that any bridges will be used as part of the final infrastructure design.

12.81 Detailed watercourse crossing design will be specified within the appropriate section of the CMS and will require authorisation by SEPA under the Controlled Activities Regulations.

Table 12.7: Water Crossing Descriptions

Map Reference Number	Description	Type	Location
1	Upgraded crossing on track near northern site entrance	Upgraded half moon culvert	NY 286 814
2	Upgraded crossing on track near northern site entrance	Upgraded half moon culvert	NY 286 815
3	Upgraded crossing on track near northern site entrance	Upgraded half moon culvert	NY 288 815
4	Upgraded crossing over Gowdmuir Sike.	Upgraded half moon culvert	NY 285804
5	New crossing over Hallsike Burn.	Half moon culvert	NY 285 796
6	New crossing over field drain between Turbine 12 and Turbine 13.	Culvert	NY 289 792
7	Palling Burn Tributary. New crossing over Palling Burn Tributary	Half moon culvert	NY 299795
8	Crossing north-west of Pingle Farm	Culvert	NY 317785

12.82 There are a significant number of field drains within the site. It is not anticipated that these drains or ditches will require crossings and several will be blocked as part of the Habitat Management Plan (HMP) (see **Chapter 9: Ecology).** Detailed drainage proposals will be developed as part of the CMS.

[15] Forestry Commission (2003) Forest and Water Guidelines, 4th Edition.

[16] SEPA (2010) WAT-SG-25 SEPA Good Practice Guide: River Crossings, Second Edition

Peat Slide Risk

12.83 A Peat Landslide Hazard Risk Assessment (PLHRA) report has been carried out for the proposed wind farm and assesses the conditions of the peat with respect to peat stability for baseline (pre-construction), during construction and post construction. The findings of the PLHRA report concluded that baseline risks from peat instability are predominantly Low and Very Low to Negligible risk. The full PLHRA report is included as **Appendix 12.1**.

Potential Effects

12.84 Potential effects are considered with regard to the sensitivity of the receiving environment to the nature and extent of the proposed wind farm activities, which are described in **Chapter 4: Development Description**. Reference is also made to the duration of any potential effect.

Potential Construction Effects

Erosion/Sedimentation

12.85 One general potential effect of forest felling, construction (excavation), dewatering of turbine foundations, and passive road drainage, is disturbance to soils and a consequent rise in the sediment loads observed in rivers and streams. Potential effects may occur from the following:

- Forest felling will be required to allow for the construction of the proposed wind farm (refer to **Chapter 6: Forestry**). This involves the use of heavy machinery, often running across felled areas. This can make certain areas of soil susceptible to erosion, through the loss of canopy cover and the degradation of the soil surface layer.
- The initial stages of construction operations will involve stripping of surface vegetation to expose underlying soils or bedrock which will increase runoff and the potential for transportation of sediment;
- The construction of new tracks. Any operations involving stream crossings would also increase the potential for increased runoff of silt and debris. The crossings between Turbine 15 and Turbine 11 (Hallsike Burn) and Turbine 3 and Turbine 4 (Tributary of Palling Burn) have been identified as being at risk as these are natural channels connected to highly sensitive receptors.
- Dewatering of shallow groundwater and direct rainfall into excavations (potentially containing silt and other debris) may result in transportation of fine sediments from glacial till into watercourses, unless correctly managed. This is compounded by increased movement of construction vehicles over and around these disturbed environments.
- Peat is considered to have a low potential for sediment transport, although it is highly vulnerable to erosion.
- Silt laden runoff could be generated from stockpiled material excavated from foundation bases;
- Potential effects associated with extreme rainfall events include the overflowing of existing on-site drainage and resulting erosion and sediment transport, as well as the potential failure of pollution prevention measures to operate under high runoff flow conditions.
- Trenches dug for cabling may develop into preferential flow pathways where erosion can take place. They may also act as a rapid conduit for the transport of sediment.

12.86 Sediment entering watercourses may have effects on water quality, which could potentially affect ecological receptors as well as private water supplies. Effects on watercourses as hydrological receptors are considered in this chapter. Potential effects on ecological receptors are considered in **Chapter 9: Ecology**.

12.87 Deposited sediment may reduce channel conveyance and/or block structures such as culverts leading to localised flooding. Sediment may also potentially block private water supply intakes and could lead to temporary deterioration in drinking water quality.

12.88 The probability of an erosion or sedimentation event cannot be estimated quantitatively with any accuracy. Similarly, the duration of a sediment or erosion event is dependent upon a number of factors, from the type of sediment source to the characteristics of the agent causing erosion (for example the length of a storm).

12.89 Based on previous studies and professional judgement, the magnitude of a sedimentation or erosion event is considered to be moderate as it is only likely to have a short-term effect on hydrology.

12.90 Groundwater bodies are generally not at risk from an erosion or sedimentation event as surface lithography prevents the transport of sediment into aquifers (in this case of the mapped hydrogeology on site).

12.91 The principal receptors for an erosion or sedimentation event are the Kirtle Water, River Sark and River Esk and associated private water supplies (Callisterhall, Collins, Bigholms, Solway Bank cottage and Kirtleton Farm cottage although these are all outside the site boundary). All are considered highly sensitive receptors and therefore, using the significance matrix provided in Table 12.5, the significance of an erosion or sedimentation event is moderate and mitigation will be required.

Pollution

12.92 This section assesses the potential effects of a pollution event on watercourses and groundwater. Pollution events that may result from the proposed wind farm include:

- Fuel and oil spillages. Tracks, compounds and parking areas where vehicles are re-fuelled or are on stand-by, and areas of chemical/fuel storage, are potential sites of contamination. Pollution of watercourses could potentially occur through corrosion of containers, and subsequent contamination through leakage and/or leaching of chemicals such as fuels, lubricants and solvents
- Spillage of concrete from workings. Concrete is highly alkaline and has the potential to affect the pH balance of a receptor. Concrete will not be mixed on site therefore the risk from a release of concrete into the environment relates to cement escaping from workings before it has set.
- Pollution of groundwater and surface water can also arise due to the improper management of rubbish, sanitary plumbing and other water storage in the construction compound.
- Existing drainage may act as a conduit for runoff during periods of extreme rainfall. This has consequential effects on pollutant transport, sediment transport and runoff. The existing drainage structure from forestry activities is complex, and specific assessment is difficult. Paragraph12.133 onwards states specific mitigation which can be implemented to deal with drainage on site and to mitigate against a runoff event.

12.93 Four principal hydrological receptors have been identified, and based on the sensitivity criteria in Table 12.4 are highly sensitive to any change (River Sark, Kirtle Water, River Esk and Liddlesdale Bedrock).

12.94 The magnitude of a pollution event is dependent upon the duration and probability. The duration of a pollution event is specific to the receptor. Pollutants can remain in groundwater bodies for many years, whereas they may flush out of watercourses in a matter of days. However, the effect upon a watercourse may be much greater due to the rapid nature of pollutant dispersal. As a pollution event may result in a temporary deterioration of a receptor, the magnitude of a pollution event is considered moderate.

12.95 Similarly, pollution may potentially render water undrinkable. While no direct on-site abstractions from surface water have been identified, the precautionary approach assumes a connection between a watercourse and adjacent supply user. To this end the magnitude of a pollution event is considered moderate.

12.96 Based on the significance matrix provided in Table 12.5, the significance of an event of moderate magnitude on highly sensitive receptors is moderate. This requires that mitigation is put in place.

12.97 The precautionary approach taken assumes a direct connection between watercourses and adjacent supplies and so proposed mitigation will aim to protect the private water supplies of Callisterhall, Collins, Bigholms, Solway Bank cottage and Kirtleton Farm cottage.

Alteration to Natural Drainage Patterns/ Runoff Volumes and Rates

12.98 This section considers the potential effects of the proposed wind farm construction activities on runoff patterns, volumes and rates. There are several activities carried out during construction that may affect runoff patterns:

- The development of tracks and cable trenches has the potential to alter natural drainage patterns on site by the development of preferential flow pathways. If constructed against the topographic gradient, tracks could act as barriers to run-off resulting in the ponding of water. During construction, partially completed tracks and trenches may divert runoff into sensitive areas.
- Areas of hard standing created to enable construction (such as turning and lay-up areas) may temporarily increase runoff.
- Dewatering of turbine foundations (either passive or active) may result in localised, temporary lowering of the groundwater table.
- There are some crossings which will require culverting in a manner to ensure maintenance of natural water flows.
- No on-site concrete production will occur; therefore little or no abstraction will be required. There will be a small requirement for temporary on-site water supplies, with these requirements likely be <50 m³/day. Any abstraction location will be identified within the CMS and will require authorisation under the CAR (depending upon level of abstraction).

12.99 Four principal hydrological receptors have been identified, and based on the sensitivity criteria in Table 12.4 are highly sensitive to any change (River Sark, Kirtle Water, River Esk and Liddlesdale Bedrock).

12.100 The overall magnitude of a change to runoff patterns is assessed as being moderate due to the temporary nature of any change.

12.101 The effect of a moderate magnitude event on highly sensitive receptors is of moderate significance and therefore will require mitigation.

Effects of Construction on Peat Landslide Hazard Risk

12.102 The effects of the construction phase of the proposed wind farm on peat landslide hazard risk are discussed in detail in the PLHRA report (Appendix 12.1). The findings of the report state that providing good construction practices and mitigation measures are incorporated into the construction of the proposed wind farm, risks would remain at Low or Very Low, and therefore not significant.

Potential Operational Effects

12.103 This section assesses the potential effect of any operational activities on the hydrology, hydrogeology and peat stability of the site. In general, activity is reduced during the operational phase which reduces the risks to the water environment. The following effects have been assessed with regards to the magnitude of their effect upon the receptors:

- Vehicle/plant use will be minimal and therefore the likely magnitude of effects from pollution, prior to mitigation and management, are assessed to be negligible;
- Access tracks will be complete and no construction work will be required other than periodic or unplanned maintenance. As the potential for any additional erosion and sedimentation is therefore low, the likely magnitude of an erosion and sedimentation event, prior to mitigation and management, is considered to be negligible.
- Although the control building and substation are permanent, they represent a minor change to the hydrological characteristics of the site. Turbine bases and areas of hardstanding will increase surface run-off, however, the total area of turbine bases and hardstanding will be small in relation to the overall catchment area. Furthermore, this infrastructure will be distributed throughout the site. Therefore, the potential magnitude of any interference to natural drainage patterns by tracks and other infrastructure, prior to mitigation and management is considered to be minor.
- However, there is a potential for smaller streams to become blocked if not maintained. Due to the terrain however, and size of the crossings, only minor flooding would be expected. The potential magnitude of any effects on natural water flows due to un-maintained stream crossings in the operational phase, prior to mitigation, are assessed as moderate.
- The PLHRA report did not identify any specific hazards associated with the operation of the proposed wind farm and the magnitude of effects are considered to be negligible.

12.104 Four principal hydrological receptors have been identified, and based on the sensitivity criteria in Table 12.4 are highly sensitive (River Sark, Kirtle Water, River Esk and Liddlesdale Bedrock).

12.105 As described above, the magnitude of effect of an erosion, pollution or sedimentation event during the operational phase is negligible. No operational effects have been identified which have the potential to impact upon private water supplies.

12.106 The magnitude of effect of a runoff event during the operational phase is minor in relation to interference to natural drainage patterns. Based on the previous experience of the EIA team, changes to runoff volumes using a modelling methodology have shown to be <5% due to the small amount of hardstanding present in individual catchments. However, the magnitude of a runoff event is moderate in relation to watercourse blockage of minor watercourses.

12.107 The overall significance of any potential effect during the operational phase of the proposed wind farm is therefore assessed as **negligible** for pollution and erosion events. The significance of the effect of runoff events on smaller streams of blockages is assessed as being of moderate significance and as such will require mitigation measures. The significance of any specific hazards associated with peat slide risks is assessed as being minor.

Mitigation

12.108 Mitigation measures presented in this section aim to reduce the significance of any effect on a receptor. Best practice will be followed throughout, and covers a number of aspects such as:

- the contractor tendering process;
- site induction;
- the development and implementation of a CMS (see Chapter 5: Construction and Decommissioning for more detail); and
- adherence to standard pollution prevention guidance.

12.109 Best practice measures can be found in a number of sources (such as SEPA PPG and the Forestry Commission Forests and Water Guidelines) and as such are not reproduced here in detail. Important aspects will be highlighted in the appropriate mitigation sections below.

12.110 Where specific activities have been identified as having a moderate significance (or higher), best practice in conjunction with specific mitigation measures will be required to reduce the significance to an acceptable level.

General Measures

12.111 The Tender procedures for construction contracts will include the requirement to develop a CMS, in consultation with SEPA and SNH (refer to **Chapter 5: Construction and Decommissioning**).

12.112 Following from the more detailed design of tracks and drainage, the CMS will define the construction planning and procedures to be applied. This will ensure that specific procedures with regard to sedimentation and oil/fuel contamination as well as other requirements are implemented. The CMS will demonstrate, to the satisfaction of SEPA, how construction will be in accordance with PPG5; PPG6; Forests and Water Guidelines 2003 and SEPA Special requirements for Civil Engineering Contracts for the Prevention of Pollution V2.

12.113 Sediment management will have regard to the latest SEPA position statement which reflects the requirements under the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (SEPA, 2005a).

12.114 The application for authorisation under the Water Environment (Controlled Activities (Scotland) Regulations 2005 will necessitate a detailed design of proposed engineering features. It is understood that the design of these crossings will need to demonstrate minimisation of effect, consideration of ecological features and the appropriate best practice for the risk posed to the watercourse. As stated above, water crossings will be designed in accordance with current Scottish Government Guidelines on design and with regard to the SEPA position statement on the culverting of water crossings (SEPA, 2005b). As part of the proposed wind farm design, at least one culvert will be upgraded (crossing of Gowdmuir Sike).

12.115 A location map of all potential contamination sources will be produced, and will include fuel, oil and chemical storage areas; vehicle compounds, refuelling sites, waste depots and on-site sewage systems. Mitigation will be demonstrated in accordance with PPG1, PPG2, PPG4, PPG5, PPG6, PPG8, PPG21, PPG26, Technical Guidance Manual for Licensing Discharges to Water, including Ecological Assessment).

12.116 Mitigation measures stated in the following sections are used to illustrate specific measures to minimise potential effects. However, the CMS will be used to develop a detailed plan of when, and where, these measures will be implemented in order to gain maximum benefit from their use.

12.117 The CMS will detail the measures to be taken should any additional private water supply be identified on site. This will involve liaison between the contractor, supply owner and suitably qualified person in order to review the risk to the supply.

12.118 The use of a comprehensive Sustainable Drainage Systems (SUDS) design philosophy will mitigate against runoff, sedimentation and pollution events identified within this chapter. This philosophy will seek to ensure that all runoff is intercepted, prior to entering a natural watercourse.

12.119 These measures are considered as additional to those measures used to inform the proposed wind farm layout.

Specific Mitigation against a Pollution Event

12.120 Specific measures for the mitigation of a pollution event include:

- the placement of drip trays under plant/vehicles when not in use;
- the regular inspection and maintenance of plant to prevent leakage of fuel or oil;
- the use of interceptors to prevent oil/fuel/grit discharging into watercourses;
- the bunding of any fuel or oil store to at least 110% of the volume of the contaminant being stored (or to contain 25% of the largest tank's capacity in the case of multiple storage tanks);
- the siting of potentially polluting activities such as refuelling and vehicle maintenance within the identified construction compounds/parking area;
- the use of impermeable membranes wherever there is a risk of a potentially polluting substance infiltrating the ground.

Procedures in the Case of a Pollution Event

12.121 A set of procedures to be adopted in the case of a pollution event occurring will be kept on site at all times. All construction staff will be made aware of these procedures and the location where they are kept.

12.122 The procedures will detail the location(s) of potential sources of contamination, the responsible person on site to deal with any contamination event, emergency contacts in the event of a spill and initial actions to be taken should any spill occur.

12.123 Spill kits will be kept on site at all times and staff will be made aware of their location and procedures for use.

12.124 While no direct abstractions from surface waters have been identified within the site, the precautionary approach used to protect private water supplies aims to prevent pollution entering watercourses. The above mitigation, in conjunction with appropriate buffer zones will achieve this.

Specific Mitigation against a Sedimentation or Erosion Event

12.125 The primary mitigation against a sedimentation or erosion event will be the design and implementation of a comprehensive SUDS philosophy.

12.126 This will include (but is not limited to):

- the treatment of runoff in settling ponds;
- the minimisation of exposed earth;
- the minimisation of steep slopes through appropriate design;
- the use of sediment traps to prevent sediment discharging into watercourses;
- the use of check dams in existing drainage systems. Existing drainage adjacent to infrastructure will be identified pre-construction and appropriate management to prevent runoff/pollutants/sediment entering these drains will be employed. Blocking existing drainage with check dams can prevent these drains developing into preferential flow pathways. In certain circumstances, drain blocking can also provide habitat improvement.

12.127 All three assessed watercourses (River Sark, Kirtle Water and River Esk) support fish populations. Therefore, specific mitigation is required to prevent sediment entering the tributaries of these waters. Critical areas for the implementation of the above measures concern the crossings adjacent to Turbine 15, Turbine 4 and Turbine 12 (these are indicated on Figure 12.1 as crossings 5, 7 and 6).

12.128 While no direct abstractions from surface waters have been identified within the site, the precautionary approach used to protect private water supplies aims to prevent sediment entering watercourses. The above mitigation, in conjunction with appropriate buffer zones will achieve this.

12.129 The access track from Pingle farm has been identified as requiring the use of appropriate drainage mitigation measures (as specified above) to prevent sediment entering the Palling Burn.

12.130 As the site is being clear felled, there may be opportunities to install check dams in existing drainage. This would prevent the transport of sediment from recently felled areas.

12.131 At all times, the Forests and Water guidance[17]will be followed. This document provides clear guidance on specific aspects of felling.

Specific Mitigation against a runoff event

12.132 The following measures will be used to mitigate against a runoff event:

- the attenuation of runoff on site using SUDS, with features such as swales, filter strips and attenuation barriers, with reference to the Local Plan, and best practice guidance from SEPA and CIRIA; and
- for the operational phase of the proposed wind farm, a programme of watercourse maintenance will be developed to reduce the risk of blockages and therefore of minor flooding.

12.133 Water crossings will be the subject of authorisation under CAR and detailed designs will be submitted at the time of application. On the basis that new water crossings will be of small size and some distance from sensitive receptors, the magnitude of potential effect and potential effects of stream crossing design in causing erosion and sedimentation, prior to mitigation and management, is assessed as minor to moderate. An operational method and programme for maintenance of crossings (to prevent blockages and flooding) will be provided within the CMS and is anticipated to be a condition of authorisation.

[17] Forestry Commission (2003) Forest and Water Guidelines, 4th Edition

Specific Mitigation against a peat slide event

12.134 Although the risk of a peat slide has been assessed to range from Very Low to Low for areas affected by the proposed infrastructure, methodologies will be developed as a contingency to minimise the effects on watercourses in the unlikely event of peat instability.

12.135 A Geotechnical Risk Register will be compiled to include risks relating to peat instability, as this will be beneficial to both the applicant and the Contractor in identifying potential risks that may be involved during construction. A Peat Stability Pre-Construction Geotechnical Risk Register has been developed as part of the PLHRA Report provided in **Appendix 12.1**.

12.136 Good construction practice and methodologies will be considered for incorporation into the CMS to prevent peat instability within areas that contain peat deposits. They will include but not be limited to the following:-

- measures to include the identification and demarcation of zones of sensitive drainage or hydrology in areas of construction;
- the minimisation of 'undercutting' of peat slopes, but where this is necessary, a more detailed assessment of the area of concern would be required;
- careful micro-siting of turbine bases, crane hardstandings and access track alignments to minimise impacts on the prevailing surface and sub-surface hydrology;
- measures to raise peat stability awareness for construction staff by incorporating the issue into the Site Induction (e.g. peat instability indicators, best practice and emergency procedures);
- use of a 'Peat Hazard Emergency Plan' to provide instructions for site staff in the event of a peat slide or discovery of peat instability indicators;
- measures to ensure that accelerated degradation and erosion of exposed peat deposits does not occur as the break up of the peat top mat has significant implications for the morphology, and thus hydrology, of the peat (e.g. the minimisation of off-track plant movements within areas of peat); and
- the development of robust drainage systems that will not create areas of concentrated flow and that will require minimal maintenance.

12.137 In addition, an appropriately experienced and qualified engineering geologist / geotechnical engineer will be appointed as a supervisor, to provide advice during the setting out, micro-siting and construction phases of the proposed wind farm. This will ensure that the detailed design and construction practices take into account the particular ground conditions and the specific works at each infrastructure location throughout the construction period to further minimise potential risks relating to peat instability.

Residual Effects

12.138 The assessment has identified specific activities, particularly during construction, which have the potential to affect the hydrology and hydrogeology of the site and overall surface water quality.

12.139 The assessment of residual effects considers the significance of a particular effect after mitigation measures have been introduced. These are summarised below.

12.140 From the assessment of potential effects, the following potential effects are identified as of moderate significance and will need particular attention in terms of mitigation and management. All other potential effects were identified as minor.

Residual Construction Impacts

- prior to mitigation, the potential for sedimentation from construction operations, particularly post-felling, the temporary construction compounds, and turbines and tracks <50 m from headwater streams. The residual effect after mitigation is assessed to be of **minor** significance;
- five private water supplies have been identified which may source water from site runoff. These are Kirtleton Farm cottage, Solway Bank cottage, Callisterhall, Collins and Bigholms;
- private water supplies are inherently considered when assessing watercourses, as receptors carry a higher sensitivity if a private water supply is adjacent(irrespective of whether there is a direct hydrological connection). The residual significance of construction impact on private water supplies is considered **minor** if appropriate buffers and mitigation are implemented;
- prior to mitigation, there was the potential for pollution effects of moderate significance for all four receptors (River Sark, River Esk, Kirtle Water and Liddlesdale Bedrock). Residual effects are assessed as being of **minor** significance;
- prior to mitigation, there is a moderate significance attached to the effect of changes in natural drainage patterns on the three surface waterbodies (River Sark, River Esk and Kirtle Water) due to the partially constructed nature of the drainage system. Following mitigation, the significance is assessed as being **minor.**

Residual Operational Effects

- The risk of blockages on watercourses (flood risk) was assessed as being of moderate significance prior to mitigation. Following mitigation, it is assessed as being of **minor** significance.

Cumulative Effects

12.141 A cumulative effect is considered to be an additional effect on hydrological resources arising from the wind farm development in combination with other proposed developments likely to affect the hydrological environment. At distances greater than 10 km it is considered that schemes are unlikely to contribute to a cumulative hydrological effect due to attenuation and dilution over distance of potentially polluting chemicals. Similarly, to affect the hydrology of a catchment would require the developments considered within the cumulative assessment to be located within the same catchment or aquifer (i.e. there requires some to be some hydrological connectivity between developments) as the proposed wind farm.

12.142 Figure 8.26 identifies those wind farms that are existing, consented or under construction which have been assessed in **Chapter 8: Landscape and Visual**. The consented Ewe Hill Wind Farm and also the Ewe Hill Section 36 application to the north of the site are the nearest wind farms to the Solwaybank site. Minsca Wind Farm to the east is the nearest operational wind farm. These wind farms are all outside the catchments potentially affected by the wind farm and so are not included in the assessment and there are no other relevant developments that the assessment team are aware of.

12.143 The Ewe Hill and Newfield overhead line (hereafter referred to as the Ewe Hill and Newfield OHL' is a proposed electricity transmission line that connects Gretna substation (to the south of the development), with Ewe Hill wind farm (to the north of the development). The proposed alignment for this connection runs adjacent to the Solwaybank site and lies within the catchments potentially affected by the wind farm.

12.144 The Ewe Hill and Newfield OHL would require some forestry removal in order for transmission poles to be installed. All transmission poles will be located at least 10 m from the nearest watercourse bank.

12.145 The amount of forest felling required for the Ewe Hill and Newfield OHL is small compared to the Solwaybank site and there is nothing to suggest that any detectable change in water quantity will occur as a result of felling on either site.

12.146 Short term impacts may occur on water quality if sediment is not managed during the felling process. Sediment management measures are proposed for both Solwaybank Wind Farm and the Ewe Hill Grid Connection, to the extent that it is predicted that the sum of the effect of forest felling for both schemes will be no greater than the effect of felling for the larger scheme on its own (in this case the proposed wind farm as it will require more forest removal).

12.147 Therefore, it can be reasonably concluded that no cumulative effects would arise as a result of the proposed wind farm development as there are no other developments with the potential to affect the hydrology of the catchments associated with Solwaybank Wind Farm.

Summary

12.148 A number of activities have been identified which have the potential to affect the hydrology and hydrogeology of the site. These include potential effects from construction and operational activities such as pollution from plant and water course blocking.

12.149 To reduce the significance of these effects, a number of mitigation and management measures are proposed.

12.150 With these measures in place, it is considered that the significance of the residual effect of the proposed wind farm on the hydrology and hydrogeology of the site is negligible to minor. Table 12.8 outlines the significant effects and residual effects after mitigation.

Table 12.8: Summary of Potential Effects, Mitigation and Residual Effects

Potential Effect	Mitigation Proposed	Means of Implementation	Outcome/Residual Effect
Construction			
Sedimentation of surface water bodies and private water supplies from construction activities. (Moderate)	-use of comprehensive SUDS philosophy including: -settling of runoff from track construction; -use of sediment traps at regular intervals along drains; -use of check dams; and -minimisation of exposed earth.	through identification in the CMS; and through specific action by contractors.	Minor

Potential Effect	Mitigation Proposed	Means of Implementation	Outcome/Residual Effect
Pollution of all four receptors (River Sark, River Esk, Kirtle Water and Liddlesdale Bedrock) and private water supplies from fuel/oil spill (Moderate)	- potentially polluting activities such as refuelling and vehicle maintenance to be contained within the construction compound and parking areas identified to reduce risk of runoff in these areas; -use of oil/fuel/grit interceptors and a roofed refuelling area; -use of drip trays under plant; -regular maintenance of plant; and -use of an impermeable barrier when working on impermeable soils	through general principles in the CMP; through training/induction of appropriate site personnel; and development of a maintenance programme pre-construction;	Minor
Changes in natural drainage patterns on all four receptors (River Sark, River Esk, Kirtle Water and Liddlesdale Bedrock) (Moderate).	-phased construction of drainage systems to ensure risk is minimised at the end of each working day; -appropriate use of sustainable drainage features such as filter ;strips/swales/leaky barriers; -no drainage water to be directly discharged into natural watercourses; and -minimisation of partially constructed drainage systems at times of high risk (i.e. wet weather)	through specification in the CMP and final design; through specification in the CMP and final design; CMP to detail forward planning and use of weather forecasts to highlight high risk periods.	Minor
Runoff event/sedimentation (blocked culverts leading to localised flooding) - (Moderate)	-design of water crossings to standard CIRIA and SEPA guidance; and -operational programme of maintenance to inspect culverts for blockages.	through appropriate design in the CMP; design team use latest version of SEPA watercourse crossing guidance; through implementation of stated mitigation measures by contractor.	Minor
Peat landslide hazard risk (Minor)	- minimised through appropriate layout of the proposed wind farm infrastructure -micro-siting of infrastructure using Engineering Geologist	through communication of peat depths on site to design team. -through employment of an appropriately qualified engineering geologist to provide advice during construction.	Minor
Operation			
Runoff event (blocked culverts leading to localised flooding) (Minor)	operational programme of maintenance to inspect culverts for blockages.	through implementation of stated mitigation measures by contractor.	Minor
Sedimentation/pollution event (Minor)	none required (not possible to reduce residual effect below minor due to sensitivity of receptors)	n/a	Minor
Peat slide hazard risk (Minor)	detailed drainage design to avoid areas of concentrated flow and minimise the maintenance requirements	CMP and through employment of an appropriately qualified engineering geologist to provide advice during construction.	Minor