13.28. Reviewing the relative location of the main TV transmitters that serve the area, towns and households in the vicinity of the proposed windfarm, and the nature of the terrain between these, it is possible to conclude that the likelihood of any effect due to shadowing or reflection caused by the proposed windfarm on domestic TV reception is **negligible.**

Aircraft Disruption

13.29. The consultation indicates that there will be no significant effects on civilian or military airspace.

Mitigation

13.30. It is not anticipated that any mitigation will be required. However, in the unlikely event that the turbines cause television interference, the operators shall undertake measures to rectify the problem.

Residual Effects

13.31. No residual effects are anticipated.

SUMMARY AND CONCLUSIONS

13.32. **Table 13.3** below summarises the predicted effects, mitigation and residual effects of the windfarm in relation to telecommunications and aviation.

Table 13.3 Summary of the Effects of the Windfarm on Telecommunications and Aviation

Potential Effect	Significance	Mitigation	Residual Effect
Interference with point to point transmission links operated by telecommunication service providers in the area	None	None required	None
Interference with military and civilian aviation radar / communication systems	None	None required	None
Interference with the reception of terrestrial TV at residences in the surrounding area	Negligible	Technical solutions in the event of isolated TV interference	None
Interference with the reception of radio services at residences in the surrounding area	None	None required	None
Disruption to aircraft activity in the area	None	None required	None

REFERENCES

[i] Scottish Executive, (Revised 2000), National Planning Policy Guideline (NPPG)6, *Renewable Energy Developments*

[ii] Scottish Executive, (2002), Planning Advice Note (PAN)45, *Renewable Energy Technologies*

[iii] Scottish Executive, (2001), Planning Advice Note (PAN) 62, *Radio Telecommunications*

[iv] Highland Council, (2001), *Highland Structure Plan*

14. HYDROLOGY AND HYDROGEOLOGY

INTRODUCTION

14.1. This chapter assesses the hydrological and hydrogeological effects of the Gordonbush windfarm. Hydrology refers to the nature of surface and soil waters, as opposed to hydrogeology, which refers to water within drift and solid geologies. The potential effects that may be caused by development are described and possible mitigation measures to ameliorate these effects proposed. The residual effects of windfarm development, taking into account the possibility for mitigation, are considered and the overall effect of the development on hydrology and hydrogeology is assessed in relation to the overall sensitivity of the site.

14.2. The development elements that are considered are those with the potential to interact with the ground and surface water systems. These are: use of mobile construction plant, formation of foundations, operation of borrow pits and batching plant, establishment of the contractor's compound, formation of tracks (with associated drainage) and cable trenches. Hydrology has close links with ecology issues (**Chapter 8**).

14.3. This part of the assessment has been undertaken by Arupscotland. A fuller description of the company's relevant experience is provided in **Appendix 1.1**.

POTENTIAL SIGNIFICANT EFFECTS

14.4. The construction phase of the project may have significant effects on a number of hydrological and hydrogeological conditions. Construction may affect the natural drainage pattern of the area, the runoff volumes and base flows, and the runoff rates. Changes may occur to ground water levels and the quality of the ground water and surface water. Construction may impact water supplies, flow in natural watercourses and flush zones. There may be modifications to the stream morphology directly, or through erosion and deposition processes.

14.5. The ongoing and operational impacts will be different to the construction impacts but the hydrological and hydrogeological elements affected will remain similar. **Table 14.1** below sets out the potential significant effects of the development on the water and geological environment. Potential effects are those which could result from the construction and operation of a windfarm, according to the project, site and receptor characteristics and their interactions, and their inclusion in **Table 14.1** does not imply that they will occur, or be significant at Gordonbush. The hydrology and hydrogeology assessment is based upon an assessment of the potential effects, in order to identify predicted effects.

Table 14.1 Potential Signifcant Effects of the Windfarm on Hydrology and Hydrogeology

- Increase in the volume of runoff due to increased impermeable areas and modifications to natural drainage patterns;
- Deterioration in surface and groundwater quality due to increased sediment loads, pollution incidents during construction and alteration of drainage patterns;
- Impediment to flow where tracks and trenches cross natural watercourses and flush zones;
- Effects on private water supplies;
- Modification of stream channel morphology (erosion / deposit);
- Loss of sensitive soils or geological features;
- Indirect effects on ecology.

CONSULTATION

14.6. **Table 14.2** summarises the responses of those consulted in relation to hydrology and hydrogeology.

Table 14.2 Summary of Consultation Responses

Consultee	Summary of Comments
Scottish Water	Provided information detailing water supplies in the area.
District Fisheries Authority Association of Salmon Fishery Boards	General comments on potential impacts on watercourses, water quality and migratory and other fish species.
Scottish Executive Water Team	Noted that the EIA will include a Hydrology assessment. No comment to make on the proposed development and SEPA as statutory consultees will take into account any potential impacts that fall under the remit of the EC Water Framework Directive.
SEPA	Requested that the following be considered; - Pollution Prevention (Pollution Prevention Guidelines) - Method statements to be prepared - Fuel transport & storage management. - Concrete production and potential requirement for a Part B authorisation for batching process - Disposal of sewage - Vehicle and plant maintenance - Access Road construction - On-site environmental management - Hydrology & culverting - Waste - Borrow Pits - Nature Conservation Provided information on water quality.
SNH	Details provided on - Coir' an Eoin Site of Special Scientific Interest (SSSI) - Caithness & Sutherland Special Protection Area (SPA) - Caithness & Sutherland RAMSAR site - Caithness & Sutherland candidate Special Area of Conservation (cSAC)
Scottish Executive Consents and Emergency Planning Unit	Highlighted pollution issues and the sensitivity of the receiving waters
Gordonbush Estate	Provided information relating to private water supplies in the immediate vicinity of the site.

14.7. The following data sources have been referred to in this assessment:

Topographical maps

- Ordnance Survey Landranger 16 & 17 (1:50,000)
- Ordnance Survey Explorer 1:25,000.
- Soil maps: Soil Survey of Scotland - sheet 103
- BGS (British Geological Survey) (1988). Hydrogeological Map of Scotland Geological (1:1,625,000). Published by Ordnance Survey for BGS, NERC.
- BGS (British Geological Survey) (1979). Geological Survey Ten Mile Map North Sheet, 3rd Edition (Solid) (1:1,625,000). Published by the Ordnance Survey, Southampton for the Institute of Geological Sciences (now BGS)
- BGS (British Geological Survey) (date) Sheet 103 Golspie, Solid edition (1": 1mile). Southampton: Ordnance Survey for BGS, NERC.
- BGS (British Geological Survey) (date). Sheet 103 Golspie, Drift edition (1": 1mile). Southampton: Ordnance Survey for BGS, NERC.
- BGS (British Geological Survey) (1969). Geological Map of the British Islands, Solid Edition (1: 1,584,000, or 25 statute miles to 1"). Published by the Ordnance Survey, Southampton for the Institute of Geological Sciences (now BGS).
- BGS (British Geological Survey) (2002). Helmsdale. Scotland Sheet 103W, Solid and Drift Geology, 1:50,000 Provisional Series. (Keyworth, Nottingham: BGS).
- BGS (British Geological Survey) (2002). Golspie. Scotland Sheet 103E, Solid and Drift Geology, 1:50,000 Provisional Series. (Keyworth, Nottingham: BGS).

British Regional Geology

- Johnstone, GS and W Mykura (1989). *British Regional Geology: The Northern Highlands of Scotland* (4th Edition). London: HMSO for the British Geological Survey.

Hydrological Reports

- NERC (1999) *Flood Estimation Handbook CD-ROM.* Version 1.
- NERC (1975) Flood Studies Report. Volume V - maps. Winter Rainfall Acceptance Potential map, (1:625,000 scale), 1st revision 1978. Wallingford.

Groundwater vulnerability maps

- BGS (British Geological Survey), SSLRC (Soil Survey & Land Research Centre, Cranfield University) & MLURI (Macaulay Land Use Research Institute) (1995). Groundwater Vulnerability Map of Scotland (1: 625,000).

Public register of private water supplies

Others

- EA (Environment Agency for England & Wales), SEPA (Scottish Environment Protection Agency) & EHSNI (Environment and Heritage Service in Northern Ireland). Pollution Prevention Guidelines (PPGs) including:
    - PPG 1: Prevention of Pollution of Controlled Wastes.
    - PPG 2: Above Ground Oil Storage Tanks.
    - PPG 5: Works In, Near or Liable to Affect Watercourses.
    - PPG 6: Working at Construction and Demolition Sites.
    - PPG 21: Pollution Incident Response Planning.
- Forestry Commission (2000) Forests and Water Guidelines.

ASSESSMENT APPROACH

14.8. A qualitative approach to assessing the hydrological and hydrogeological effects of the windfarm development has been adopted and has involved the following steps:

- Identification of the existing conditions;
- An assessment of the sensitivity of the site;
- Identification of the potential impacts and their magnitude;
- Evaluation of effects;
- Identification of any necessary mitigation measures;
- Identification of the likely residual effects of the scheme.

14.9. A combination of a study and fieldwork was used to support the assessment process, as noted below.

Baseline Assessment

Desk Study

14.10. A baseline desk study has been conducted and the following activities undertaken:

- A review of existing soils and geological base map information;
- A review of groundwater vulnerability maps;
- A review of any site survey / investigation information;
- A review of hydrogeology, with reference to groundwater protection mapping;
- The identification of known public water abstractions in the vicinity of the site;
- The identification of private water supplies from local authority records, together with discussion with estate staff;
- Third party liaison (with SEPA and Highland Council).

Field Survey

14.11. A site visit was conducted on the 16th October 2002 to identify local conditions. The weather for the site visit was cloudy but dry. During the site visit the following activities were undertaken:

- Identification of potential sources of private water supply that are sensitive to pollution risk
- Identification of source areas for groundwater or natural springs
- Verification of site geology conditions
- Verification of site soil conditions

Effects Assessment Methodology

14.12. The assessment considers the characteristics of predicted impacts of the development, and the sensitivity of the receptor, in order to evaluate the significance of any consequential effects. For there to be an impact there has to be change in existing conditions, either due to a physical change to surface and ground water systems, or to a 'pathway' linking potential pollution sources to a receptor.

14.13. Prediction of effects is therefore based on the identification of hydrological and hydrogeological impacts and the identification of receptors that will be affected by the development. Pollution impacts have been assessed by the identification of potential sources of pollution that may be linked to receptors by 'pathways'. The predicted impacts are characterised in terms of their probability, scale, extent, duration, and permanence.

14.14. There has been input into the windfarm design process to avoid and minimise the potential impact of the development on the hydrology and hydrogeology of the site. Guidelines for best construction practice, and siting of wind turbines and tracks were suggested so that major effects on the hydrology and hydrogeology could be prevented. These have been taken into account in the assessment.

14.15. Where significant effects have been predicted, specific mitigation measures have been developed. Potential effects are then reassessed taking the mitigation into account, to give a residual effect.

Significance criteria

14.16. The significance of potential effects has been assessed by taking into account the sensitivity of the baseline environment and the potential magnitude of the predicted impact. Criteria for assessing the magnitude of the predicted impact are given in **Table 14.3**.

14.17. Impacts may be permanent or temporary, and may have a negative (detrimental) or positive (beneficial) impact on the environment. Impacts may have a local, regional, national or international effect.

Table 14.3: Criteria for Impact Magnitude

Major	Fundamental changes in the regional hydrological or hydrogeological regime
Medium	Fundamental changes in the local hydrological or hydrogeological regime, some noticeable changes to the regional regime.
Minor	Some noticeable changes to the local hydrological or hydrogeological regime
Negligible	No perceptible changes to the hydrological or hydrogeological regime

14.18. The ecological and resource characteristics of the receiving environment are major factors in the determination of its sensitivity to change. The sensitivity of the environment to each impact was considered and qualitatively assessed as being negligible, low, moderate or high based on professional judgement. For example, a high sensitivity environment would be a hydrological unit with designated ecological significance, or which is adjacent to a ground or surface water abstraction; an environment of moderate sensitivity would be a hydrological unit with local ecological importance; and a low sensitivity environment would be a watercourse of low-grade water quality with no ecological significance or water abstractions.

14.19. The sensitivity of the receiving environment, together with the magnitude of the impact, will define the significance of the effect. The significance criteria are therefore summarised in **Table 14.4.**

Table 14.4: Significance Criteria for Effect Assessment

	RECEPTOR SENSITIVITY			
IMPACT MAGNITUDE	**Negligible**	**Low**	**Moderate**	**High**
Major	Negligible	Minor	Moderate	Major
Medium	Negligible	Minor	Moderate	Moderate
Minor	Negligible	Negligible	Minor	Minor
Negligible	Negligible	Negligible	Negligible	Negligible

EXISTING SITUATION

Climate

14.20. The climate in northern Scotland is strongly influenced by cool, humid Atlantic weather systems. However, southeast Sutherland lies in the precipitation shadow of the North West Highlands, so the climate is drier than that experienced further west. The average annual rainfall at the site is estimated at approximately 900mm[1].

[1] from the deer management plan (ref).

Geology

Solid Geology

14.21. The solid geology is shown in **Figure 14.1**. Much of the Northern Highlands is formed by the Precambrian Moine Succession, an ancient complex of metasedimentary strata. The windfarm site lies on the Moine, where it comprises the Kildonan psammite formation, a schist intruded with igneous veins of granite, syenite and granophyre. There is relatively little solid geology outcrops at the site. The windfarm site is adjacent to the eastern boundary of the Moine, beyond which younger sedimentary strata (including sandstones mudstones, conglomerates and breccia), and Moine schists are mapped intruded by granite. Nearer the coastline, the Helmsdale Fault is mapped, indicating the boundary of Moine schists with downthrown younger sedimentary strata to the east.

Drift Geology

14.22. Drift geology is shown on **Figure 14.1**. The mapped drift geology of the area indicates that the site is overlain partially by peat and partly by undifferentiated glacial deposits. The proposed windfarm access track is mapped as mostly located on glacial deposits, though it is partly located on peat to the northwest of Cnon a' Ghrianain. The glacial deposits comprise till and hummocky glacial deposits, likely to consist of a compact boulder clay composed of rock clasts of local and distant origin set in a sandy, silty clay matrix, of Late Devensian age. Peat, typically brown and fibrous, locally up to several metres thick, dominates the northern part of the site, interspersed with patchy, localised areas of glacial deposits. To the south of the site, glacial deposits dominate interspersed with patchy, localised areas of peat. Alluvium occurs at the base of several river valley locations.

14.23. Erosion of drift is an ongoing process, in particular along the banks of deeply incised streams. There are, for example, several landslip scars along the Allt Smeorail valley.

Topography and Landuse

14.24. The study area is bordered in the north by the Strath of Kildonan and to the south by Strath Brora. Land cover over the majority of the area is wet modified bog, a nationally important habitat listed within Biodiversity Action Plans. There is also a significant amount of Blanket Bog considered to be of International importance and designated a priority habitat under annex 1 of the EC Directive 92/43/EEC. Land use within the site area is restricted to deer management and small areas of coniferous forest.

14.25. The turbine site (excluding the access track) is approximately 6km^2. It is set on a south west-facing slope with an average gradient of about 7%. The proposed turbine positions are at an elevation of between 270m and 390mAOD.

Soil

14.26. The soil map (**Figure 14.2**) indicates that the site is predominately underlain by 'Blanket Peat' with a depth greater than 1 m. A small area to the southwest includes 'Blanket Peat' that is between 0.5 m and 1 m deep. Field observations confirmed the widespread presence of peat. However, an ecology survey on a more local basis differentiated the 'Blanket Peat' into different types. A peat probe survey indicates that peat depth is typically 1m. This varies from less than 50cm on the hardest ground, to 2m in the deeper areas. In isolated locations, peat depth is 3m. Erosion of the peat has led to the development of peat haggs in some areas

of the site. Drainage is in some sections by means of natural pipes, or runnels, which generally occur within the peat soil or, at the interface between the organic and mineral horizons.

14.27. All the mineral soil in the area belongs to the Arkaig Association and is derived from schists and granulites. In the north east of the turbine site the area is covered by the Kildonan soil series, a peaty podzol that is freely draining below the iron pan. The Poolie Complex is found along the southern border of the turbine site. Its component soils include peaty podzols, peaty gleys, shallow peat and some deep peat. The Poolie complex is associated with non-rocky land with gentle to moderately steep slopes.

14.28. The access track to the site passes over a range of soil types. The northern end of the track is surrounded by Peat, Poolie complex and Strathnaver complex soils. The Strathnaver Complex includes peaty podzol, shallow and deep peat and peaty gleys. Strathnaver Complex is associated with moundy moraine landforms. To the south the track passes through soil of the Gordonbush series, a freely drained humus-iron podzol. Where the track reaches the valley bottom it passes over Yetts soil series, an undifferentiated alluvial fan.

Hydrology

Catchment Areas

14.29. As shown in **Figure 14.3**, the windfarm site lies within the catchment area of the Brora River, and drains into two southwards draining tributaries, the Allt a' Mhuilinn to the west and the Allt Smeorail to the east. The River Brora runs to the south of the site through Brora Loch and enters the North Sea approximately 8 km from the site. The catchment is dominated by upland peat bog with an area of coniferous forest to the southwest.

Watercourses

14.30. The windfarm site is predominately drained by a network of tributaries that form two sub catchments of the Allt a' Mhuilinn. These tributaries run in a westerly direction across the site. The Allt a' Mhuilinn runs south from 380m AOD for approximately 4 km before joining the River Brora, 0.5 km above Loch Brora, at 30m AOD, with a small reservoir at 150m AOD.

14.31. The eastern section of the site is drained by tributaries of the Allt Smeorail, which runs south for approximately 5km before joining the Brora River, from an altitude of 400m to 30m AOD. The catchment is blanket peat with coniferous forest in the south. The southern end of the burn is flanked by broad-leaved semi-natural woodland.

14.32. The water quality of the River Brora above Brora Loch is classified as excellent.

Lochs and Lochans

14.33. The reservoir on the Allt a' Mhuilinn stream was originally constructed as part of a small estate hydroelectric scheme. The scheme is now decommissioned, and the dam sluice valve is open. The watercourses on the site drain into the River Brora that feeds Loch Brora. Neither Loch Brora nor the River Brora is used for public water supply.

Drainage

14.34. The site is situated on peat bog with a high drainage density. The presence of peat on the site indicates that surface water may be expected, in some areas, for much of the year. The site is drained through a network of surface and subsurface channels. Localised flooding may occur if heavy rainfall exceeds the capacity of the minor watercourses.

14.35. A network of artificial drains is present on the site. Where gradients are shallow there is no erosion in the drains that run across the site. However where gradients are steeper there are signs of erosion in the drains.

14.36. The runoff regime is likely to be flashy due to the high drainage density created by the numerous small channels and ditches. The percentage runoff will also be high as the water table is close to the soil surface preventing infiltration. Dry peat has a low infiltration rate and also results in a flashy runoff regime.

14.37. Localised peat haggs can be over 2m deep and several meters wide. Locally, drainage is via natural pipes within the peat (i.e. subsurface streams with the peat forming a roof over them.) Pipes may be identifiable from the ground at their entry and exit points, where they have subsided or where they are marked by a change in vegetation. Other pipes may not be visible from the ground.

Flooding and Floodplains

14.38. The disused reservoir on the Allt a' Mhuilinn does not normally have water ponded upstream. However during large storm events the dam does act to restrict flow and water builds up temporarily behind the dam

Hydrogeology and Groundwater

Hydrogeological Units

14.39. The hydrogeological map indicates that the site is underlain by impermeable Precambrian rocks, which are generally without groundwater except at shallow depth. Any groundwater flow in these rocks is likely to be through fissure/ fracture systems and the weathered rock. It is expected that the flows will be restricted to relatively shallow depths, and that the resulting springs and seepages will be relatively small. The glacial deposits are anticipated to have a low permeability and will limit recharge to the underlying rocks in those areas where it is found. However, peat can exhibit large variations in permeability and thickness, and where present in shallow thickness, may facilitate recharge to fissures/ fractures within the underlying strata.

Groundwater Vulnerability

14.40. The groundwater vulnerability map classifies the bedrock as 'weakly permeable'. Weakly permeable formations are generally of low permeability and do not widely contain groundwater in exploitable quantities. However, locally, the formations can yield water supplies in sufficient quantities for private/ domestic use, as observed during the detailed hydrogeological assessment. Where the igneous rock is present (such as to the northwest of the proposed windfarm location) and is highly fractured, the permeability may be significantly higher.

14.41. The presence of the overlying low permeability glacial drift is likely to result in low overall groundwater vulnerability. However, natural variability within the peat may result in elevated groundwater vulnerability. Overall, it is anticipated that groundwater vulnerability will be low.

Groundwater resources

14.42. The Strath Brora area relies on private water supplies. It is likely that the sources for these supplies originate from either one or a combination of surface water runoff, shallow groundwater from within the glacial drift and peat deposits, and locally, from fissures/ fractures within the solid rock strata. Detail on the closest properties to the turbine area and access tracks is noted in **Table 14.5.**

Table 14.5 Private Water Supplies

Property	Grid ref.	Details
Oldtown	NC 85219 08954	Two properties, one privately owned and one owned by the estate. A salmon hatchery is also situated in this area. Water for the hatchery is abstracted from the burn to the north of the properties. A tank for the private water supplies is located approximately 30 m further to the north of this abstraction point, from which the water is piped down to the houses. The water supply is understood to be potable without treatment.
Gordonbush	NC 86055 09843	This settlement comprises five properties, all owned by the estate. The supply for these properties was installed in 1979. The supply is essentially surface water, taken from fractures in the conglomerate in the source area that flows into a stream. A cofferdam has been installed across the stream that allows sediment to settle out; water passes through into a side channel and then into the holding tank, from where it is piped down to the properties. Given the distance of this tank from Gordonbush there is an intermediate holding tank some distance downstream, to reduce the water pressure.
Moulin Cottage	NC 82597 11044	This is a privately owned property. The water supply is surface water, collected from the area to the north of the wood surrounding the cottage. Pipe work collects water from whichever rivulets appear to be providing the greatest flows. The pipes are checked and their locations altered during the year as necessary. It is understood that there is some difficulty with obtaining a supply in summer.
Ascoile	NC 82350 11100	Two properties, only one of which is habitable. Surface water run-off is collected from the face to the north east of the property and is then stored in a holding tank. Difficulties have been encountered obtaining a decent and continuous supply for this property, and are yet to be resolved.

14.43. All the private water supplies were assessed to establish whether they are at risk from the windfarm development. It was concluded that the house at Ascoile is the only property whose water supplies may be affected by the windfarm development.

Nature Conservation Designations

14.44. There are two Sites of Special Scientific Interest within 2km of the proposed windfarm, Carrol Rock SSSI to the south of the site on the south-westerly shore of Loch Brora and the Coir an Eoin SSSI north-west of the site, west of Allt a' Mhuilinn. The Coir an Eoin SSSI is also part of the Caithness and Sutherland Peatlands Special Area of Conservation. The drainage on the development site is discreet from that of the SSSI, although they both ultimately drain into the Allt a' Mhuilinn, which forms the eastern boundary of the SSSI. None of these designated sites will be directly affected by the proposed development.

Future Situation without the Scheme

14.45. If the scheme did not go ahead, it is unlikely that any significant changes to the hydrology or hydrogeology of the area would occur in the near future. However, erosion is a current and ongoing feature at this site.

Summary – Sensitive Receptors

14.46. The following are the main sensitive receptors that have been highlighted from the desk and field assessment:

- The private water supply at Ascoile will be highly sensitive to disturbance and pollution.
- Peat bogs are an EU priority habitat, although this is a modified bog.
- A network of peat pipes cross the site. These are not always easy to identify and are at risk of disruption during construction and site operation.
- Local watercourses are likely to be sensitive to sediment production and transport, particularly during the construction phase.

ASSESSMENT OF POTENTIAL EFFECTS

Project Assumptions

14.47. In order to assess the effects of the windfarm a number of assumptions have been made about its nature and extent.

- **Design:**
  - Where the peat is greater than1m deep it is assumed that floating tracks will be built and therefore no drainage will be needed.
  - Where the peat is less than 1m deep cut tracks will be built and drainage put in only where necessary.
  - The access track up to the old reservoir will be an upgrade of an existing track.
  - The turbine bases will be buried and turfed over.
  - Where it is necessary to cross watercourses, appropriately designed culverts will be installed.
  - Drain lengths will be kept to a minimum.
  - Drain gradients will be kept to a minimum.
  - Buffer strips will be left between drain outfalls and watercourses.

Management:

- Contractors will produce a construction methodology statement including appropriate management of potentially polluting activities. As a minimum, the following Pollution Prevention Guidance (PPG) published by SEPA will be followed:
    - PPG 1: General Guide to the Prevention of Pollution;
    - PPG 2: Above Ground Oil Storage Tanks;
    - PPG 5: Works In, Near or Liable to Affect Watercourses;
    - PPG 6: Working at Construction and Demolition Sites;
    - PPG 21: Pollution Incident Response Planning.
- Best practice will be adopted for handling potentially polluting substances, such as fuel, oil, cement, and concrete additives, including:
    - Designated facilities will be designed and used for storage and refuelling, away from watercourses.
    - Staff will be trained in emergency procedures
    - Emergency response equipment will be available at appropriate locations
- Drip trays will be provided for machinery
- Machinery will be repaired and maintained, where practicable, in suitable designated locations
- Facilities will be provided to ensure appropriate waste management
- Wheel washing facilities will be located away from watercourses
- Pumped water will be discharged via settlement ponds or filter strips prior to direct discharge into a watercourse

CONSTRUCTION EFFECTS

Change to run off regime

14.48. Any changes to the run off regime may affect the characteristics of stream systems draining the site, in terms of the sensitivity of their response to precipitation, and could also affect the water table level. In turn, changes to the water table could affect ecology, especially in areas of peat, which is likely to be sensitive to changes in the water table. The site currently experiences relatively high run off rates and volumes due to the water table being close to the surface, and the high drainage density. Consequently the site run off regime has a low sensitivity to changes caused by the following aspects of the development.

Impermeable areas

14.49. During the construction process, the following facilities will be created[2]:

- Temporary contractors' compound (50m by 50m);
- Possibly an additional temporary laydown area at Ascoile (50m by 50m);
- Borrow pits (total footprint approximately 11500m^2).

14.50. These will introduce areas with reduced permeability and artificial drainage, and will therefore increase surface run off volumes and rates. Drainage would be discharged to adjacent unaffected ground that would lead to some attenuation of flows from these areas. The impact would be localised, temporary and on a relatively small scale, affecting approximately 0.3% of the site area. Consequently the impact, and hence effect would be **minor.**

Drainage patterns

14.51. There are two potential means by which existing drainage patterns may be affected during construction activities, with consequences for run off volumes, runoff rates and water table levels. Firstly by the disturbance of existing drainage routes by construction plant, so that the drainage is diverted into new routes; secondly by the creation of new drainage routes by construction activities.

14.52. The layout has been designed to minimise stream crossings as far as practical. The new access track to the windfarm site will cross five small streams[3] at existing track crossings, and a further small stream by means of a new culvert. There will be four principal stream crossings by site tracks, the largest stream to be crossed being adjacent to the substation. In all cases appropriate culverts will be designed to ensure that flow is unimpeded, and that there is minimal possibility of blockage by water-borne debris, such as eroded blocks of peat. (These culverts will also take into account any ecological requirements in relation to otters.) Consequently, it is predicted that natural drainage patterns will be unaffected along stream channels, and there will be minor impact and **negligible** effect on the routing and volume of run off.

14.53. Use of heavy plant machinery may lead to localised peat compaction, which may reduce local ground water levels and inhibit groundwater flow through peat due to reduced permeability. This may lead to surface saturation. Such impacts would be localised to working areas, and would be temporary, and are therefore considered to be minor. Peat and associated ecology will have a high sensitivity to changes in groundwater. Overall the effect is considered to be **minor**.

14.54. Whilst stream crossings are easily identifiable, some peat pipes may not be readily detectable to a plant operator. There is therefore a possibility of causing a peat pipe to collapse blocking the drainage route and possibly causing the subsurface stream to create an alternative route. Whilst it is unlikely that such an event would cause a diversion of a catchment, for example from the Allt a' Mhuilinn to the Allt Smeorail, there is a small possibility that on flat ground there could be a diversion between minor tributaries of the Allt a' Mhuilinn, which exhibits a high drainage density. It is difficult to quantify the impacts of such an event, although a single occurrence is unlikely to affect a large proportion of the site. The impact may be reversible naturally through erosion processes, and could be reversed by excavating the blockage. However, the initial event may have secondary effects such as creating an episode of erosion to create a new channel. The impact is predicted to be minor or medium, depending on the frequency and extent of occurrence, and the peatland receptor is judged to have a moderate to high sensitivity. Consequently the effect is judged to be **minor or moderate**. Given the

[2] Effects of permanent features, such as tracks are considered in ongoing and operational effects

[3] A small stream is defined as a stream marked on the 1:50,000 Ordnance survey map

uncertainty, and the practical difficulties that widespread collapse of peat pipes may cause, it is proposed that specific mitigation measures be adopted to reduce the effect. These are outlined in paragraph 14.94.

14.55. During construction works, it will be necessary to introduce artificial drains, or possibly pumps, in particular at foundation sites and borrow pits. These will remove groundwater and discharge to the surrounding ground as surface water. At the point of discharge, the run off may infiltrate back into the groundwater. Two borrow pit sites are on knolls, which are unlikely to be sources of significant quantities of groundwater. The third site is close to an area of springs forming the headwaters of the Ristocky Burn, so it is probable that any shallow groundwater in the borrow pit site area currently discharges to surface water within a few hundreds of metres. Given the nature of the bedrock it may be expected that groundwater flows into excavations will be limited and therefore the volume of water removed is likely to be minor. The site has a low sensitivity and therefore the effect is **negligible.**

Water Quality

Pollutants

14.56. Construction activities introduce a number of potential sources of pollution, which will be managed in accordance with best practice measures. The primary potential sources of pollution are:

- Plant diesel fuel, to be stored in bunded tanks at the contractors' compound.
- Hydraulic oil in drums stored at the contractors' compound.
- Fuel and hydraulic oil in mobile plant and concrete additives.
- Cement, stored in batching plant silos[4].

14.57. The primary potential receptors are:

- Surface water, groundwater and soil at the point of any incident and downstream of an incident.
- Badan Burn, a tributary of the Allt Smeorail

14.58. The substation compound is the closest windfarm element to a watercourse at 30m, the other windfarm elements are at a distance of at least 50 meters, this will limit the disturbance to channels and limits the pathway for pollutants. With good management practices in place, any spillages within the contractors' compound will be contained by bunds and enclosures, and will therefore be denied a pathway to sensitive receptors. The impact, and hence effect are therefore predicted to be negligible. The less controlled situation occurs where there is a leakage at mobile plant. Fuel tank failure is a relatively unlikely event with well maintained plant; more likely is a hydraulic hose failure. The volumes of oil associated with such an occurrence are relatively low, but oil will have a pathway to surrounding receptors. The impact of such an incident would be localised and temporary, and could be remediated. There is also a risk that a traffic accident involving a construction vehicle could occur with the worst-case scenario being a spillage of fuel or concrete at a stream crossing, whilst the risk is low the impact could be major. It is difficult to definitively quantify the impact and effect, but taking into account the relatively low probability of a major spillage, and its localised extent, the impact is predicted to be no more than minor, the receptor moderate to high sensitivity, and the effect **minor**.

Suspended solids

14.59. There are two potential causes for additional water borne suspended solids during construction:

- Creation or exposure of fine materials by construction activities.
- Enhanced run off rates causing additional erosion.

14.60. Paragraph 14.50 demonstrated that catchment run off will not be significantly increased due to construction facilities, and on this basis it is concluded that this on its own will have a negligible impact on discharge of suspended solids. However, local velocities may be increased and this together with disturbance of vegetation cover may increase erosion.

14.61. The following activities will create or expose fine materials that are susceptible to discharge:

- Creation and working of a borrow pit;
- Excavation of lengths of drainage ditches;
- Excavation of cut tracks, and laying of crushed rock to form tracks;
- Excavations and material handling for foundations, compounds and crane pads;
- Temporary stockpiling of excavated materials.

14.62. These activities may result in increased discharge of suspended solids where they are exposed to high run off rates, and are improperly designed.

14.63. Borrow pits, at least as they are enlarged, constitute an area liable to experience high run off rates, and are therefore susceptible to wash out of suspended solids. Significant volumes of sediment will be generated during the excavation of borrow pits, consequently the borrow pit designs will incorporate one or more settlement facilities so that fine sediments washed out of the workings will be substantially removed prior to discharge. In normal circumstances, this should result in negligible impact. In storm conditions, the run off rate within the borrow pit may increase the suspended solid loading, and flow rate through the settlement facilities, and hence lower the efficiency of the suspended solids removal. However, in such circumstances the rate of natural erosion of streambeds and banks within the catchment is likely to be significant as indicated by the existing landslip scars. Upon completion, the borrow pits would be reprofiled, and revegetated. Consequently, the impact of discharges from the borrow pit are likely to be no more than local, and the broader impact is likely to be no more than minor. Consequently, the effect on the stream network, which is considered to be of moderate sensitivity, is **minor**.

14.64. Excavation of drainage ditches clearly involves disturbing and exposing fresh fine material to running water, and is therefore potentially an important source of suspended solids in high flow conditions. It is therefore important to design drainage to ensure that run off volumes and velocities are restricted to minimise ditch erosion. The design principle is to limit the length of ditch, which is typically formed on the uphill slope, by forming a headwall or stop

[4] A closed system will minimise fugitive emissions during cement deliveries.

end, and culverting it under the track approximately every 30m[5], depending on the gradient. The culvert would typically drain onto open ground, which acts as a deposition area, rather than into a stream. With a suitably designed scheme, the impact can be localised and the quantities of eroded material minimised. The impact is therefore judged to be minor. Consequently, the effect on the stream network, which is considered to be of moderate sensitivity, is **minor**.

14.65. During the excavation of cut tracks it will be important to ensure that the drainage system is constructed at the same time. This will therefore provide a mechanism, as described above, to control the discharge of suspended solids created during track excavation and laying. Consequently, in general, the effect will be **minor.** Construction works at stream crossings, however, will be more sensitive. In these areas particular precautions will be adopted (e.g. use of coarse screened materials, and emplacement by excavator rather than tipping by dumper) to minimise the occurrence of fine materials within the rock fill surrounding the culverts. Inevitably there will be discharges of suspended solids from the fill material or disturbed from the stream during emplacement of the culvert. However, with good practice these will be minimised. Any impact would consequently be local, temporary and small, resulting in a minor impact, and **minor** overall effect.

14.66. Siting of turbines away from watercourses will ensure that materials will not be readily washed into streams during excavation and formation of foundations and crane pads. Similarly, the contractors' compound is at least 150m from the nearest watercourse. As any drains from these areas will discharge onto undisturbed ground rather than directly into watercourses any mobilised fine materials generated by construction activities at these sites will not have a ready 'pathway' to the sensitive watercourses. Impacts and effects are therefore predicted to be **negligible**.

14.67. Unvegetated stockpiles of material will be liable to erosion, and are therefore a potential source of suspended solids. Minimising the size of stockpiles, and profiling them to reduce run off velocities will reduce the amount of washed out materials. Locating stockpiles on shallow gradients and away from watercourses will reduce the likelihood of mobilisation of suspended solids into sensitive receptors. Consequently the impact, and effect, is predicted to be **minor**.

Flow Obstruction

14.68. As discussed in paragraph 14.52 above, with suitably designed culverts in place, it is predicted that tracks will not obstruct stream courses, and there will be negligible impact and effect. However, it was also recognised that peat pipes may be caused to collapse, and that appropriate mitigation measures should be introduced to minimise this occurrence. Without mitigation, the impact is predicted to be minor to medium, and the effect **minor to moderate**.

Private Water Supplies

14.69. Of four private supplies identified in **Table 14.5,** it is only the Ascoile supply which is susceptible to impacts from windfarm construction activities, due to upgrading of the access track that is adjacent to the private supply source area. The supply could be affected in three principal ways:

- Construction disturbance causing local diversion away from the collection area;
- Construction disturbance causing suspended solids to enter the supply;
- A pollution event.

14.70. Without site specific control and mitigation measures in place, it is predicted that impacts could be major, and with the high sensitivity of the receptor, a **major** effect might occur. It will therefore be necessary to develop additional control and mitigation measures to reduce the effect. These are described in paragraph 14.96.

Erosion and Deposition

14.71. The following may cause increased erosion, and associated deposition, during construction:

- Increased surface run off volumes;
- Formation of drainage ditches and cable trenches;
- Disturbance to vegetation which binds the soil;
- Localised velocity enhancements through and adjacent to culverts;

14.72. There is abundant evidence of ongoing localised erosion at the site, both of stream banks and of peat. Erosion of peat, in particular, is a process that is difficult to control once established, and peat is therefore highly sensitive. As demonstrated in paragraph 14.50, the construction works will result in a negligible increase in catchment run off volumes which will therefore result in a **negligible** effect in terms of erosion.

14.73. In the most sensitive areas, deep peat, the site tracks will be of a floating construction, and in general it will not be necessary to create a drainage ditch. Where drains are necessary, the length of individual sections will be minimised to ensure that drainage volumes are minimised. Consequently there will be minor impact and effect on erosion. However, all turbines will require a cable trench, which, when left open, will provide a drainage route with possibilities of enhanced erosion if gradients and run off are sufficient. Cable trenches will, in general, follow the side of track routes. Consequently approximately half of the trenches will be dug across the slope, and half down the slope. It is the latter which are most susceptible to erosion. Of the down-slope trenches, that adjacent to turbines 4, 11 to 15, and 17 will cross areas of deeper peat (>2m); other down slope trenches will cross shallower peat, typically 1m. The extent of vulnerable areas is therefore relatively localised. Construction practice will involve backfilling cable trenches with local material as soon as practical, so the length of trench left open at any time across the site will be minimised. This will minimise the length of time during, and area over, which erosion may occur. Any trench erosion would subsequently be backfilled. Consequently the impact and effect are predicted to be **minor.**

14.74. In general, construction plant movements will be limited to track routes. However, there will be some movement over unmade ground, for example adjacent to foundation excavations and if it is necessary to lay sections of cable 'cross country'. These areas will necessarily be very localised, with a working area around foundations of approximately 3m. Disturbed areas will be reinstated as soon as practical. Where such disturbance occurs, there is the potential for enhanced erosion if exposed to high run off rates. However, the turbines are in general located on relatively shallow gradients that will reduce run off rates. Considering the localised extent of disturbance, temporary vulnerability, and low probability of run off rates adequate to promote erosion on relatively level ground, the impact is predicted to be minor, and the effect on high sensitivity peat is **minor**.

[5] Recommended in Forest and Water Guidelines.

Soil loss

14.75. As discussed in 14.71 to 14.74, the construction process will not significantly enhance levels of erosion over the site. Given the extensive blanket peat at the site, the soil is considered to be of value. Consequently, impacts and effects on soil are predicted to be **minor.**

OPERATIONAL AND ONGOING EFFECTS

Change to run off regime

Impermeable areas

14.76. Following completion of construction, the following surface hard standing areas will remain for the lifetime of the windfarm.

- Access and site tracks (18,818m by 4.5 to 5m wide).
- Buried turbine foundations (35 turbines 16m by 16m).
- Crane hard standings (35 approximately 20m by 30m).
- Substation compound (approximately 63m by 54m) and control building (approximately 19m by 5m).

14.77. These will introduce areas with reduced permeability, although floating tracks are relatively permeable. Some of these areas will have with localised artificial drainage, which would be discharged to adjacent unaffected ground. Consequently there will be an increase in surface run off. The impact would be localised, and on a relatively small scale, affecting approximately 2% of the site area. Consequently the impact, and hence effect on the low sensitivity run off regime would be **negligible**. Reprofiled and vegetated borrow pits would not represent impermeable areas.

Drainage patterns

14.78. Artificial drains would remain adjacent to tracks on steeper slopes. The individual lengths of these drains on steeper slopes are typically 30m, with a downslope discharge to open hillside. At this point drainage will soak in, unless conditions are such that there is already surface flow. The water table level in peat is often near the surface, so the introduction of drains will locally dry out the upper part of peat adjacent to new drains. Such impacts will be restricted to areas with new drains; in general floating tracks will not have an associated drain. Existing artificial drains demonstrate that dewatering effects occur only within one to two metres of the ditch. Consequently, impacts associated with new drainage ditches are predicted to be very localised, and of minor magnitude. Peat will be moderately sensitive to such changes, so the overall effect on groundwater levels is predicted to be **minor**.

14.79. The artificial drainage will not affect the integrity of the overall site drainage pattern. Run off changes are therefore predicted to have a local minor impact, and consequently a **negligible** effect on the low sensitivity run off regime.

14.80. Floating tracks will be a potential ongoing source of compaction, potentially reducing groundwater flow in the immediately affected area. The impact will be localised, and hence minor. Peat and associated ecology will have a high sensitivity to changes in groundwater. Overall the effect is considered to be **minor**.

Water Quality

Pollutants

14.81. The windfarm will have few significant potential sources of pollution. Quantities of turbine hydraulic and lubricating oils are small, and turbines are located away from watercourses. Consequently the predicted impact and effect of oil spillages is **negligible.**

14.82. The substation grid transformer, however, will be oil filled. The grid transformer will be bunded, alarmed, and subject to an appropriate inspection and maintenance regime. Although the substation is located within 100m of The Long Burn, a tributary of the Allt a' Mhuilinn, which will have medium to high sensitivity to pollution, the control measures in place will ensure that a major leak would be prevented or contained. There is an ongoing risk of vehicle fuel spillages although there will be fewer movements than during construction and less movement of potential pollutants and therefore the risk is low. Consequently the impact, and effect, is predicted to be **minor.**

Suspended solids

14.83. Paragraph 14.77 demonstrated that catchment run off will not be significantly increased during operation, and on this basis it is concluded that this on its own will have a negligible impact on discharge of suspended solids. This therefore constitutes a **negligible** effect.

14.84. The existence of tracks and drains present a potential ongoing source of fine materials, which could be eroded. However, the tracks and any associated drains will be subject to a maintenance programme to minimise the occurrence of wash out and erosion. Consequently the impact, and effect on water quality is predicted to be **minor.**

Flow Obstruction

14.85. There will be no direct interaction with the drainage system on an ongoing basis. However, the existence of the windfarm will introduce culverts that have the potential to become blocked. Best practice design can prevent blockage, but it will also be necessary periodically to inspect the culverts and adjacent stream bank areas. With these controls in place, any impacts would be localised, reversible, and consequently negligible. Overall the effect would be **negligible.**

Private Water Supplies

14.86. After construction, the access track is not predicted to interact with the Ascoile water supply on an ongoing basis given the mitigation measures proposed in paragraph 14.96.

Erosion and Deposition

14.87. Increased erosion, and associated deposition, may be caused by the following during the lifetime of the windfarm:

- Increased surface run off volumes;
- Existence of drainage ditches;
- Localised velocity enhancements through and adjacent to culverts.

14.88. There is abundant evidence of ongoing localised erosion at the site, both of stream banks and of peat. Erosion of peat, in particular, is a process that is difficult to control once established, and peat is therefore highly sensitive.

14.89. As demonstrated in paragraph 14.79, the ongoing existence of the windfarm will result in a negligible increase in surface run off volumes, and will therefore result in a **negligible** impact in terms of erosion. The effect will therefore be **negligible.**

14.90. In the most sensitive areas, deep peat, the site tracks will be of a floating construction and will not have associated drains. On the shallower peat where drains are necessary, the length of individual sections will be minimised to ensure that drainage volumes are in turn minimised. Consequently there will be **minor** impact and effect on erosion.

14.91. Stream channels adopt a natural form, which changes over time according to discharge characteristics and the morphology and characteristics of banks and streambed. Introduction of culverts introduces an artificial element to the channel, which may serve to inhibit erosion over the culvert length, and enhance erosion or deposition at the inlet or outlet due to abrupt changes in velocity associated with changes in stream cross section, or hardness of channel banks. Consequently well designed culverts will take account of the channel and flow conditions[i], and may feature erosion protection such as:

- Vegetation of banks;
- Dumped stone;
- Stone pitching;
- Gabion pitching.

14.92. Appropriately designed culverts will minimise erosion, and given the relatively few culverts required, will have a **negligible** impact and effect on erosion.

Soil loss

14.93. During the lifetime of the windfarm there will not be significantly enhanced levels of erosion over the site. Given the extensive blanket peat at the site, the soil is considered to be of value. Consequently, impacts and effects on soil are predicted to be **minor.**

MITIGATION MEASURES

Peat pipes

14.94. The assessment identified that the collapse of peat pipes may have a minor to moderate effect on drainage patterns and run off regime, and could also create practical difficulties during construction. In order to reduce the effect, the following mitigation will be undertaken:

- Prior to construction, a detailed track route survey will be undertaken to identify visible and audible signs of peat pipes, supplemented where necessary by probing.
- Based on the survey, tracks will be locally modified to avoid peat pipes where practical.
- Where peat pipes are unavoidable, the pipe will be excavated and an appropriately sized artificial pipe placed in the void, and recovered.
- Where undetected pipes are disturbed by construction activities, an artificial pipe will be emplaced as above if practical.

14.95. With this mitigation in place, the residual impact and effect is judged to be **negligible.**

Ascoile Water Supply

14.96. The assessment identified that the Ascoile private water supply is vulnerable to disruption and suspended solids due to adjacent access track construction. In order to reduce the effect, it is proposed that the following mitigation be undertaken:

- Prior to construction, a detailed survey will be undertaken to identify the layout of the water supply arrangements.
- Based on the survey, the track will be locally modified to avoid if practical any areas integral to the water supply, and critical areas should be fenced off.
- If it proves impractical to avoid impacts on the water supply, the contractor will identify and install alternative temporary arrangements, and provide a standby tank of potable water.
- Upon completion, existing facilities will be reinstated, or alternative supplies installed.

14.97. With this mitigation in place, the residual impact and effect is judged to be **minor**.

SUMMARY AND CONCLUSIONS

14.98. Details of the potential effects, the mitigation measures and the residual effects are summarised in **Table 14.6** and **Table 14.7**.

Table 14.6: Summary of Construction Effects on Hydrology and Hydrogeology

Potential Impact	Impact Magnitude	Sensitivity of the site	Mitigation	Effect
Natural drainage patterns	Minor	Low Due to the high drainage density, all the site drains into the same catchment and there are no surface water resources that may be affected.	Undertake site survey to identify peat pipes Modify tracks locally to avoid peat pipes where practicable. Use artificial pipes where peat pipes are disturbed.	Negligible
Runoff volumes and rates	Minor	Low	Minimise drain lengths Buffer strips No impediment of watercourses	Negligible
Groundwater and surface water quality	Minor (major with a low probability of occurrence)	Moderate Relatively untouched catchment (this does not include water supply issue)	Good working practice including appropriate and well-located storage/ bunding of concrete and oils Follow SEPA PPG guidelines No on-site maintenance of vehicles and equipment Use of drip trays Pollution response plans developed for emergency procedures	Minor
Groundwater levels	Minor	Moderate Presence of peat over the site, Water supply located at the edge of the site, but no public water supply	Minimise depth and extent of trackside drains Appropriate groundwater control measures	Minor
Water supplies	Minor	High Private water supply in the area	Undertake pre construction survey. Modify access track locally to avoid sensitive areas. Identify and install temporary arrangements. Reinstate existing facilities on completion of construction.	Minor
Erosion and deposition	Minor	High Peat is sensitive to erosion and once erosion has started it is difficult to control.	Erosion & sedimentation controls Disposal of dewatering discharge appropriately Settlement / filtration Appropriate access track design, especially in gully bottoms	Minor
Compaction	Minor	High Peat is susceptible to compaction	N/A	Minor

Table 14.7 Summary of Ongoing and Operational Effects on Hydrology and Hydrogeology

Potential Effect	Impact Significance	Sensitivity of the site	Mitigation	Effect
Natural drainage patterns	Minor	Low Due to the high drainage density, all the site drains into the same catchment and there are no surface water resources that may be affected.	Construction of appropriately sized culverts Maintain land drainage standards	Negligible
Runoff volumes and rates	Minor	Low	Minimise drain lengths Minimise impermeable areas Buffer strips No impediment of watercourses	Negligible
Groundwater and surface water quality	Minor	Moderate Relatively untouched catchment (this does not include water supply issue)	Good working practice Pollution response plans	Minor
Groundwater levels	Minor	Moderate Presence of peat over the site, Water supply located at the edge of the site, but no public water supply	Minimise drain extents and depths Watching brief in ecologically sensitive areas Ecological monitoring of blanket bog area once windfarm is operational	Minor
Water supplies	Minor	High Private water supply in the area	N/A	Minor
Erosion and deposition	Minor	High Peat is sensitive to erosion and once erosion has started it is difficult to control.	Monitor drainage network Plant exposed surfaces	Minor
Compaction	Minor	High Peat is susceptible to compaction	Appropriate access track design	Minor

REFERENCES

[i] CIRIA (Construction Industry Research and Information). (1997) *Culvert Design Guide*. Report 168. CIRIA, London.