British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

A REVIEW OF THE HYDROGEOLOGY ELEMENT OF THE KNOWEHEAD WIND FARM ENVIRONMENTAL STATEMENT

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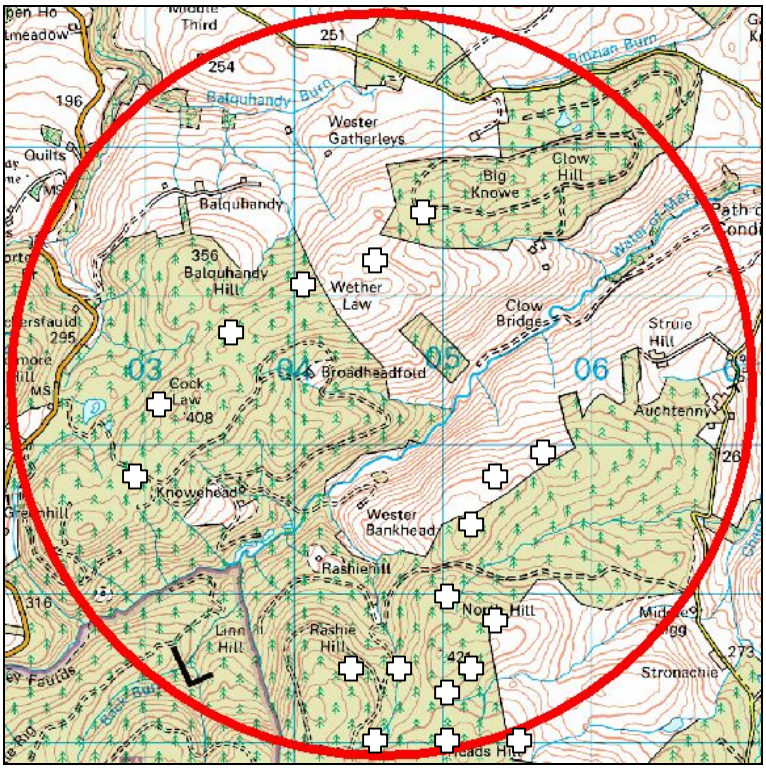
Section 1

Location of the Knowehead site

The Knowehead site is located in the eastern Ochil Hills between Kinross and Dunning.



Scale: 1:50000 (1cm = 500m)

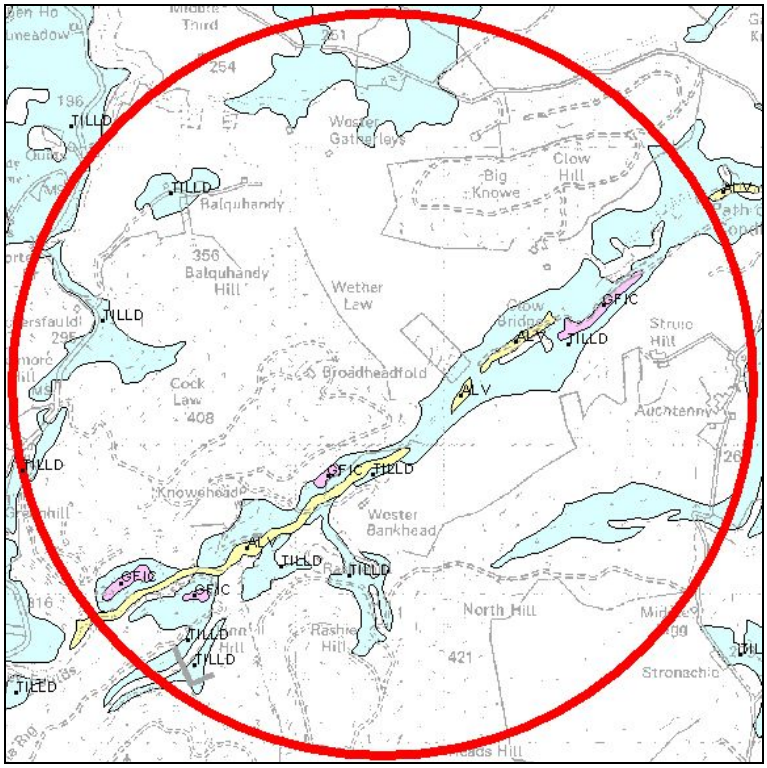
Approximate area of turbines

Figure 1: Location of the Knowehead site

1 Geology

Superficial Deposits

These include fairly recent geological deposits, such as river sands and gravels, or glacial deposits, which lie on the bedrock in many areas (an alternative term for superficial deposits is 'drift deposits')



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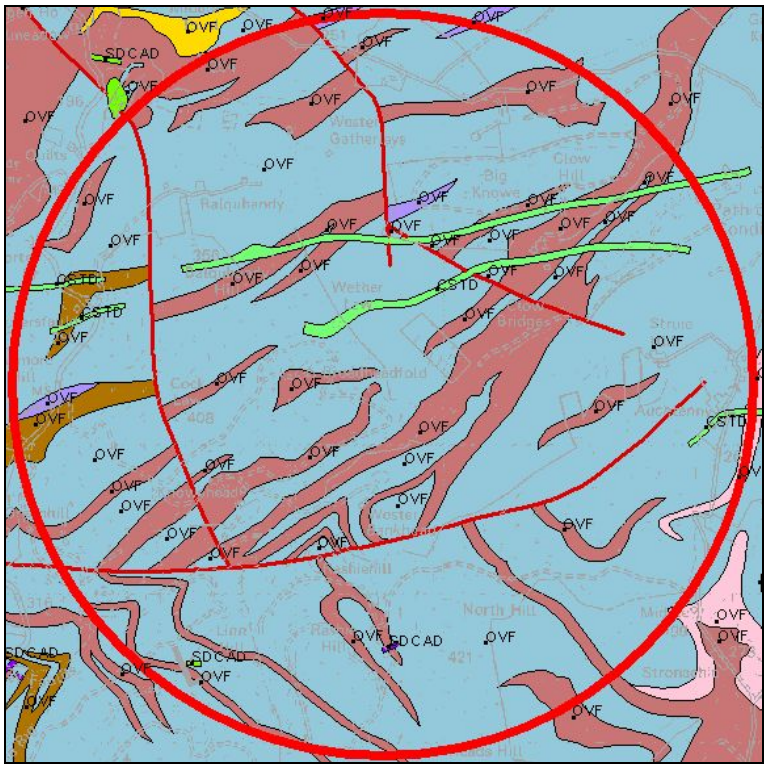
Key to Superficial deposits:

Map colour	Computer Code	Rock name	Rock type
	ALV	ALLUVIUM	CLAY, SILT, SAND AND GRAVEL
	GFIC	GLACIOFLUVIAL ICE-CONTACT DEPOSITS	GRAVEL, SAND AND SILT
	TILLD	TILL, DEVENSIAN	DIAMICTON

Figure 2: Superficial deposits

Much of the middle and lower parts of the hillsides are underlain by thin, patchy glacial till (Figure 2). This is a predominantly clayey, stony deposit with occasional coarser grained sand and gravel horizons. The proposed areas for turbine installation are underlain either by very thin superficial deposits (generally <1 m thick) or where bedrock is either at or very close to surface. Alluvium (typically comprising poorly consolidated sands, gravels, silts and clays) is mapped as patchy deposits along the valley of the Water of May. A few areas of glaciofluvial deposits (comprising sand and gravels with clays and silts) are also mapped along the valley at levels generally higher than the alluvium.

Bedrock



Scale: 1:50000 (1cm = 500m)

Fault

Coal, ironstone or other mineral vein

Note: Faults and Coals, ironstone & mineral veins are shown for illustration and to aid interpretation of the map. Not all such features are shown and their absence on the map face does not necessarily mean that none are present

Key to Bedrock geology:

Map colour	Computer Code	Rock name	Rock type
	CSTD	CENTRAL SCOTLAND LATE CARBONIFEROUS THOLEIITIC DYKE SWARM	QUARTZ-DOLERITE
	OVF	OCHIL VOLCANIC FORMATION	ANDESITE
	OVF	OCHIL VOLCANIC FORMATION	PYROXENE-ANDESITE
	OVF	OCHIL VOLCANIC FORMATION	ANDESITIC TUFF
	OVF	OCHIL VOLCANIC FORMATION	BASALT, MACROPORPHYRITIC (UNCLASSED)
	OVF	OCHIL VOLCANIC FORMATION	CONGLOMERATE
	OVF	OCHIL VOLCANIC FORMATION	TRACHYTE GROUP
	MVMAI	MIDLAND VALLEY SILURO-DEVONIAN MAFIC INTRUSION SUITE	DOLERITE
	SDCAD	NORTH BRITAIN SILURO-DEVONIAN CALC-ALKALINE DYKE SUITE	DOLERITE
	SDCAD	NORTH BRITAIN SILURO-DEVONIAN CALC-ALKALINE DYKE SUITE	MICRODIORITE, PORPHYRITIC

Figure 3: Bedrock geology

Lower Devonian basaltic-andesite and conglomerate belonging to the Ochil Volcanic Formation underlie the whole site (Figure 3). Igneous intrusions are also present. In the north of the site, two quartz-dolerite dykes run approximately east to west.

The upper few metres of the volcanic rock are normally highly fractured as a result of glacial activity and weathering processes. Below this, the rock is generally fresh and contains fewer void spaces.

2 Hydrogeology

Superficial deposits

Groundwater is present mainly within sandy, gravelly beds interbedded within the till deposits. These are common in the area, particularly on the lower slopes of the valleys where significant flows of groundwater may be present which can form useful, but vulnerable, domestic supplies. However, the main body of till itself can also have a significant permeability owing to the sandy nature of the material and the likely presence of fissures and fractures. In general, groundwater flow paths in till are very localised and can be complex. In some places, although not necessarily in the Knowehead area, they are dominated by the presence of higher-permeability beds of sand and gravel which may occur sporadically. Groundwater will also occur in the alluvial deposits and is likely to form a significant component of baseflow to the Water of May and other surface waters.

Bedrock

The upper weathered zone of the Ochil Volcanic Formation is the principal layer where groundwater is thought to be present. Recharge to this relatively high-permeability fractured zone occurs either by infiltration of rainwater from the ground surface where bedrock is exposed, or from the basal beds of any overlying alluvium or till. From this zone, groundwater moves down slope according to surface topography and may appear at springs. Many shallow wells are dug into this layer to intercept the water table. Deeper boreholes intercept deep, interconnected, fractures in the volcanic rock to provide a water supply.

Section 2: The Environmental Statement review

The Environmental Statement (ES) has been produced by British Energy Renewables Ltd and is dated July 2004.

The proposal is for the construction of 24 turbines at Knowehead to the south east of Dunning (centred at approximately NO 046 104).

Environmental Statement: Vol 2, Chapter 9: Geology, Hydrogeology and hydrology

Geology

9.41 and 9.42 provide a short description of both the solid and superficial geology.

Overall an accurate summary.

Hydrogeology

9.45 to 9.53 provide a description of the hydrogeological conditions across the site and the main groundwater features are discussed. The potentially significant shallow groundwater that is likely to be present in the till and in the alluvium are considered. Recognition is made of the relatively small amounts of groundwater held in storage in deeper bedrock fractures. A discussion on the likely origin of springs is included in Sections 9.47 to 9.53. The hydrogeology section indicates that groundwater may be derived from shallow superficial deposits, weathered bedrock or deeper fractures in rock.

Groundwater in the superficial deposits could be very important when considering the potential impact on surface waters as the water in these deposits, particularly the alluvium, may provide a significant contribution to baseflow in nearby surface waters and supply private properties. Abstraction of groundwater can also be made from water bearing fractures over 60 metres below surface in the weathered or fractured bedrock.

Groundwater vulnerability

9.54 describes the vulnerability of the groundwater to pollution.

SEPA's latest vulnerability maps, produced by the BGS, indicate that fractured bedrock with thin or no sandy till cover is highly vulnerable to pollution. However, these maps are not available to consultants yet. Therefore British Energy Renewables Ltd have correctly, used the latest available publicly accessible data sources.

Receptors

Private water supplies:

9.68 states that Perth and Kinross Council do not hold records of groundwater abstractions for this area as less than 25 people are supplied by each source. However it is noted that there are upwards of 20 known well, boreholes and spring abstractions in the study area and more within 1 km of the area.

Staff from BGS made a site visit to the area in November 2004. Discussions with local land owners suggests that there are significantly more than 20 private water supplies in the vicinity of the proposed development and many are not included in the ES. It is important that the location and nature of all private water supplies are identified.

Table 9.6 lists the locations and nature of all identified surface and groundwater abstractions and Table 9.7 summarises the potential effects on hydrology and hydrogeology arising from the wind farm developments. Figure 9.2 illustrates the locations of all the identified private water supplies.

Following discussions with local residents a number of errors were identified in the ES.

- *Auchtenny: have a spring supply that does not dry up. Not a borehole as detailed in the ES.*
- *Knowehead Farmstead: have one well (NO 0323 0939) not two as recorded in the ES. There is also a private water supply at Broadhead at approximately (NO 0400 1050).*

It is important that the exact location and nature of all private water supplies are correctly identified and any additional private water supplies also need to be identified. It would be useful if the source of each spring could be described, ie. whether shallow or deep in addition to an estimation of the flow rate.

Figures 9.4 to 9.6 highlight the details for 6 sites considered most at risk (Balquahandy, Gatherleys, Knowehead, Struie Hill, Stronachie and Rashie Hill). It would be useful if these figures included all features in the proposal eg. sites for borrow pits and the construction compound.

Balquhandy (Figure 9.4: Inset 1)

BGS staff were unable to speak to residents but local neighbours identified one spring used at West Balquhandy for private water supply at approximately (NO 031 115). Another spring supplies Easter Balquhandy, which comprises two properties. The springs highlighted on Fig 9.4: inset 1 (17 &18) as private water supplies were not thought to be used. A spring close to the Horse Burn (marked on Fig 9.4: inset 1) is thought to supply properties at Easter Balquhandy. This spring is approximately 150 metres downhill from Turbine 4 and, although Section 9.135 (Inset 1) states that the potential impact to the Balquhandy spring is minor to insignificant, it is possible that any groundworks at the turbine site will affect the spring. Hence, a closer look at this spring site is recommended.

Gatherleys (Figure 9.4: Inset 2)

BGS spoke to the owner of Wester Gatherleys and visited various spring sources.

The owners of Wester Gatherleys currently use a spring (Fig 9.4: inset 2: no 7) but it is located slightly above where mapped (approximately NO 046 117). There is a spring that the owners are considering using as an additional supply. (Fig 9.4: inset 2: no 19). Fig 9.4: inset 2: springs 16 & 20 are piped to neighbouring properties.

Springs 7 & 20 are only approximately 500 metres from Turbine 6 and there is a borrow pit planned that is approximately 200 metres to the east at a similar elevation to spring 19. The borrow pit is also approximately 150 metres south-west of spring 16 and at a slightly higher elevation. Spring 19 is only approximately 175 metres from Turbine 5.

These springs (7, 19 and 20) lie very close to the proposed turbines and borrow pits and could, potentially, be affected by the development. It is important that the catchments of these springs is determined and samples taken for water quality assessment prior to any development work. The risk to some or all of these springs is considered by BGS to be moderately high, with potentially significant impacts on water supply.

Knowehead (Figure 9.5: Inset 3)

According to tenants, their private water supply is from a shallow well (approx 3.5 metres deep) at location marked as Well 10 on Fig 9.5: inset 3, adjacent to a spring.

This spring is approximately 400 metres south-east of Turbine 1. There is also a proposed borrow pit approximately 200 metres north-west of the spring and an access track proposed that is upslope of it. A construction compound is also sited nearby. These developments could affect the spring supply for this property.

Struie Hill (Figure 9.5: Inset 4)

The owner indicated to BGS that the spring position as reported in the ES appears to be correct. The spring supplies Struie Hill Farm and a house at the bottom of the lane up to the farm.

The spring is approximately 300 metres from Tturbine 7. However, the spring appears to lie on the other side of the hill and therefore the springs catchment should not be affected by the turbine.

Stronachie (Figure 9.6: Inset 5)

Table 9.6 identifies 2 surface water abstractions at Stronachie from the Ray Burn and the Cairnavain Burn. Figure 9.6 identifies two spring supplies.

A neighbour thought that the owners at Stronachie use both surface water from the Rae Burn and a borehole, although the locations were not provided. The headwaters

of the Rae Burn are very close to Turbines 14, 15, 19, 23 and 24 and a number of access tracks. The installations could potentially affect the water supplies.

Rashie Hill (Figure 9.6: Inset 6)

BGS were unable to speak to owners or locate the spring.

The proposed location for Turbine 11 is upslope of the spring identified on inset 6; the is a slight possibility that the proposed development could affect the water supply.

9.69 states that due to the hydrogeological regime, groundwater is considered to be an important source of water supply in parts of the site.

It is likely that many of the properties are either supplied from shallow groundwater derived from the till or from shallow bedrock where it is locally fractured and weathered. Due to the fractured nature of the bedrock, rapid flow can occur and sources some distance away may be affected by the proposed development, although it is unlikely that any deep abstraction boreholes located more than 2km from the margins of the development would be affected.

Surface water:

9.70 states that the largest abstraction is public water abstraction from the Water of May.

9.71 states that there are also several private surface water abstractions in the site area

Table 9.6 lists the locations and nature of all identified surface and groundwater abstractions and Table 9.7 summarises the potential effects on hydrology and hydrogeology arising from the wind farm developments.

Discussions with local residents has indicated that the majority of farms in the area rely on surface water for their livestock. BGS considers that groundwater baseflow to streams may be significant. Therefore, the construction of tracks and pits some distance from steams may have a temporary effect on the quality of water in them and also the private water supplies of any properties that use surface water for water supply. This is unlikely to be significant, but the role of shallow groundwater flow in bedrock and drift deposits as baseflow to surface streams should be recognised.

Groundwater-dependent ecosystems

Chapter 6 comprises and ecological assessment of the proposed windfarm.

BGS consider that there may be a minor, localised, impact on surface waters and groundwater-dependent ecosystems during construction, operation and

decommissioning, both from the discharge of sediment into nearby water bodies and from surface water run-off. However, the risk is considered to be low.

Monitoring

9.136 to 9.140 provide details of the proposed monitoring for baseline data and during construction, operation and decommissioning.

BGS considers that routine quality inspections of sensitive environmental features within the site and the vicinity should be carried out along with monitoring of all private water supply sources that could be affected by the proposed development works.

Conclusions

- It is important that the location and nature of all private water supplies are identified. From discussion with local residents there are a large number of properties that have private water supplies in the vicinity of the proposed development that have not been included in the ES.
- Shallow groundwater present in the till and the weathered bedrock zone could be providing significant amounts of groundwater as baseflow to streams, to springs and to a large number of shallow wells and boreholes.
- Whilst BGS consider the overall risk to the groundwater receptors mentioned in the ES as low, there may be local impacts on shallow groundwater, including temporary reductions in water quality and impacts on groundwater dependant ecosystems. There are a number of private water supplies identified that may potentially be affected by the development and there may be other sources that could be affected that are not specified in the ES.
- Routine quality inspections of sensitive environmental sites within the vicinity of the development should be carried out, with monitoring of all private water supplies that could be affected by the proposed development. Monitoring is recommended prior, during, and for a short period after any construction work.