A83 Rest and Be Thankful

MTS EIAR VOLUME 4, APPENDIX 8.1 - CUTTINGS ASSESSMENT

Transport Scotland

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A8-1. Cuttings Assessment

A8-1.1. Introduction

A8-1.1.1. This assessment considers the impact of the cuttings associated with the Proposed Scheme on groundwater aquifers and specifically how these interact with potential Groundwater Dependent Terrestrial Ecosystems (GWDTE), which is the focus of the assessment within Volume 2, Chapter 8 Geology, Soils and Groundwater.

A8-1.1.2. The primary mechanism of impact is through the excavation of road cuttings. Road cuttings have the potential to affect both groundwater flow and groundwater levels while also increasing the vulnerability of local aquifers to contaminants as overlying material is removed. Where road cuttings penetrate the groundwater table this may result in permanent change to local groundwater levels and flow patterns, directly impacting the aquifer and indirectly affecting the local groundwater dependent receptors. Groundwater levels can change seasonally and cuttings that penetrate close to the groundwater table may have seasonal impact i.e. during wet periods when the groundwater table rises above the base of the cutting.

A8-1.1.3. The Study Area for the assessment is as defined in Volume 2, Chapter 8, Geology, Soils and Groundwater and the assessment considers the impacts from the Proposed Scheme.

A8-1.2. Approach and Methods

A8-1.2.1. An assessment has been undertaken on each cutting along the Proposed Scheme to assess the potential impacts on the groundwater resources within the underlying aquifer(s).

A8-1.2.2. The location of each road cutting along the Proposed Scheme was identified and the maximum depth of each cutting was calculated using QGIS and information from 3D design models. Several cuttings were identified to be present along the Proposed Scheme, however not all of the cuttings designated as an embankment cut feature in the QGIS shapefile for the Proposed Scheme are shown to be present on the 3D design Models and Proposed Scheme cross-sections as a change in ground level.

A8-1.2.3. Where a shapefile is present within the QGIS model, but no change in ground level is demonstrated on the cross-section for the Proposed Scheme, the cutting is not taken further in the assessment. These nominal changes in ground level (less than 0.01m) have been identified as cuttings in the Proposed Scheme's GIS database, however, many are associated nominal changes in the road surface elevation.

A8-1.2.4. For the purposes of the assessment, a cutting is considered to be a feature which demonstrates a clear change in the profile of the ground surface following the Proposed Scheme, as such features held within the QGIS database which do not demonstrate a change in the profile of the ground surface level following the Proposed Scheme are removed from the assessment at the initial stages.

A8-1.2.5. The geology was identified using the results from historical ground investigation (GI) logs and the British Geological Survey (BGS) online geological data.

A8-1.2.6. The depth to groundwater at each of the cuttings was calculated using a combination of available groundwater level readings and groundwater contour plots which were modelled by AtkinsRéalis on QGIS using groundwater monitoring data available at the time of authoring, only boreholes located within 25m of the cutting were used. Boreholes in which groundwater level data was available but were installed in a different geology were not used due to the potential differences in groundwater level resulting from different geologies permeabilities. Limitations to this technique are discussed below in paragraphs A8-1.2.14 and A8-1.2.17. Where no groundwater level data was available, a conservative groundwater level was applied to the cutting (assuming water table at surface).

A8-1.2.7. Where the base of the cutting, as defined by the ground surface models, was found to not intercept groundwater, where groundwater level data is available, the cutting has been removed from any further assessment.

A8-1.2.8. Hydraulic conductivity values have been derived for each unit based on rising / falling head test results from historical GI, or from literature values in the 2006 British Geological Survey's Guide to Permeability Indices.

A8-1.2.9. The base elevation of the aquifers was determined using available GI data. Regarding the superficial aquifers, geological strata information from the nearest borehole to each cutting was used to find the base of the superficial aquifer. For the bedrock aquifers, the deepest GI borehole reach a depth of 50m into the bedrock, where frequent fracturing indicates a fracture permeability, groundwater within the bedrock aquifer is likely to be present at this depth.

A8-1.2.10. For the groundwater impact assessment, the aquifer thickness is not applicable for the relevant equations to define flow rates or zone of influence. As such, the total depth of bedrock aquifer is immaterial and has not been considered further within this specific assessment.

A8-1.2.11. To determine the likely impact of the road cuttings on groundwater flows and groundwater levels, the drawdown and the distance / area of influence has been calculated for each cutting.

A8-1.2.12. The method for estimating the distance of influence of individual road cuttings has been based on the widely used empirical formula for calculating the radius of influence of point groundwater abstractions, as presented in 2016 CIRIA report C750 Groundwater Control: Design and Practice. This method is considered appropriate to this level of assessment and the available data. Limitations to this technique are discussed below in paragraphs A8-1.2.14 and A8-1.2.18.

A8-1.2.13. The radius of influence for a given drawdown and hydraulic conductivity is given by the Sichardt equation:

$$R0 = Ch\sqrt{k}$$

- Where R0 = distance / radius of influence (m);
- k = hydraulic conductivity (m/sec);
- h = drawdown in groundwater level (m) i.e. penetration of the cutting beneath the water table; and,
- C = 2000 for linear flow, where C is a constant.

A8-1.2.14. The Sichardt equation method has inherent uncertainties. The calculations depend on an empirical constant (C = 2000 for linear flow) for which a conservative value has been used, which may result in an overestimation of the flow as this is likely to be representative of a permanent flow rate, which is considered unlikely to be the case. It also relies upon the assumptions that the aquifer is unconfined, has an infinite areal extent and that the aquifer is homogenous, isotrophic and of uniform thickness. However, it is considered a reasonable estimate of likely zone of influence.

A8-1.2.15. The flow discharge rates were also calculated for each of the cuttings using the following equation:

$$Q_W = \left[0.73 + 0.27\frac{P}{H}\right]\frac{kx(H^2 - h_w^2)}{L_0}$$

Where:

- Q_W = calculated flow discharge rate
- P = the penetration below the original water table (m)
- H = initial piezometric head (m)
- x = linear length of the cut (m)
- h_W = drawdown head (m) and
- L_0 = distance of influence (m).

A8-1.2.16. The following assumptions have been applied to the use of the above equation:

- the aquifer is unconfined, homogenous, isotrophic and of uniform thickness;
- the initial water table is horizontal; and
- L_0 is obtained using Sichardts equation, with the use of C as 2000.

A8-1.2.17. The following limitations have been identified for the use of the flow discharge rate equation:

- cuttings are only partially penetrating the unconfined aquifer below the original water table;
- the calculation assumes the cut area is completely dewatered;
- the recorded groundwater level (where available) is assumed to be the original water table;
- the true aquifer thickness may not have been proven during the ground investigation, therefore a value that best represents the on-site conditions may have been used in the assessment;
- the equation assumes that the impact from dewatering impacts the full aquifer thickness when in reality a minor cut (i.e. 5m into a 30m thick aquifer) will not impact the saturation zone beneath the base of the cut; and
- permeability may vary across the cut i.e. variable lithologies and variations in measured values may be because of limitations in test techniques undertaken during the GI and results may not reflect the properties of the ground across the cut.

A8-1.2.18. At this stage there is limited groundwater level data available for the Proposed Scheme and therefore the assessment has been undertaken using conservative worst-case scenario levels where there is an absence of data.

A8-1.3. Groundwater Assessment

Groundwater Levels

A8-1.3.1. A total of 34 cuttings have been identified along the Proposed Scheme.

A8-1.3.2. The minimum elevation for each cutting was extracted using GIS and from 3D design models of the alignment and checked against 25m interval cross sections of the alignment.

A8-1.3.3. Where groundwater level information is available, the deepest penetration of the cutting into the groundwater table has been taken to provide a worst-case estimate of the impact for the cuttings located along the Proposed Scheme.

A8-1.3.4. For the cuttings the following criteria have been utilised:

- Where there is a groundwater monitoring point at the location, or immediately nearby (within 25m of the cutting), the recorded depth to groundwater has been used in the assessment. However, where a groundwater monitoring point is located within 25m of the cutting but the geology of the installation is not the same as that of the cutting, this data has not been utilised.
- Where no groundwater level data is available, or a suitable monitoring point, and no significant surface water features are present, a conservative groundwater level estimate of 0.0m below ground level (bgl) has been utilised in the assessment (i.e. at surface). This value was selected due to the presence of very shallow groundwater recorded across the Proposed Scheme.

A8-1.3.5. Limited groundwater monitoring data has been provided from 2022 historical GI (Preliminary Sources Study Report (PSSR), Jacobs AECOM). This data is presented in Table A8-1-1. Further groundwater monitoring and investigation is recommended to infill the data gaps present.

Table A8-1-1 – Groundwater Levels along the Proposed Scheme

Borehole ID	Easting	Northing	Average Groundwater Levels (m AOD*)	Maximum Groundwater Levels (m AOD)	Minimum Groundwater Levels (m AOD)
AAB-BH1026	223739.2	706538.9	124.64	125.12	124.24
AAB-BH1027A	223691.1	706705.0	141.44	141.68	141.06
AAB-BH1041	224634.8	704763.9	90.54	90.79	90.35

Note: *AOD – Above Ordnance Datum

Drawdown

A8-1.3.6. Estimations of drawdown have been produced by subtracting the estimated maximum groundwater levels (m AOD) from the cutting base elevations. Cuttings where the groundwater level is considered likely to be deeper than 1m below the base of the cutting were considered to pose no significant risk of affecting groundwater and were screened out from further assessment.

A8-1.3.7. For cuttings in which nominal changes in the ground surface level are demonstrated on the design models these cuttings have been screened out of further assessment. Numerous of these nominal cutting features were identified in the QGIS shapefiles for the Proposed Scheme and allocated an individual cutting reference. These are primarily associated with nominal changes to the road surface level, and the tailing out across the road surface of the main embankment cutting (which has separate cutting identification) to the north-east of the existing road network.

Hydraulic Conductivity

A8-1.3.8. Hydraulic conductivity of the ground, defined by the nature of the geology in the area, is highly variable. This has been confirmed by the on-site in-situ permeability testing.

A8-1.3.9. Where data is available, aquifer hydraulic conductivity has been estimated from GI infiltration tests carried out in the course of the 2022 GI for each of the geological formations (Table A8-1-2). For the rest of the cutting locations, generic and relatively conservative hydraulic conductivity values have been used based on the geological formation shown to be present at the location, these were used for three formations which were not tested in the 2022 GI and were based on ranges presented in the 2006 British Geological Survey's Guide to Permeability Indices.

Table A8-1-2 – Hydraulic Conductivity of on-site Geological Formations

Geology	Hydraulic Conductivity* (m/s)	Exploratory Hole Number
Hummocky (Moundy) Glacial Deposits	1.36x10-07 9.21x10-8 8.10x10-8 Average: 1.03x10-7	AAB-BH1037 (3 tests)
Till, Devensian	6.53x10-7	AAB-BH1032 (1 test)
South Of Scotland Granitic Suite - Intrusion-Breccia and Tuffisite	9.96x10-7 1.27x10-7 7.64x10-8 Average: 4.00x10-7	AAB-BH1020 (3 tests)
Beinn Bheula Schist Formation - Psammite and Pelite	1.47x10-7	AAB-BH1036 (1 test)
Alluvium - Clay, Silt, Sand and Gravel	1.81x10-07	AAB-BH1026 (1 test)
River Terrace Deposits, 1 - Gravel, Sand, Silt and Clay	1.00x10-03	BGS Literature value
South Of Scotland Granitic Suite - Diorite, Pyroxene-Mica	1.15x10-10	BGS Literature value
South Of Scotland Granitic Suite - Tonalite	1.15x10-10	BGS Literature value

A8-1.4. Results

A8-1.4.1. Following completion of the assessment it was found that 17 of 34 cuttings relating to the Proposed Scheme would intercept the groundwater table, due to the intermittent presence of groundwater level data along the Proposed Scheme and a conservative level being used of 0.0m bgl (i.e. at surface) where no groundwater level data is available.

A8-1.4.2. The remaining 17 of the identified 34 cuttings were considered to have no impact on groundwater flows and have been screened out of the assessment as they were modelled to not intercept groundwater or to have only nominally cut into existing surface.

A8-1.4.3. Several cuttings were presented in the QGIS shapefile for but did not appear to demonstrate a change in ground level in the cross-sections for the Proposed Scheme and have been discounted from the assessment for the OMR cuttings as they are not 'true cuttings'.

A8-1.4.4. It has been anticipated that groundwater would be intercepted at 17 locations, shown in Table A8-1-3. Details are provided of the estimated drawdown and calculated radius of influence for each of the cutting locations.

A8-1.4.5. For many of the cuttings, the limited availability of accurate groundwater level readings and site-specific hydraulic conductivity values, has likely over-estimated the impact of the cuttings on the groundwater at that location, with acknowledged uncertainty due to the lack of GI data.

A8-1.4.6. As presented in Table A8-1-3, lateral distance values for radii of influence are very limited; all cuttings being estimated as less than 2m. This information is a key input within the GWDTE assessment presented in Volume 2, Chapter 8: Geology, Soils and Groundwater, demonstrating that cuttings introduce very limited alterations to groundwater levels in the Study Area.

Table A8-1-3 – Cuttings Assessment Results

Cutting ID	NGR (centre)	Chainage	Drawdown (m)	Permeability value (m/sec)	Radius of Influence (m)	Discharge flow rate (L/sec)	Groundwater Body
9	224332,705457	Ch1080. to Ch1190.	0.06	6.53x10-7	0.10	0.12	Till
10	224350,705417	Ch1090. to Ch1095.	0.52	6.53x10-7	0.84	0.01	Till
11	224318,705542	Ch1100. to Ch1320.	1.96	1.47x10-7	1.51	0.22	Beinn Bheula Schist Formation - Psammite and Pelite
12	224304,705542	Ch1220. to Ch1240.	0.18	6.53x10-7	0.29	0.02	Till
13	224286,705573	Ch1250. to Ch1275.	0.04	6.53x10-7	0.06	0.03	Till
15	224226,705706	Ch1320. to Ch1470.	1.16	6.53x10-7	1.88	0.20	Till
16	224241,705650	Ch1350. to Ch1355.	0.01	6.53x10-7	0.01	0.01	Till
17	224231,705667	Ch1360. to Ch1380.	0.13	6.53x10-7	0.2	0.02	Till

Cutting ID	NGR (centre)	Chainage	Drawdown (m)	Permeability value (m/sec)	Radius of Influence (m)	Discharge flow rate (L/sec)	Groundwater Body
18	224186,705740	Ch1455. to Ch1460.	0.05	6.53x10-7	0.09	0.01	Till
19	224194,705757	Ch1470. to Ch1480.	1.07	6.53x10-7	1.72	0.01	Till
21	224144,705839	Ch1480. to Ch1650.	2.20	1.47x10-7	1.68	1.26	Beinn Bheula Schist Formation - Psammite and Pelite
22	224153,705795	Ch1490. to Ch.1550.	0.04	6.53x10-7	0.06	0.06	Till
23	224092,705898	Ch1630. to Ch1650.	0.09	6.53x10-7	0.15	0.02	Till
24	224093,705954	Ch1660. to Ch1725.	0.95	6.53x10-7	1.53	0.09	Till
25	224083,705928	Ch1670. to Ch1675.	0.07	6.53x10-7	0.11	0.01	Till
26	224072,706034	Ch1765. to Ch1800.	0.23	6.53x10-7	0.37	0.05	Till

Cutting ID	NGR (centre)	Chainage	Drawdown (m)	Permeability value (m/sec)	Radius of Influence (m)	Discharge flow rate (L/sec)	Groundwater Body
27	224054,706038	Ch1775. to Ch1795.	0.07	6.53x10-7	0.11	0.02	Till