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GLEANN MOR FOREST ROAD ARGYLL & BUTE, SCOTLAND

A Report on a demonstration of the ROADEX method for assessing forest roads on the Gleann Mor forest road in the Cowal & Trossachs forest district, Argyll & Bute, Scotland

ABSTRACT

The European Union ROADEX Project 1998 – 2012 was a trans-national roads co-operation that aimed at developing ways for interactive and innovative management of low volume roads across the European Northern Periphery. Its main goals were to facilitate co-operation and research into the common problems of constructing and maintaining low volume roads in harsh climates.

This report gives a summary of a local demonstration of ROADEX methods for assessing forest roads for heavy timber traffic. The work was carried out by the road condition survey team of the Forestry Commission's Civil Engineering Central Services on the Gleann Mor forest road in Cowal & Trossachs Forest District, Argyll & Bute, Scotland over the period June 2009 to June 2010

The road was first surveyed using the modern non-destructive road survey techniques of video, ground penetrating radar (GPR) and falling weight deflectometer (FWD). Following this an integrated analysis was carried out using Road Doctor software to produce a metre by metre strength assessment of the road.

The results were then further developed by the Forestry Commission (FC) to create a suite of spreadsheets to identify the amount of additional stone required for the road to bring it up to the required strength.

The paper discusses the methods of survey involved, the interpretation of the collected data, the development of assessment methods and the presentation of the resulting information to managers. It includes:

- A summary of the ROADEX Project
- The initial surveys in June 2009 and their interpretation
- The assessment method
- The follow-up GPR survey in June 2010
- A discussion of what was achieved
- The lessons learned

KEYWORDS
ROADEX, forest roads, assessment, strengthening

PREFACE

This is a final report from Task D3 of the ROADEX "Implementing Accessibility" project, a technical trans-national cooperation project between The Highland Council, Forestry Commission Scotland and the Western Isles Council from Scotland; The Northern Region of The Norwegian Public Roads Administration; The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency; The Centre of Economic Development, Transport and the Environment of Finland; The Government of Greenland; The Icelandic Road Administration; and The National Roads Authority and The Department of Transport of Ireland.

The lead partner of the ROADEX "Implementing Accessibility" project was The Northern Region of The Swedish Transport Administration and the project consultant was Roadscanners Oy from Finland.

This report records a demonstration of the use of ROADEX methods to assess a forest road for heavy timber traffic. The works includes the initial survey, interpretation and assessment, recommendation for strengthening measures, and a follow-up survey with lessons learned. The report was prepared by Alan Drake of the Forestry Commission's Civil Engineering Central Services. Mika Pyhähuhta of Laboratorio Uleåborg designed the graphic layout.

The author would like to express his gratitude to the following persons for their assistance in the work:

- David Killer (Head of Civil Engineering - retired) who inaugurated and steered the Forestry Commission project through the first formative years,
- Timo Saarenketo of Roadscanners who supported David Killer throughout the development of the project and continues to support the author,
- Pekka Maijala of Roadscanners who devised the software modifications for stiffness moduli calculation,
- Gordon McCheyne formerly of Civil Engineering Central Services who devised the Stone Depth analysis spreadsheet procedure,
- Frank MacCulloch, former Head of Civil Engineering and Director Forestry Business Units Forestry Commission, who has been an enthusiastic advocate of the project throughout.

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1. INTRODUCTION

1.1. THE ROADEX PROJECT

The ROADEX Project was a technical co-operation between road organisations across northern Europe that aimed to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finnish Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX “Implementing Accessibility” from 2009 to 2012.

Figure 1.1 The Northern Periphery Area and ROADEX Partners

The Partners in the ROADEX “Implementing Accessibility” project comprised public road administrations and forestry organisations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and the Western Isles Council from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency, The Centre of Economic Development, Transport and the Environment of Finland, The Government of Greenland, The Icelandic Road Administration and The National Roads Authority and The Department of Transport of Ireland.

The aim of the project was to implement the road technologies developed by ROADEX on to the partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland.

The project was awarded NPP funding in September 2009 and held its first steering Committee meeting in Luleå, November 2009.

A main part of the project was a programme of 23 demonstration projects showcasing the ROADEX methods in the Local Partner areas supported by a new pan-regional "ROADEX Consultancy Service" and "Knowledge Centre". Three research tasks were also pursued as part of the project: D1 "Climate change and its consequences on the maintenance of low volume roads", D2 "Road Widening" and D3 "Vibration in vehicles and humans due to road condition".

All reports are available on the ROADEX website at www.ROADEX.org.

1.2. ROADEX DEMONSTRATION PROJECTS

The aim of the ROADEX demonstration projects was to demonstrate the use of ROADEX strategies and technologies locally in the Partner areas to encourage their general use in the Partner offices. Projects were funded and executed by the local Partner offices with design and management support from the ROADEX consultancy service. The demonstration groups were:

D1 Drainage maintenance guidelines
D2 Road friendly vehicles and tyre pressure control
D3 Forest road policies and maintenance
D4 Rutting, from theory to practice
D5 Roads on Peat
D6 Health and vibration

All projects were delivered within the project timescale and reports are available on the ROADEX website at www.roadex.org.

1.3. TASK D3 FOREST ROADS POLICIES AND MAINTENANCE

The aim of the Task D3 projects, "Forest Roads Policies and Maintenance"" was to demonstrate the ROADEX methods of using integrated survey and analysis for assessing of public and forest roads. These forms of integrated methods did not exist before being introduced in the ROADEX pilot project in 1998 but since then have gained increasing popularity in roads districts across the Northern Periphery.

The Forestry Commission had been a Partner in the ROADEX Project since 2002 and had invested heavily in personnel and resources to manage their forest road networks to their maximum potential. A recent innovation has been the introduction of GIS tools to enable improved recording of road data, including usage, construction and maintenance details. This information had been needed to create up-to-date databases, improve road planning and justify infrastructure investments on the Forestry Commission forest road network of 30,000 km of roads.

The ROADEX methodologies for assessing forest roads, and the development of new rehabilitation strategies, were a key component in achieving the new direction. As part of their investment in modern technologies, the Commission established a dedicated 2-man Road Condition Survey team and developed a survey vehicle for the assessment of their 30,000 km forest road network. The vehicle was equipped with state-of-the-art GPR, GPS and video systems following discussions within ROADEX.

The survey and assessment of the Gleann Mor Forest Road that follows is an example of the work produced by the team.

2. GENERAL DESCRIPTION OF THE ROAD

2.1. LOCATION

The Gleann Mor forest road is located on the main timber extraction route from Lochgoilhead in Arygyll & Bute. The road runs from the B839 public road, 3km west of Lochgoilhead, in a north-easterly direction to the B828 public road just south of its junction with the A83 trunk road at the "Rest and be Thankful" summit. The road was constructed in the 1950's as a dedicated forest route to allow timber vehicles to transport timber from the forest blocks in the Lochgoilhead area to the main A83 trunk road, thereby bypassing the steep gradients and tight bends of the existing B828.

The forest blocks at Lochgoilhead have reached maturity and are in full production with the Gleann Mor road acting as the main arterial route out for loaded timber vehicles. The road is expected to be in constant use for the foreseeable future and deemed to be in need of upgrade in 2009. The surveys and assessments that follow were commissioned to inform the planning of the upgrade.

The Gleann Mor forest road is 5623 metres long and is single track throughout its length.

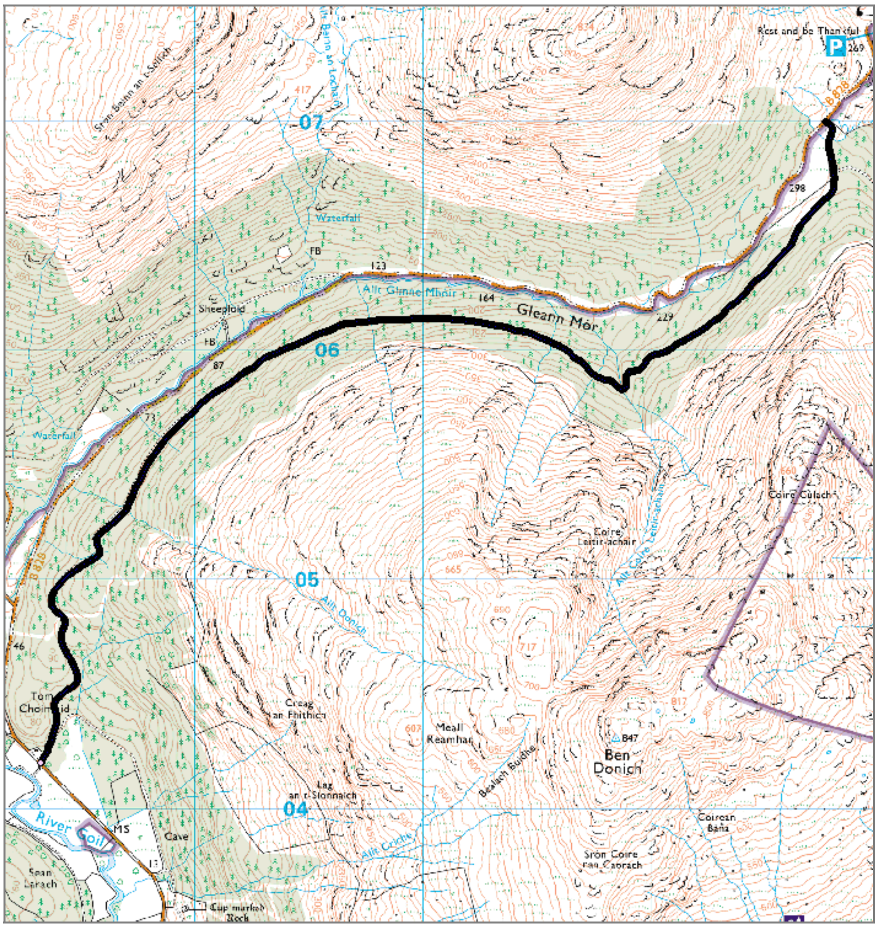


Figure 2-1 Location of the Gleann Mor Forest road

2.2. TRAFFIC VOLUME AND TYPE OF TRAFFIC/IMPORTANCE OF THE ROAD

The Gleann Mor forest road is defined as a Class A forest "main" or arterial road within the Forestry Commission's forest road classification. The full forest road classification comprises:

1. Class A - main roads
2. Class B - spur roads
3. Class C - other roads
4. Unclassified roads

Roads are classified as Class A "main roads" where they :

- Are principal timber haulage routes on a long-term basis.
- Are constructed to high specification.
- Are maintained to a high standard.
- Have their limiting features shown on road maps.
- Are available for use throughout the year but not necessarily in all weather conditions.

2.3. TYPE OF ROAD STRUCTURE

The Gleann Mor Forest road is a gravel road with a running width of between 3.0m and 3.5m The general construction is water-bound macadam. No formal records exist of the construction details of the road before the present surveys but it was thought to have been constructed using a combination of as-dug materials and imported fill. The wearing surface had been imported from either Corrow gravel pit or Glendaruel quarry.

Test holes were however excavated at various locations along the road as part of the work being reported and the records obtained are listed in Appendix 1.

2.4. LANDSCAPE AND TERRAIN

The road is cut into steeply sidelong ground with mature forest on both sides.

Figure 2-2 Typical photograph of the landscape of the Gleann Mor forest road

2.5. GROUND CONDITIONS ON A GENERAL LEVEL

The ground conditions associated with the road are as shown on the following diagrams held in the Forestry Commission's in-house record system.

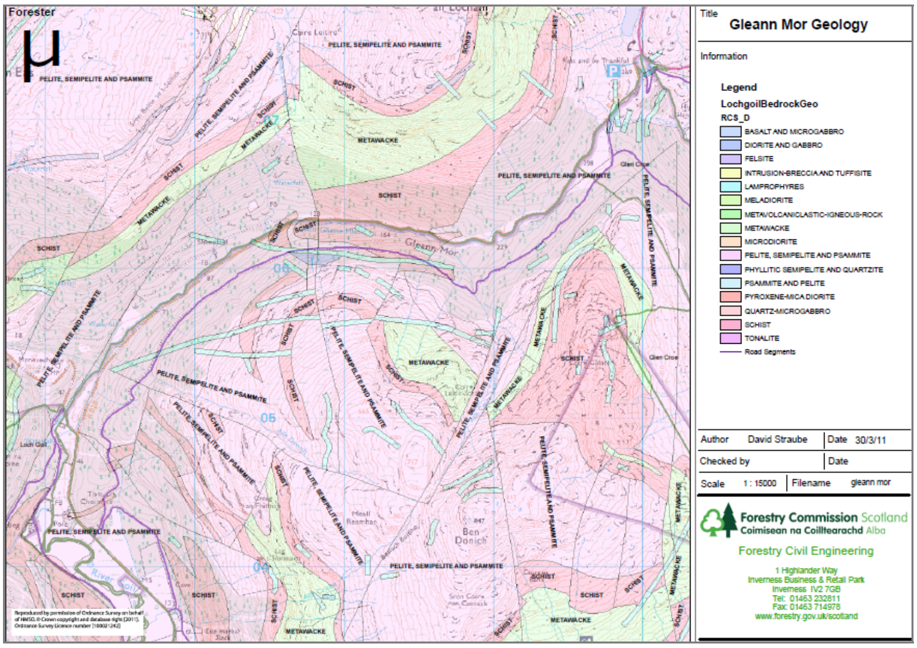


Figure 2-3 Map showing the underlying geology of the Gleann Mor forest road

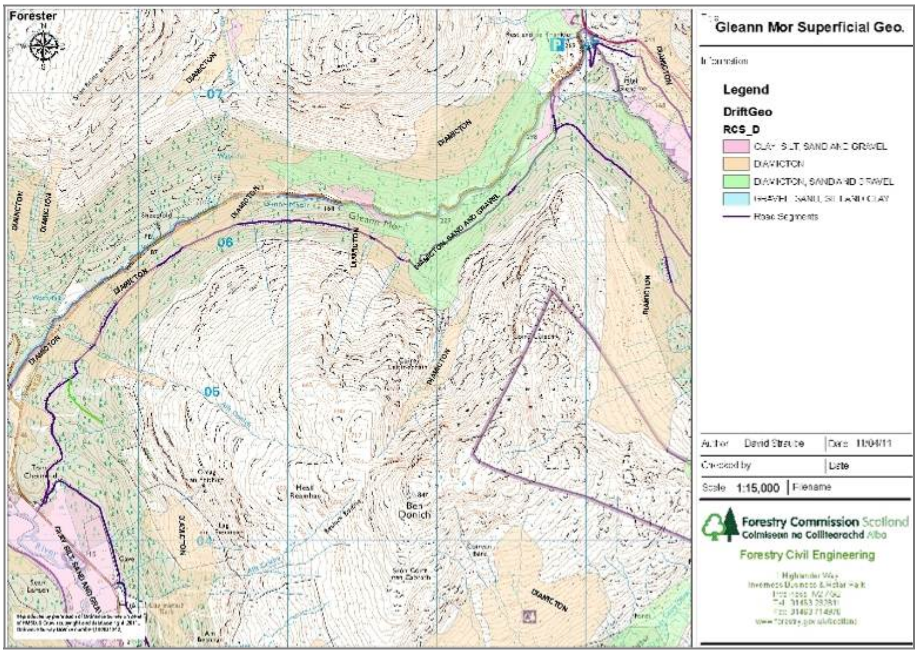


Figure 2-4 Map showing the superficial deposits on the Gleann Mor forest road

These show that the underlying soils are predominantly sands and gravels.

2.6. TYPICAL PROBLEMS OF THE ROAD

The road was scheduled for upgrading so that it could continue to act as the main arterial timber transport route out of Lochgoilhead. The road would be in constant use for the foreseeable future and it was important therefore that it had an appropriate construction. A robust rehabilitation specification was therefore necessary and that the remedial work was correctly targeted.

The budget unit cost to upgrade the road was £20.84 per metre run and of that figure, approximately £18.00 per metre could be attributable to stone production, haulage and laying. Therefore the aim of the project was to identify the sections of the road where additional stone was needed, how much stone was needed on each section and how much stone would be needed in total. A successful outcome would also show those sections of road which did not need additional stone.

The existing conditions on the road were

1. the maximum permissible gradient of 10% for most of the route
2. a poor surface in many areas resulting in lack of traction and retention of surface water
3. sub-standard bend geometry in places
4. areas susceptible to rutting

Figure 2-5 Photograph showing typical conditions on the Gleann Mor forest road in June 2009

3. SURVEYS AND TESTS

3.1. GENERAL

The initial surveys of the road were carried out on 17 June 2009 during a period of heavy rain causing the road surface to be very wet. Following these, a series of trial trenches were excavated across the road on 1 September 2009 to confirm the road structure and materials, and obtain typical dielectric values.

The project was then resurveyed on 2 June 2010 after the strengthening works had been carried out. The aim of this survey was to identify what had been done, and to compare it with the brief.

3.2. GROUND PENETRATING RADAR SURVEY, 17 JUNE 2009

The ground penetrating radar (GPR) survey of the road was carried out by the Forestry Commission's in-house GPR survey team using a GSSI SIR-20 unit with two antennae: a 2 GHz air-coupled horn antenna and a 400MHz ground-coupled unit (Fig.1).

Ground penetrating radar is a non-destructive ground survey method that transmits short pulses of electromagnetic energy through the road structural layers and subgrade soils to determine layer thicknesses. Its main advantage is the continuous profile of layers that it provides along the road section being surveyed. As a result of this GPR is becoming an increasingly important survey tool for the structural assessment of roads.

Once collected, GPR data must be processed with appropriate computer software in order to achieve understandable results. These results can be interpreted in a number of ways in road surveys, e.g. the calculation of the thickness of the pavement and road structure in general, the estimation of subgrade soil types, or the presence of peat or bedrock.

A range of different electromagnetic wavelengths and antenna frequencies can be used in GPR surveys depending on which layers are being surveyed. The 400 MHz antenna has good signal penetration and provides good information on the subgrade soils, whilst the higher frequency of the 2 GHz antenna provides a better resolution of the surface layers. A trained interpreter can generally achieve an accuracy of +/- 10% in thickness surveys provided that the materials in the layers and their respective dielectric values differ to the extent that identifiable reflections are generated. This can be improved to +/- 5 % with reference drill cores or test pits.

A secondary output of a GPR survey is the indication of the roughness of the road. This can be obtained by measuring the "bounce" in the GPR signal time of the air-coupled antenna as it passes along the road. This gives the change in the distance between the antenna and the pavement surface. This "bounce" is shown in the panel for Antenna Elevation in the Road Doctor screen outputs in Section 4.2.

Figure 3-1 The Forestry Commission Road Condition Survey vehicle

3.3. FALLING WEIGHT DEFLECTOMETER SURVEY, 17 JUNE 2009

The falling weight deflectometer (FWD) survey on the road was carried out by Scott Wilson Ltd on the same day as the GPR survey (Fig.2). The FWD is an automated impulse load device that measures deflections in the road surface. These deflections, when combined with GPR thickness measurements, can give an indication of the bearing capacity along the road as part of the general road assessment. The FWD device consists of a weight that drops from a pre-specified height on to a plate supported by rubber dampers on a circular plate on the road. The drop of the weight is designed to simulate the load produced by a passing heavy vehicle. The system is fully automated. The driver does not need to leave the vehicle in order to carry out the measurements. The vehicle has to stop however for the FWD tests. The FWD survey for the Gleann Mor road used the standard load of 50 kN falling on to a 300 mm diameter loading plate.

Figure 3-2 The URS Scott Wilson falling weight deflectometer vehicle and trailer

3.4. TRIAL PITS, 1 SEPTEMBER 2009

Seventeen trial pits were excavated through the road on 1 September 2009 as a “ground truthing” exercise for the GPR surveys. The information obtained is listed in

Appendix 1 and shown as vertical white bars on the Road Doctor screen outputs in Section 4.2. These pits show a close relationship with the interpreted road layer depths.

3.5. DIELECTRIC VALUES, 1 SEPTEMBER 2009

Fixing a typical dielectric value for the materials in the road is an important consideration in the processing of GPR data. As a check on the assumed values, a number of random readings of the dielectric values of the material layers in the road were taken in the test pits using an Adek Percometer. The information obtained is again listed in Appendix 1 and shown in the Road Doctor screen outputs in Section 4.2.

Figure 3-3 Photograph of the Adek Percometer being used to measure the dielectric value of the materials in the road embankment Processing and Interpretation

3.6. METHOD

All GPR, FWD and video data collected in the surveys was synchronised, processed and interpreted by the Forestry Commission team with Road Doctor Pro® software. Map data was imported from ArcGIS using GPS co-ordinates.

The GPR data was interpreted to establish the surfacing/basecourse interface and the basecourse/subgrade interface. The depth of the latter interface was exported at 1 metre intervals to a Stone Depth Analysis Excel spreadsheet developed in-house by the Forestry Commission.

Road Doctor software calculated the stiffness modulus of the subgrade at 50 metre intervals (the spacing of the FWD tests) by analysing the layer depths and FWD deflection bowls. The modulus values were then exported into the spreadsheet and converted into CBR values using the formula $E = 17.6 \times CBR^{0.64}$ MPa. ("*Interim*

Advice Note 73/06, Revision 1 (2009) - Design Guidance for Road Pavement Foundations”). This formula has been found to be particularly relevant to UK soil conditions however in the rest of Europe, an alternative, and commonly used, relationship for the subgrade modulus is E_{sg} = 10.3 x CBR)

The required total depth of roadstone for each CBR value was then found by reference to the undernoted embedded look-up table from the Forestry Commission’s Civil Engineering Handbook data and this “design depth” compared to the actual depth as determined from the GPR interpretation.

CBR	Design Thickness	CBR	Design Thickness
0	850 min	11	240
1	850 min	12	230
2	700	13	220
3	550	14	210
4	475	15	200
5	425	16	190
6	375	17	180
7	325	18	170
8	300	19	160
9	275	20	150
10	250	>20	150

Forestry Commission Table
“An indication of required total pavement thickness for given CBR values”

The following excerpt from the Stone Depth Analysis spreadsheet shows the procedure

Distance (m)	X-coord(m)	Y-coord(m)	Depth(mm)	Subgrade Stiffness (MPa)	CBR	CBR Rounding	Design Depth (mm)	Additional Depth Required (mm)	Notes		CBR	Design Thickness
0	222759.974	706998.395	506.26	35	2.927472175	3	550	50	Additional stone required <50mm		0	850
1	222760.602	706997.869	497.961	35	2.927472175	3	550	52.039	Additional stone required		1	850
2	222761.469	706997.377	481.362	35	2.927472175	3	550	68.638	Additional stone required		2	700
3	222762.333	706996.88	473.063	35	2.927472175	3	550	76.937	Additional stone required		3	550
4	222763.19	706996.371	456.464	35	2.927472175	3	550	93.536	Additional stone required		4	475
5	222764.048	706995.863	448.165	35	2.927472175	3	550	101.835	Additional stone required		5	425
6	222764.933	706995.403	431.566	35	2.927472175	3	550	118.434	Additional stone required		6	375
7	222765.817	706994.943	423.267	35	2.927472175	3	550	126.733	Additional stone required		7	325
8	222766.702	706994.483	381.77	35	2.927472175	3	550	168.23	Additional stone required		8	300
9	222767.586	706994.023	398.369	35	2.927472175	3	550	151.631	Additional stone required		9	275
10	222768.47	706993.564	439.865	35	2.927472175	3	550	110.135	Additional stone required		10	250
11	222769.345	706993.086	456.464	35	2.927472175	3	550	93.536	Additional stone required		11	240
12	222770.217	706992.602	481.362	35	2.927472175	3	550	68.638	Additional stone required		12	230
13	222771.088	706992.117	547.757	35	2.927472175	3	550	2.243	<10mm stone required - IGNORE		13	220
14	222771.943	706991.605	572.655	35	2.927472175	3	550	0	No stone required		14	210
15	222772.795	706991.087	597.553	35	2.927472175	3	550	0	No stone required		15	200
16	222773.647	706990.569	622.451	35	2.927472175	3	550	0	No stone required		16	190
17	222774.492	706990.041	647.349	35	2.927472175	3	550	0	No stone required		17	180
18	222775.335	706989.509	672.247	35	2.927472175	3	550	0	No stone required		18	170
19	222776.178	706988.977	705.444	35	2.927472175	3	550	0	No stone required		19	160
20	222776.99	706988.4	730.343	35	2.927472175	3	550	0	No stone required		20	150
21	222777.794	706987.81	730.343	35	2.927472175	3	550	0	No stone required		>20	150
22	222778.597	706987.219	738.642	35	2.927472175	3	550	0	No stone required			
23	222779.367	706986.586	746.941	35	2.927472175	3	550	0	No stone required			
24	222780.126	706985.941	680.546	35	2.927472175	3	550	0	No stone required			
25	222780.886	706985.296	580.954	35	2.927472175	3	550	0	No stone required			
26	222781.612	706984.613	539.458	35	2.927472175	3	550	50	Additional stone required <50mm			
27	222782.325	706983.917	514.56	73	9.23269365	9	275	0	No stone required			
28	222783.039	706983.22	506.26	73	9.23269365	9	275	0	No stone required			
29	222783.72	706982.493	531.158	73	9.23269365	9	275	0	No stone required			
30	222784.386	706981.751	539.458	73	9.23269365	9	275	0	No stone required			
31	222785.051	706981.009	564.356	73	9.23269365	9	275	0	No stone required			
32	222785.679	706980.236	589.254	73	9.23269365	9	275	0	No stone required			
33	222786.276	706979.437	663.948	73	9.23269365	9	275	0	No stone required			
34	222786.872	706978.639	746.941	73	9.23269365	9	275	0	No stone required			
35	222787.427	706977.812	846.533	73	9.23269365	9	275	0	No stone required			
36	222787.927	706976.95	854.833	73	9.23269365	9	275	0	No stone required			
37	222788.427	706976.088	854.833	73	9.23269365	9	275	0	No stone required			
38	222788.888	706975.206	846.533	73	9.23269365	9	275	0	No stone required			
39	222789.275	706974.287	813.336	73	9.23269365	9	275	0	No stone required			
40	222789.663	706973.369	796.737	73	9.23269365	9	275	0	No stone required			
41	222790.022	706972.439	805.037	73	9.23269365	9	275	0	No stone required			
42	222790.368	706971.504	805.037	73	9.23269365	9	275	0	No stone required			
43	222790.684	706970.56	780.139	73	9.23269365	9	275	0	No stone required			
44	222790.911	706969.59	746.941	73	9.23269365	9	275	0	No stone required			
45	222791.139	706968.619	763.54	73	9.23269365	9	275	0	No stone required			
46	222791.256	706967.63	780.139	73	9.23269365	9	275	0	No stone required			
47	222791.364	706966.639	788.438	73	9.23269365	9	275	0	No stone required			
48	222791.45	706965.645	796.737	73	9.23269365	9	275	0	No stone required			
49	222791.52	706964.651	805.037	73	9.23269365	9	275	0	No stone required			
50	222791.541	706963.655	763.54	73	9.23269365	9	275	0	No stone required			

3.7. DEPTHS & TOTAL VOLUME CALCULATION

The sections of the road which needed additional stone were then identified and the average depth of surfacing required over each section calculated.

	Metres
Total road length surveyed	5623
Total road length requiring additional stone	2621

1. Additional stone depths of less than 10 mm have been disregarded.
2. Additional stone depths of between 10 and 50 mm have been rounded up to 50 mm.
3. Road width used for volume calculation = 3.5 m

Distance (m)		***Length (m)***	***Design depth (mm)***	***Average additional depth required (mm)***	***Volume (m^3)***
Start	***End***				
0	12	12	550	99	4.2
25	26	1	550	50	0.2
144	148	4	850	50	0.7
165	182	17	850	223	13.3
184	200	16	850	83	4.6
242	295	53	475 - 700	135	25.0
313	332	19	700 - 850	77	5.1
334	354	20	850	225	15.8
361	368	7	850	52	1.3
488	575	87	475 - 850	262	79.8
625	660	35	850	167	20.5
691	694	3	850	52	0.5
775	791	16	700	119	6.7
798	825	27	700	225	21.3
875	887	12	850	164	6.9
895	904	9	850	67	2.1
906	925	19	850	139	9.2
1031	1039	8	475	72	2.0
1044	1048	4	475	57	0.8
1054	1156	102	475 - 700	135	48.2
1165	1180	15	850	165	8.7
1194	1199	5	850	70	1.2
1214	1221	7	700 - 850	135	3.3
1224	1234	10	700	69	2.4
1374	1434	60	475 - 850	356	74.8
1463	1464	1	475	50	0.2
1474	1481	7	700	65	1.6
1486	1491	5	700	51	0.9
1493	1497	4	700	50	0.7
1498	1524	26	700	113	10.3
1630	1675	45	850	101	15.9
1678	1680	2	850	52	0.4

1950	2028	78	700 - 850	150	41.0
2071	2133	62	700 - 850	329	71.4
2152	2175	23	700	122	9.8
2225	2331	106	850	390	144.7
2338	2350	12	850	194	8.1
2420	2424	4	475	50	0.7
2452	2471	19	475	54	3.6
2478	2574	96	550	134	45.0
2576	2679	103	425 - 850	340	122.6
2690	2716	26	425	98	8.9
2717	2719	2	425	50	0.4
2726	2729	3	425	50	0.5
2732	2734	2	425	50	0.4
2737	2762	25	425	83	7.3
2768	2800	32	425	54	6.0
2950	3175	225	700	215	169.3
3181	3183	2	475	50	0.4
3186	3242	56	475	96	18.8
3250	3325	75	700	255	66.9
3370	3597	227	375 - 850	346	274.9
3608	3615	7	475	58	1.4
3618	3675	57	475 - 700	215	42.9
3850	3869	19	425	61	4.1
3875	3883	8	550	54	1.5
3889	3895	6	550	50	1.1
3901	3905	4	550	50	0.7
3921	3922	1	550	52	0.2
3975	4025	50	850	268	46.9
4035	4038	3	475	51	0.5
4043	4075	32	475	104	11.6
4125	4130	5	475	135	2.4
4140	4150	10	475	64	2.2
4163	4225	62	475 - 850	316	68.6
4234	4243	9	550	105	3.3
4258	4275	17	550	60	3.6
4299	4307	8	375	50	1.4
4325	4475	150	550 - 700	303	159.1
4530	4575	45	850	374	58.9
4725	4743	18	850	148	9.3
4748	4853	105	850	211	77.5
4856	4875	19	850	67	4.5
5275	5375	100	850	303	106.1
5475	5525	50	850	275	48.1
	Totals	**2621**			**2044.9**

3.8. MAP REPRESENTATION OF RESULTS

The following map shows the survey route and the lengths assessed as requiring additional stone.

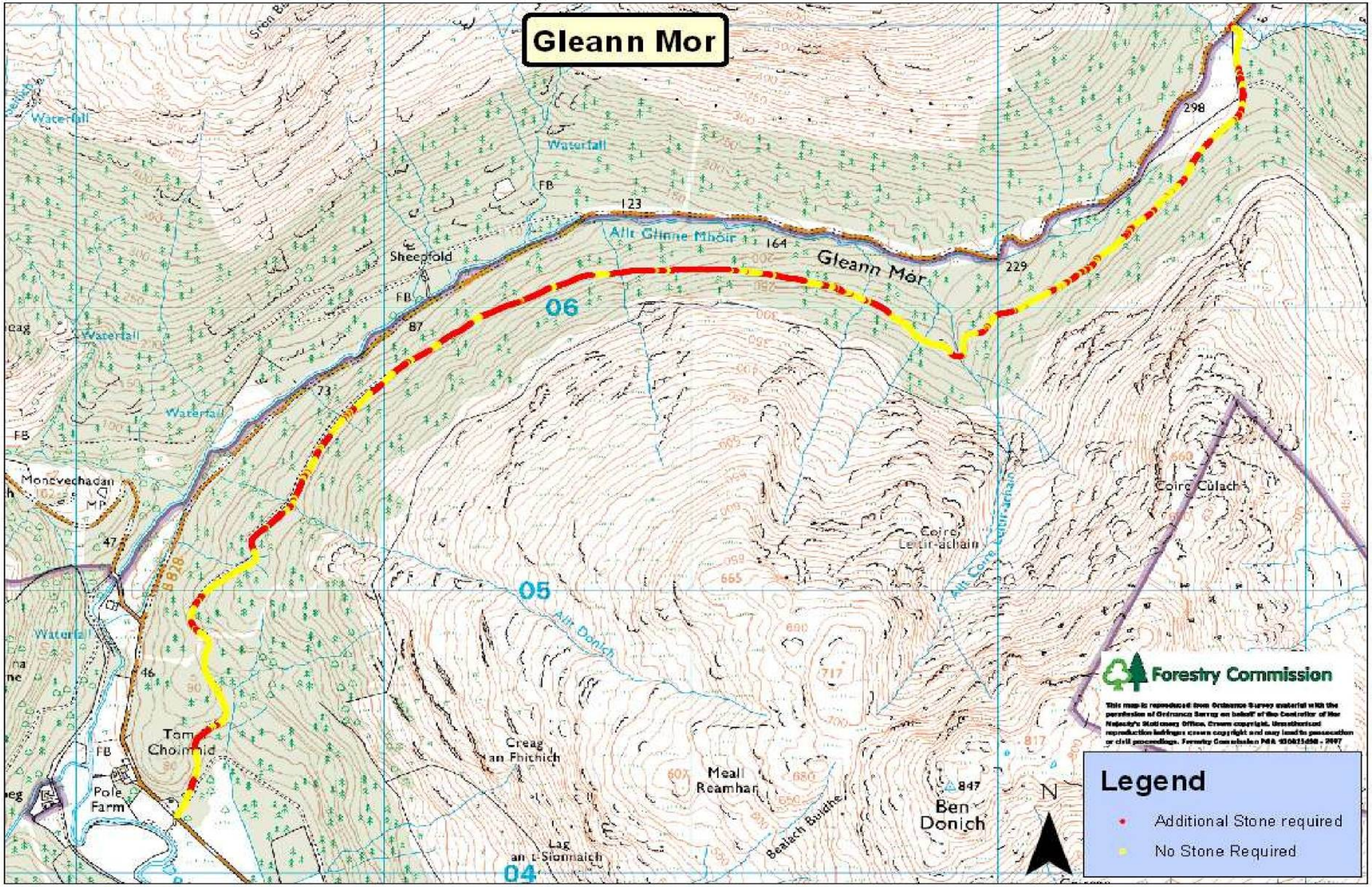


Figure 3-4 Map of Gleann Mor forest road showing the survey route and the lengths assessed as requiring additional stone.

3.9. COST SAVING

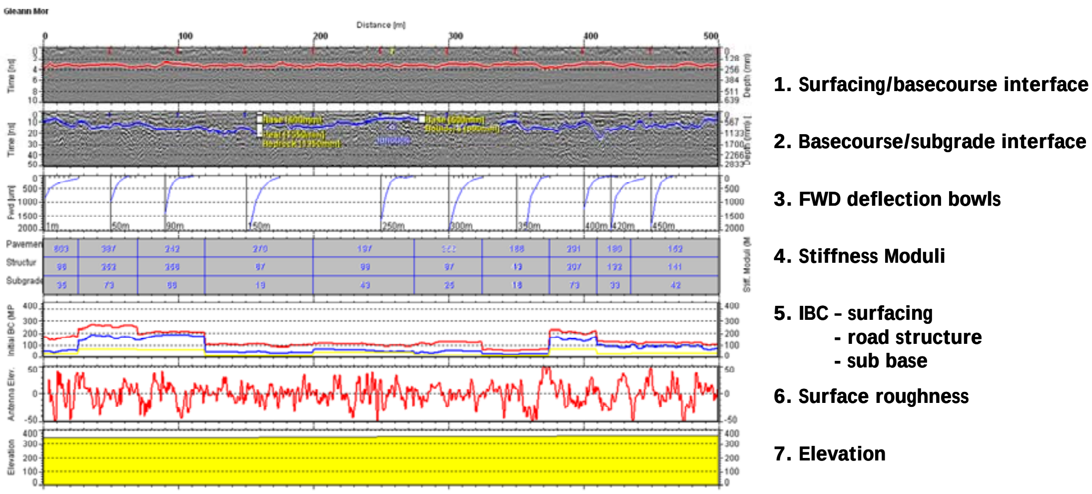
	Length (m)	Budget Upgrade Unit Cost (£)	Total Cost (£)
Total road	5623	20.84	117,183
Estimated stone costs	5623	18.00	101,214
Length needing additional stone	2621	18.00	47,178
Length needing no additional stone	3002	18.00	**54,036**

The survey showed that approximately 53% of the road did not need any more stone so generally, 53% of the budget amount for stone production, haulage, spreading and compaction was saved.

3.10. INTERPRETATION AND SCREEN OUTPUTS

The screen outputs that follow are pictorial representations of the Road Doctor outputs for each consecutive 500m length of road. From the top, the panels in the screen display are as follows:

1. Depth of the surfacing/basecourse interface from GPR
2. Depth of the basecourse/subgrade interface from GPR
3. Falling weight deflectometer deflection bowls from FWD
4. Calculated stiffness moduli from Road Doctor
5. Initial bearing capacity (IBC) of the subgrade, road structure and surfacing
6. Surface roughness
7. Elevation above sea level from GPS



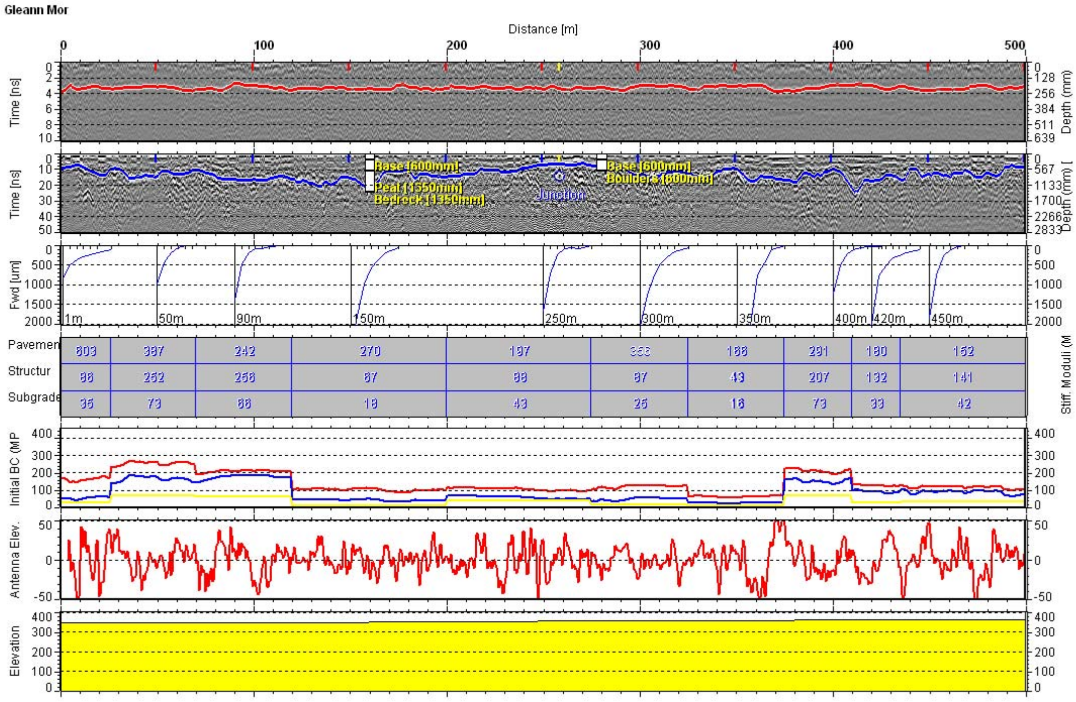
Road Doctor screen output

Panel 5, the "Initial Bearing Capacity" (IBC) is calculated using the "Odemark method". This is a relatively simple way of determining if the structural stiffness of a road is adequate for the loads it is to carry. This is done by considering the thicknesses and the moduli of the various layers in the road and rating the road accordingly. The method is regularly used for road structural design elsewhere in Europe and is being considered by the Forestry Commission for the future. For now however, it is presented for information only.

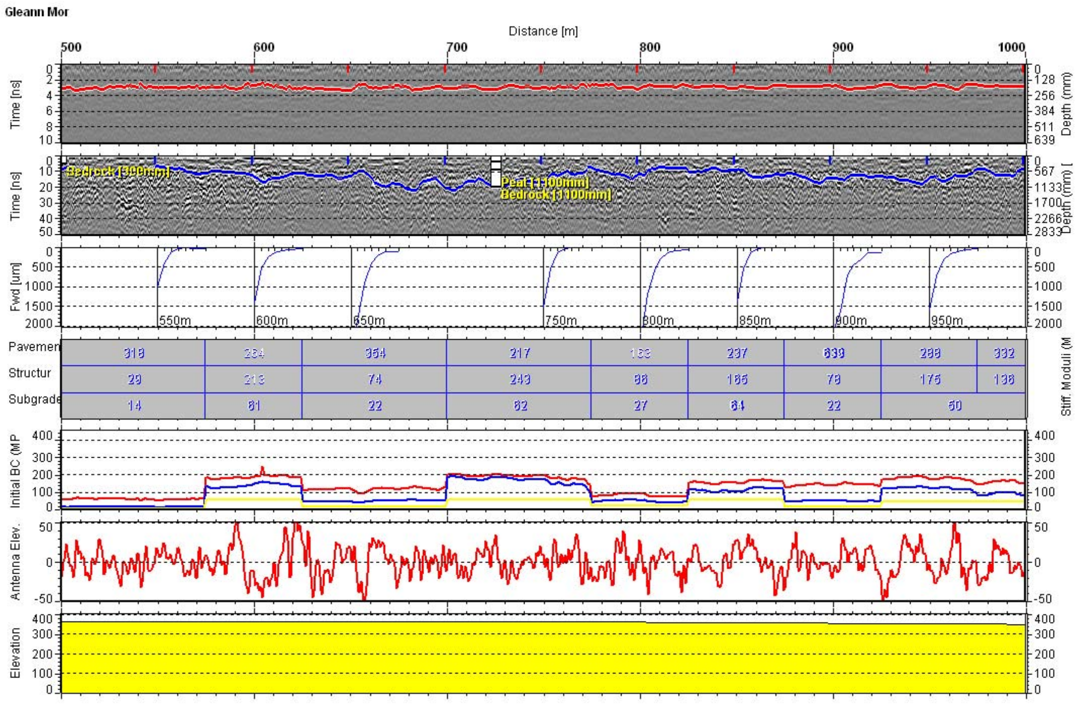
Panel 6, "surface roughness" data is the record of the "bounce" of the 2 GHz antenna as the survey vehicle passes along the road. This equates reasonably well to values established by the International Roughness Index. This can identify those areas of the surface in need of grading.

Panel 7, the elevation above sea level is the GPS "z" co-ordinate and gives an indication of the longitudinal profile of the road.

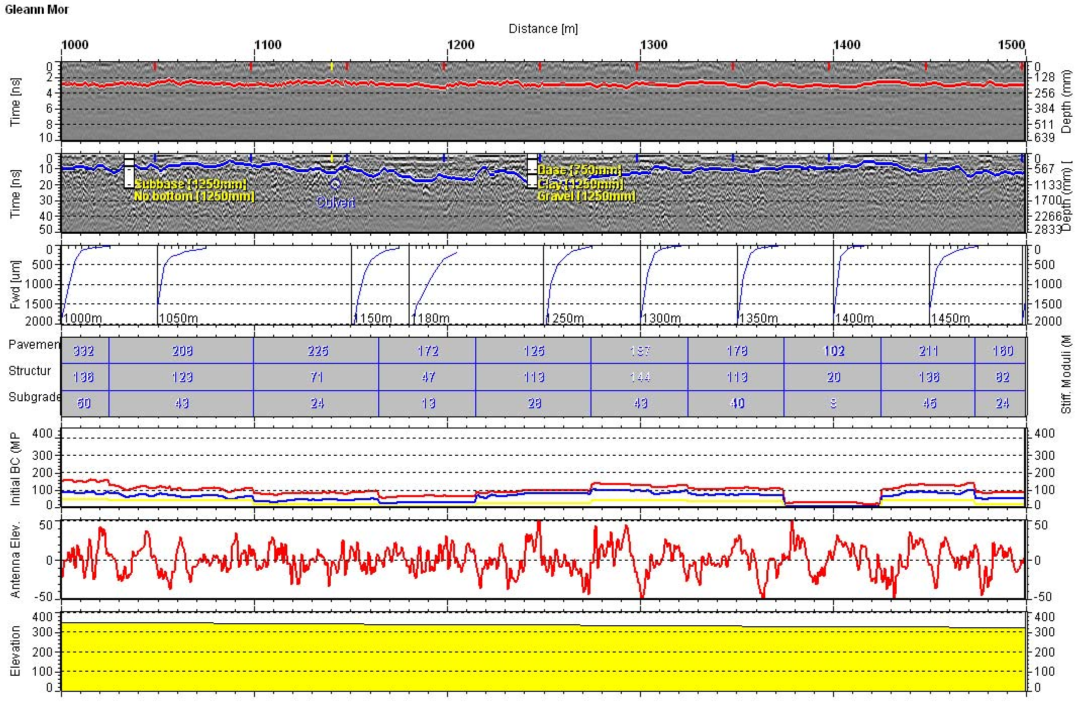
Road Doctor screen outputs for the Gleann Mor forest road:



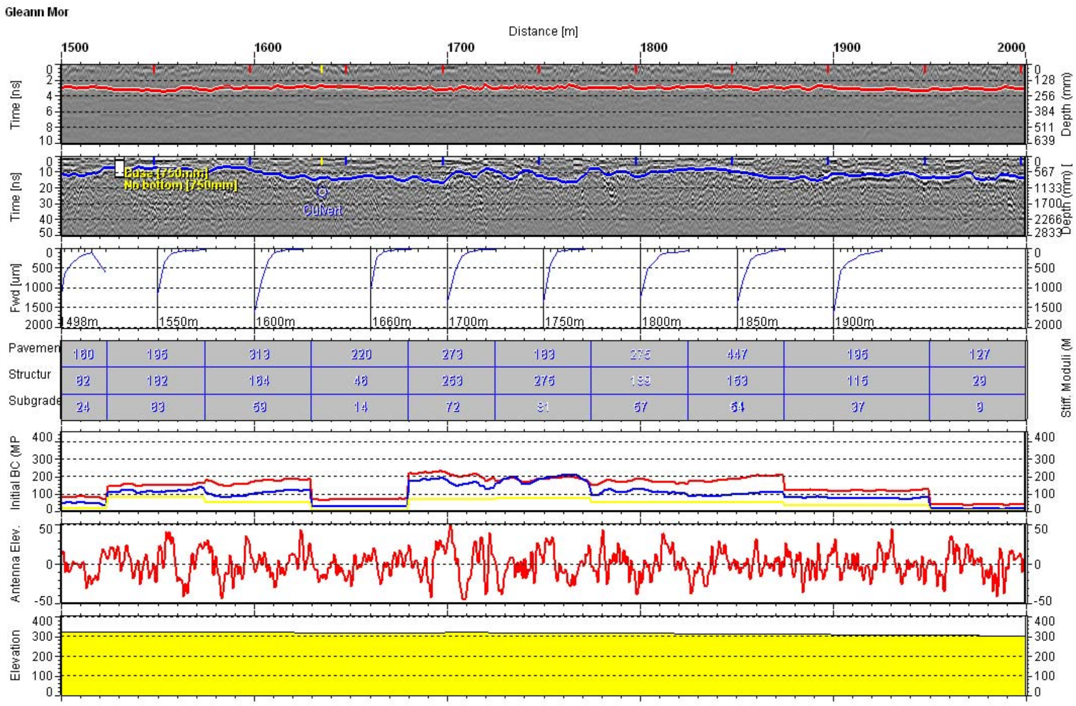
0 – 500 m



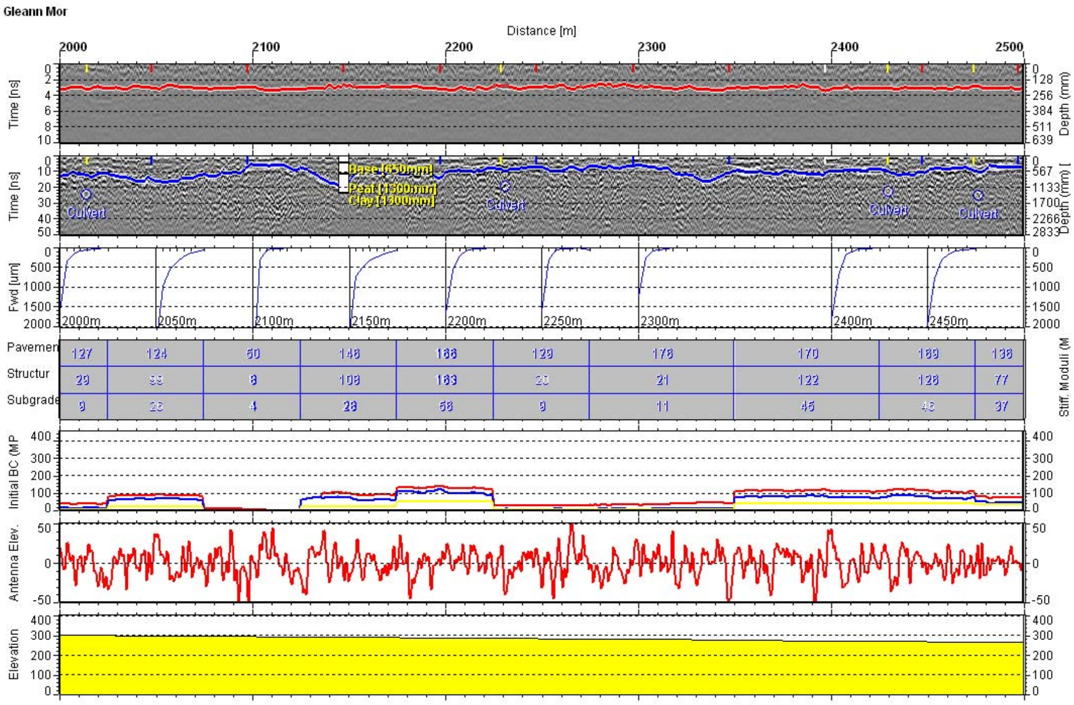
500 – 1000m



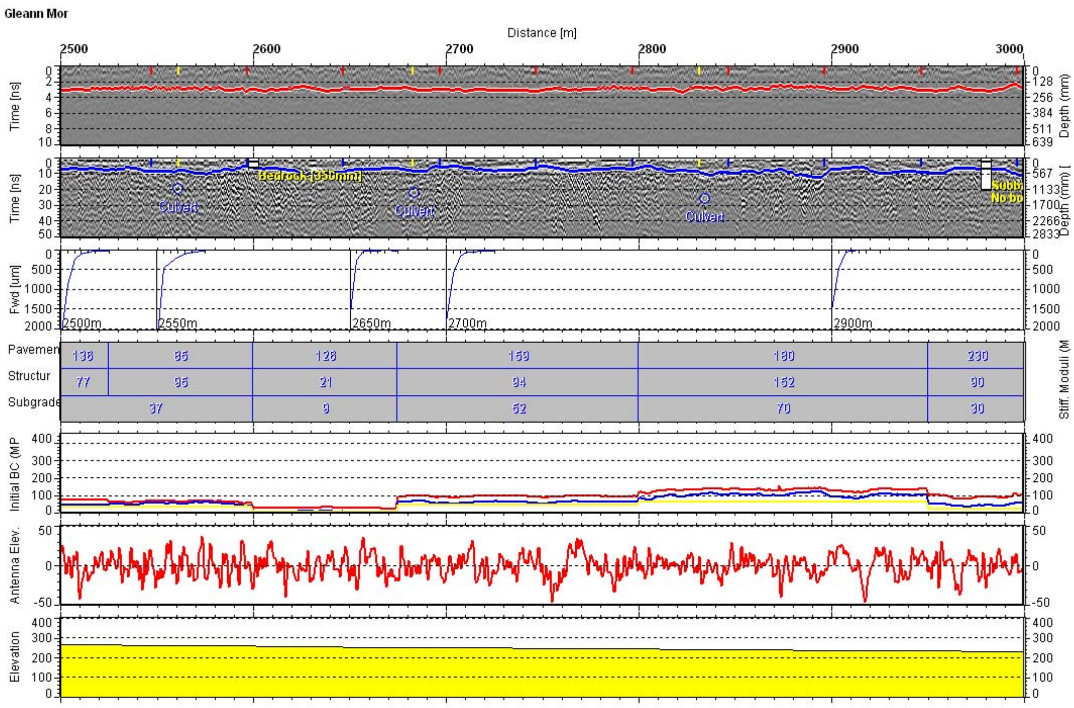
1000 – 1500m



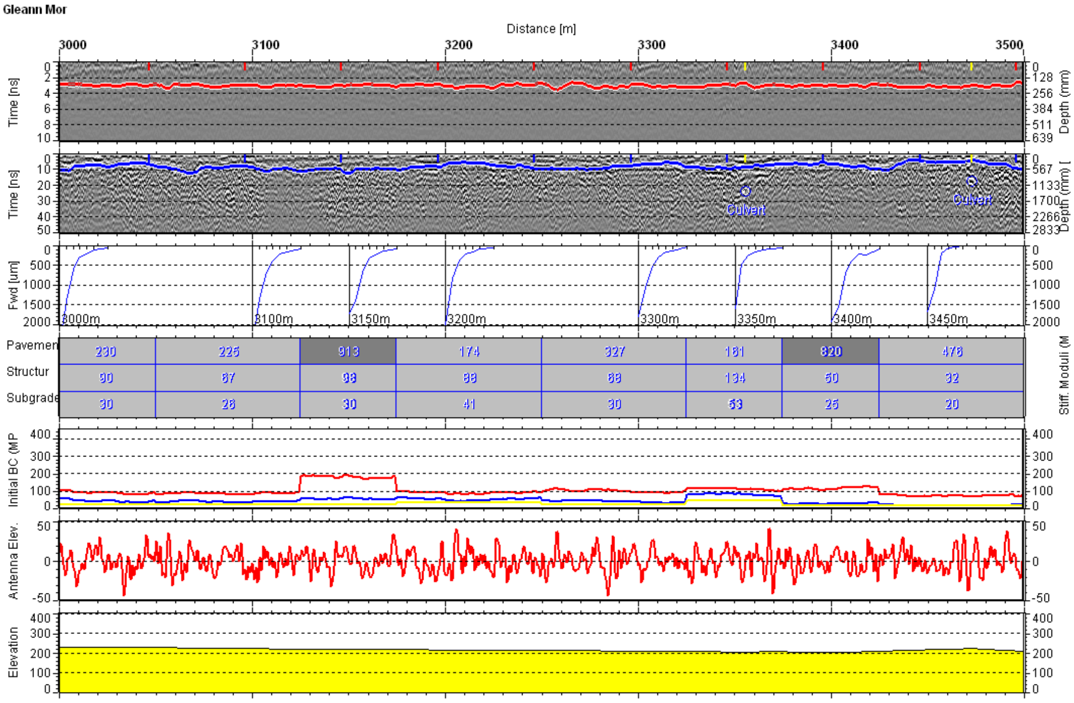
1500 – 2000m



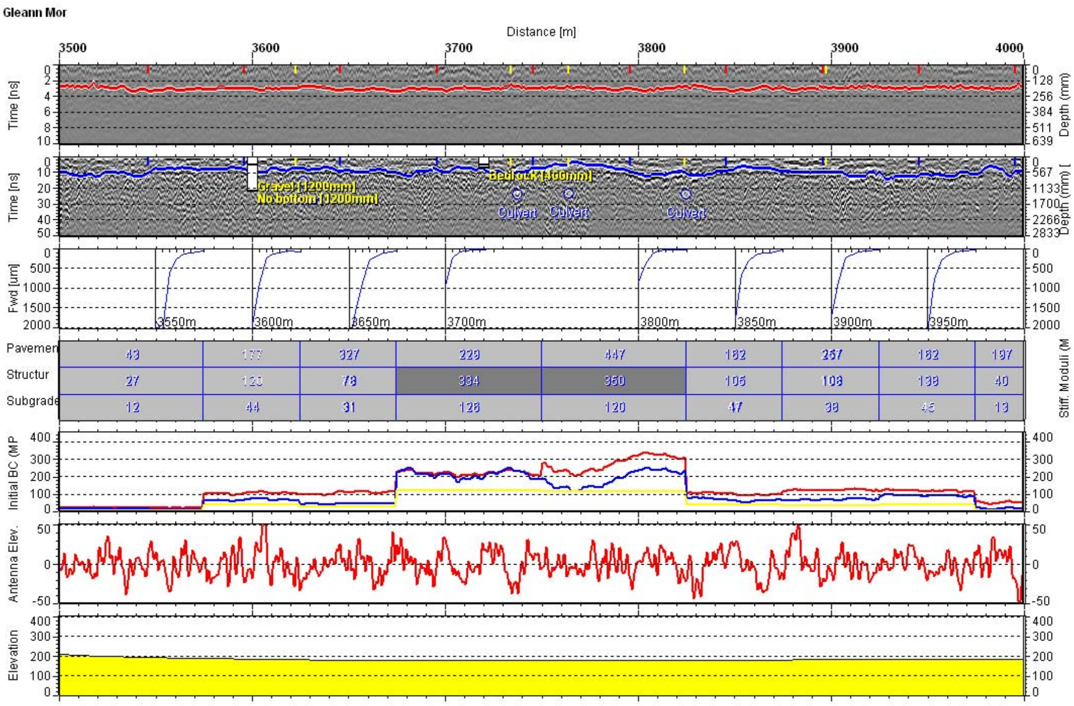
2000 – 2500m



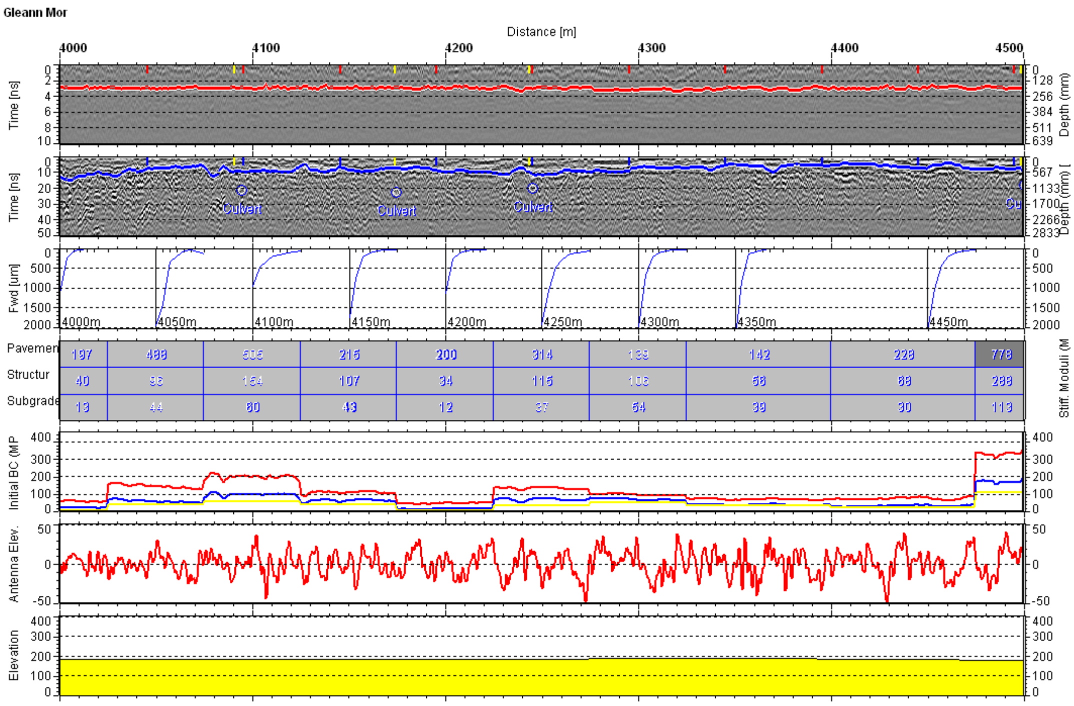
2500 – 3000m



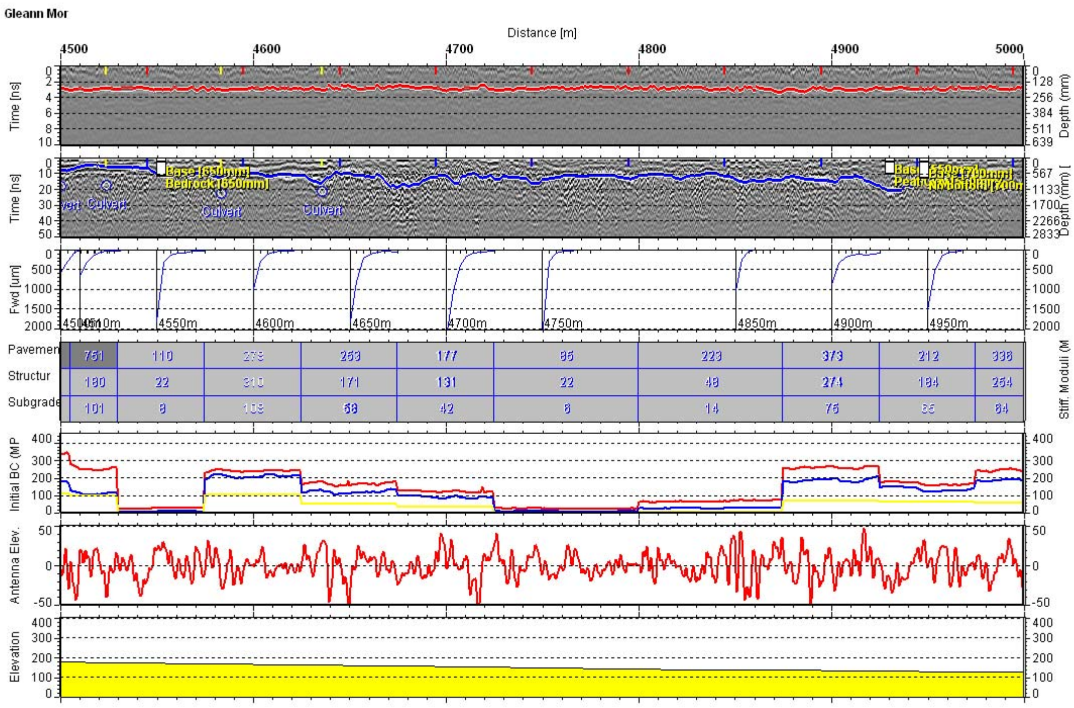
3000 – 3500m



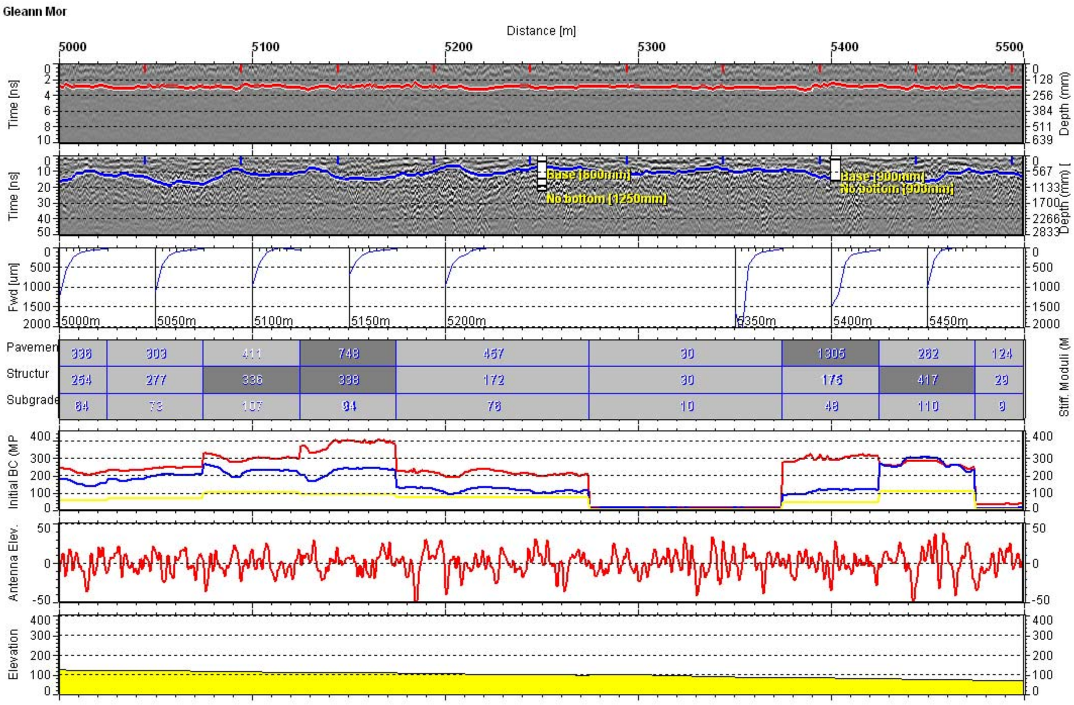
3500 – 4000m



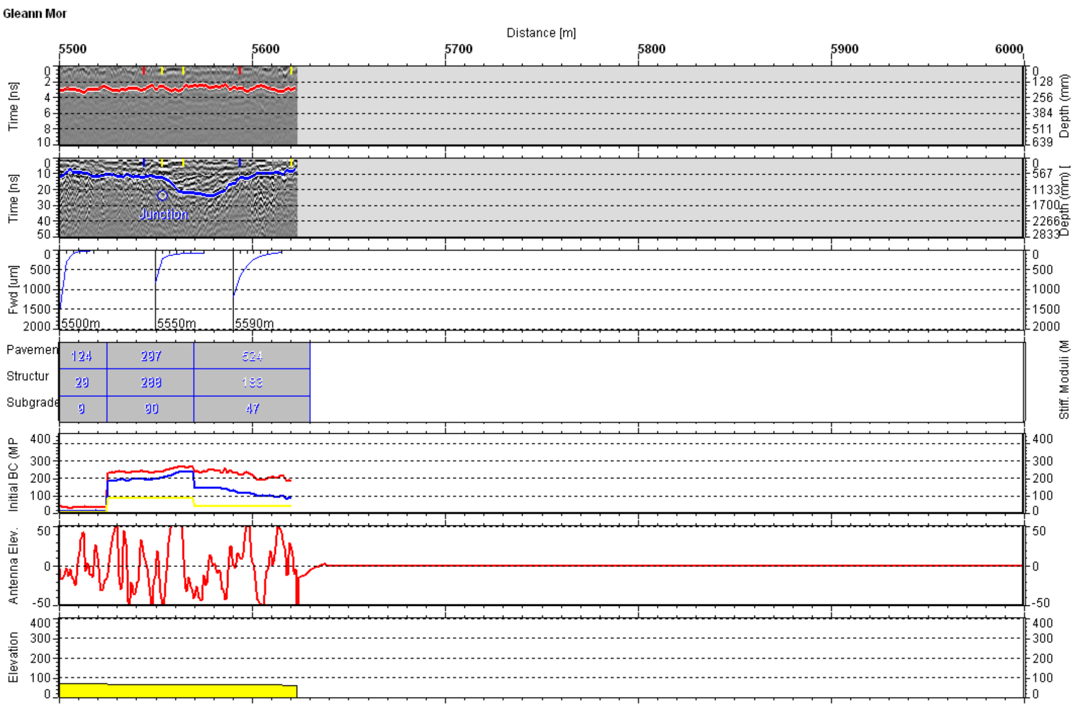
4000 – 4500m



4500 – 5000m



5000 – 5500m



5500 – 5623m

4. FOLLOW UP SURVEY & CONCLUSIONS

4.1. GROUND PENETRATING RADAR SURVEY, 2 JUNE 2010

The strengthening works on the Gleann Mor forest road were carried out between April 2009 and March 2010.

Following the work the route was again surveyed by the Forestry Commission's in-house GPR survey team using the GSSI SIR-20 unit with two antennae: the 2 GHz air-coupled antenna and the 400MHz ground-coupled unit.

Figure 4-1 Screendump from the video taken during the follow-up survey, 2 June 2010 showing sections of additional roadstone placed on the road

4.2. ANALYSIS

The collected GPR data was analysed for the depth of the stone/subgrade interface below the new road surface at 1 metre intervals within Road Doctor. This was then exported into an Excel spreadsheet and the depths compared to those from the original survey.

Overall these were variable. The first kilometre of the work appeared to fit rather well with the design plan, as can be seen in Figure 4-2.

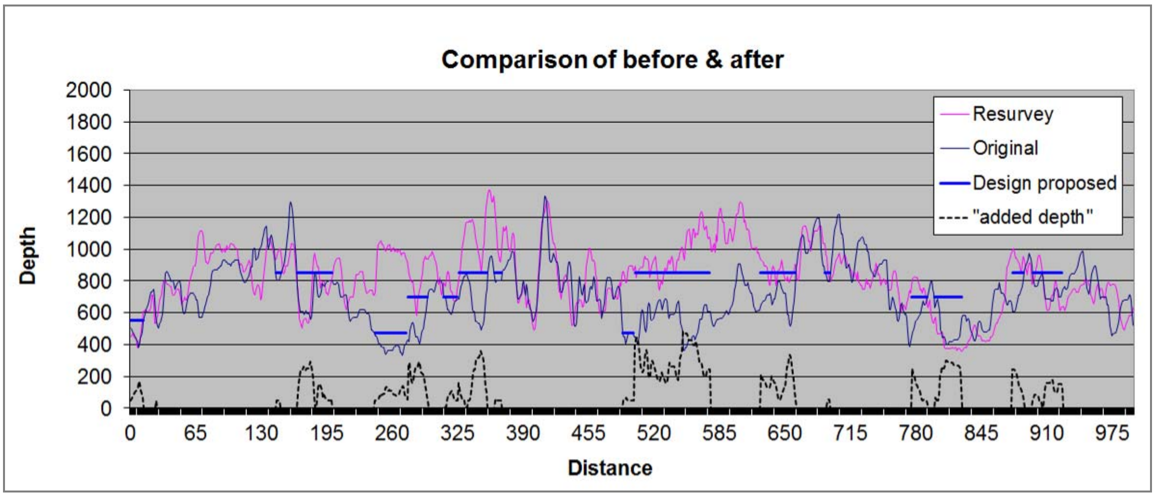


Figure 4-2 Comparison of “Before” and “After”, 0 to 1000m

Unfortunately this good initial correlation did not continue into the latter stages of the scheme where it looks like a measurement error has crept into the setting out of the rehabilitation measures as shown in Figure 4-3.

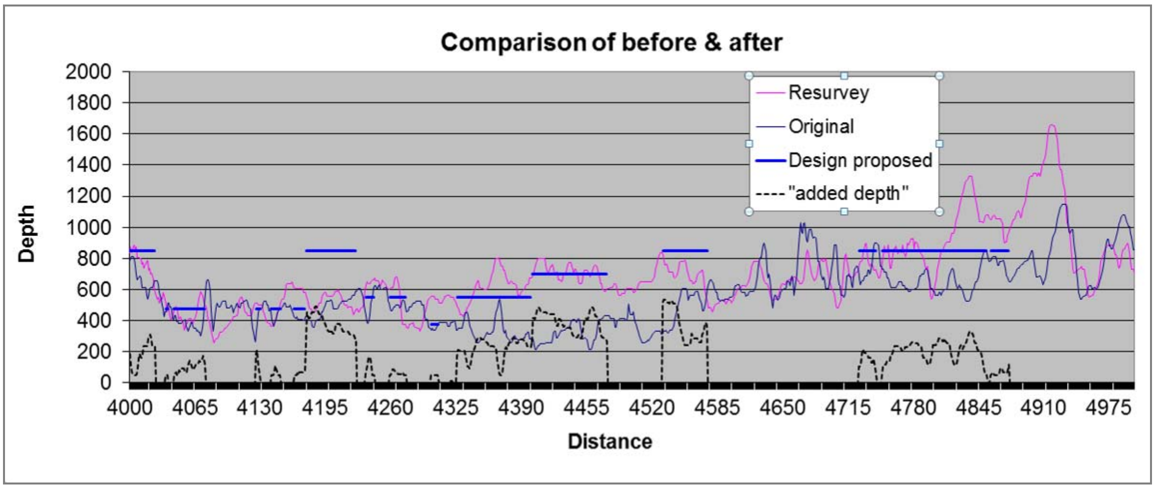


Figure 4-3 Comparison of “Before” and “After”, 4000 to 5000m

The conclusion was that although there was reasonable correlation between the “design” prescription and the “as built” result, it was clear that there was some scope for improvement in the management of the works on site .

5. LESSONS LEARNED

Most of the older Forestry Commission forest roads have had temporary repairs to keep the timber moving, and sections have been completely reconstructed following landslides etc. During these and subsequent maintenance operations, different sources and types of stone have been used which can make GPR interpretation of layer depths challenging.

It is also true to say that although the performance specification of the FC timber haulage roads is the same throughout England, Scotland and Wales, ground conditions and materials are extremely variable so the structural composition of roads can be totally different from area to area. Therefore, the establishment of appropriate area parameters using local knowledge and ground truthing is important.

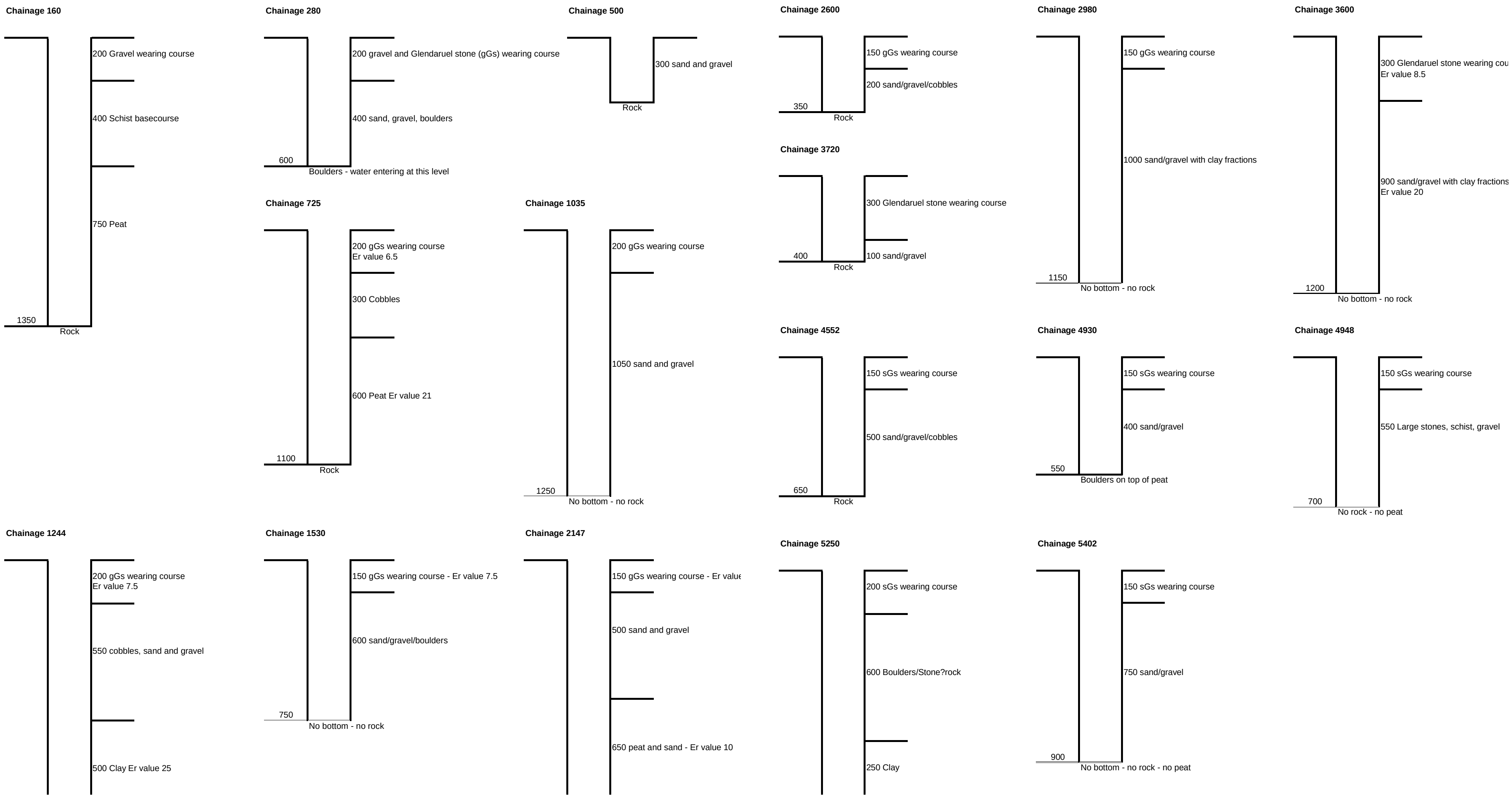
The FWD testing procedure is intended for hard road surfaces. URS Scott Wilson has confirmed that when the surface of a forest road is soft, it can be difficult to achieve a 50 kN load as some of the force is actually absorbed by the road. Consequently, FWD work should be carried out in dry conditions but this can only be aspirational in Scotland! (Note: In Sweden FWD measurements are carried out in the spring after the frost has gone. It has been found that if measurements are taken in the middle of a dry summer the values might be too good.)

It is difficult to get consistent dielectric value readings from the sides of an excavated trench using the Adek Percometer.

This survey and assessment method has subsequently been used to analyse a totally new forest road which was built to a carefully designed and monitored specification. The Stone Depth analysis procedure showed that no additional stone was required at any point. The Forestry Commission have also surveyed a road formation with no pavement at all. The same procedure showed that not only was stone required along the entire length of the alignment, but it also calculated the depths and volumes. These results were as expected and they have established an "envelope" within which all other survey data from existing forest roads should fall.

Surveys to-date have given the Forestry Commission confidence in the efficacy of the technique and the next stage of the project will be to develop improved site procedures. The aim will be to devise a method of applying the survey outputs on future roads in a manner which not only closely relates to the calculated lengths, depths and volumes but which is also practical to set out and control.

Appendix 1: Gleann Mor forest road trial pits, 1 September 2009



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- Drainage guidelines
- Environmental guidelines & checklist
- Forest road policies
- Generation of ‘snow smoke’ behind heavy vehicles
- Health issues raised by poorly maintained road networks
- Managing drainage on low volume roads
- Managing peat related problems on low volume roads
- Managing permanent deformation in low volume roads
- Managing spring thaw weakening on low volume roads
- Monitoring low volume roads
- New survey techniques in drainage evaluation
- Permanent deformation, from theory to practice
- Risk analyses on low volume roads
- Road condition management of low volume roads
- Road friendly vehicles & tyre pressure control
- Road widening guidelines
- Socio-economic impacts of road conditions on low volume roads
- Structural innovations for low volume roads
- Treatment of moisture susceptible materials
- Tyre pressure control on timber haulage vehicles
- Understanding low volume pavement response to heavy traffic loading
- User perspectives on the road service level in ROADEX areas
- Vehicle and human vibration due to road condition
- Winter maintenance practice in the Northern Periphery

All of these reports, and others, are available for download free of charge from the ROADEX website at www.ROADEX.org.