ROADEX
Implementing Accessibility

Northern Periphery Programme 2007–2013
Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

European Union
European Regional Development Fund

Annele Matintupa, Seppo Tuisku

SUMMARY OF DRAINAGE ANALYSIS IN THE WESTERN ISLES, SCOTLAND

Demonstration Project Report

ABSTRACT

Drainage is one of the most important factors to be kept in mind in road design and maintenance projects. It is accepted generally that road structures work well and last longer in dry conditions. Researches have shown that that poor drainage is often the main cause of road damages and problems with long term road serviceability. This knowledge however has not always been applied in practice with the result that the general drainage condition of the road networks is not good. Previous ROADEX projects have reported that poor drainage is the one of the biggest problems for Northern European rural roads, and parts of the main road network. Drainage improvement, and maintaining the drainage in a good condition has therefore a major effect in reducing the rate of deterioration of roads and ROADEX research has shown that drainage improvement measures can increase pavement lifetimes by 1.5-2.0 times. Drainage measures are thus very profitable and offer major savings in annual paving costs.

A drainage analysis methodology has been developed in the ROADEX project to locate those critical road sections needing drainage improvement and regular maintenance. In the analysis, data is collected from all of the important factors that affect the road drainage condition. After this data has been analysed, classified and reported, the critical road sections can be awarded a special drainage maintenance class for use in maintenance contracts. Drainage analysis can be carried out on both paved and gravel road networks. The survey results are reliable and repeatable and allow the current drainage condition of the road network to be monitored.

Demonstrations of the ROADEX drainage analysis in Western Isles were carried out on selected sections of three of the main roads in Lewis and Harris and one secondary road (a section of the B8011). The total length of the roads analysed was approximately 88km. A laser scanner was also for the first time in drainage analysis to test if the data collected could provide useful. The tests showed that the data could be very useful in drainage evaluation.

The demonstrations showed that, compared to Nordic countries, the Western Isles had a number of different drainage features, such as grass verges and in some cases a lack of traditional open ditches. These features make the improvement of drainage more difficult on established roads. The new road sections surveyed however had good drainage arrangements and usually open ditches had been provided.

KEYWORDS

Drainage, analysis, verge, pavement, life time, rutting, IRI

PREFACE

In March 2011 Roadscanners Oy carried out a series of drainage analysis field surveys in the Western Isles. The goal was to demonstrate the ROADEX drainage analysis technique and guidelines on the Western Isles road network.

The field measurements were performed by Seppo Tuisku of Roadscanners Oy with the help of Comhairle nan Eilean Siar. David Macarthur of the Technical Services Department assisted in the field surveys.

The processing and analysis of the measured data was carried out by Seppo Tuisku. This report was jointly written by Seppo Tuisku and Annele Matintupa. Timo Saarenpää and Pekka Maijala from Roadscanners Oy helped with the handling of the rutting data supplied by the client. Timo Saarenketo steered the demonstrations as lead manager of the ROADEX D1 "Drainage Maintenance Guidelines" group. Ron Munro helped with the demonstration arrangements and also checked the language. Mika Pyhähuhta from Laboratorio Uleåborg designed the report layout.

All work carried out in the project was made in close cooperation with personnel from the Comhairle nan Eilean Siar Technical Services Department. The authors would specially like to thank and acknowledge the assistance given by Donald Macrae, Principal Officer of the Technical Services Department. Without their help and support it would not have been possible to complete the work.

Finally the authors would like to thank the ROADEX IV Project Steering Committee for their guidance and encouragement in the work.

ROADEX IV Lead Partner: The Swedish Transport Administration, Northern Region, PO Box 809, S-971 25 Luleå. Project co-ordinator: Mr. Krister Palo.

CONTENTS

1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organisations across northern Europe that aims 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 Finland 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 IV from 2009 to 2013.

Figure 1: The Northern Periphery Area and ROADEX IV partners.

The Partners in ROADEX IV "Implementing Accessibility" comprised public road administrations and forestry organisations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and Comhairle Nan Eilean Siar 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.

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 pursued as part of the project: "Climate change and its consequences on the maintenance of low volume roads", "Road Widening" and "Vibration in vehicles and humans due to road condition".

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

1.2 THE DEMONSTRATION PROJECTS

Twenty three demonstration projects were planned within the ROADEX IV project. Their goal was to take selected technologies developed by ROADEX out on to the local road networks to have them physically used in practice to show what they could achieve. The projects were funded locally by the local Partners, designed and supervised by local staff, and supported by experts from the ROADEX consultancy.

The demonstrations were managed in 6 groups by a nominated lead manager from ROADEX:

D1 - "Drainage Maintenance Guidelines"

D2 - "Road friendly vehicles and Tyre Pressure Control"

D3 - "Forest Road policies"

D4 - "Rutting, from theory to practice"

D5 - "Roads on Peat"

D6 - "Health and Vibration"

This report deals with the demonstrations project in the D1 "Drainage Maintenance Guidelines" group carried out in the Western Isles.

2. ROADS SURVEYED

The drainage analysis surveys of this report were carried out on selected sections of roads A857, A858, A859 and B8011 in the Western Isles. The sections of roads surveyed are shown in the map in Figure 2 and detailed information is presented in Table 1.

- Road A857 was surveyed in two parts; first part was from Stornoway to Barvas and the second part was from Barvas to Dell cattle grid.
- Road A858 was surveyed from road A859 (Cameron Terrace) to Garynahine.
- Two main sections were selected from the road A859. The first section was from Stornoway to the intersection of the road to Keose. The second section was from intersection of the road B8060 to Scaladale Bridge. A short section from Northton to Leverburgh was also included to the survey.
- Road B8011 was surveyed from Garynahine to the intersection of the road B8059.

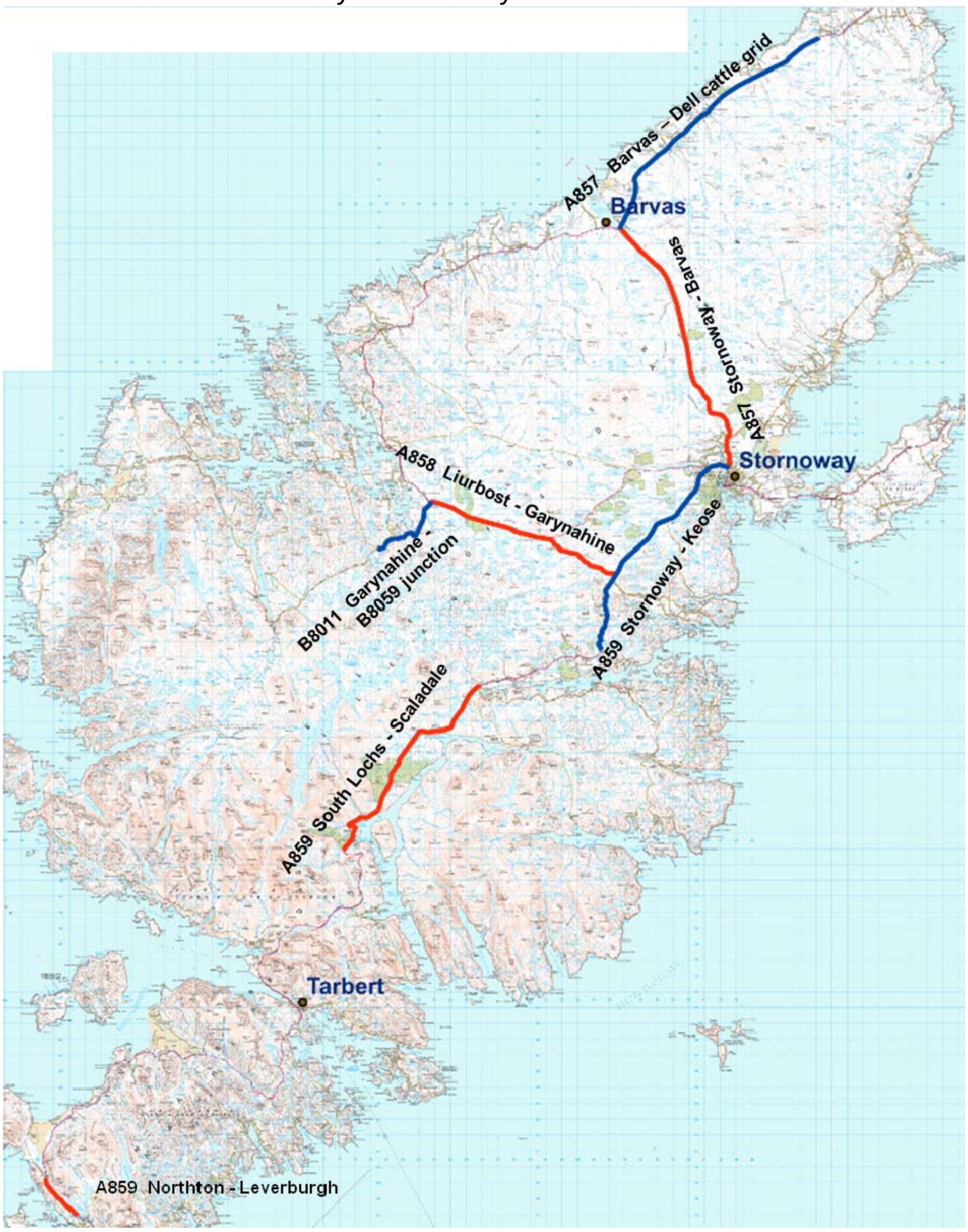


Figure 2: Surveyed roads in Western Isles.

The A857, A858 and A859 were fairly busy roads. The B8011 had noticeably less traffic. The landscape and terrain along the roads were very variable as was the subgrade soil type. Substantial lengths of peat soils were noted, especially on road A857.

Table 1. The surveyed road sections and their lengths.

Road	***Start point***	***End point***	***Length***
A857	Stornoway	Barvas	17510m
A857	Barvas	Dell cattle grid	18060m
A859	Stornoway	The junction of the road to Keose	15765m
A859	The junction of road B8060	Scaladale bridge	15185m
A859	Northton	Leverburg bridge	3130m
A858	Crossing of road A859	Garynahine, junction of B8011	12870m
B8011	Garynahine, junction of road A858	The junction of the road B8059	5330m

3. DATA COLLECTION, FIELD SURVEYS

3.1. GENERAL

The data collection for the demonstration project was carried out in March 2011. The sections for the survey were selected by the Technical Services Department of Comhairle nan Eilean Siar. The surveys started on the A857 road from Stornoway to Port of Ness. This was divided into two subsections. The first section surveyed started from a roundabout in Stornoway and ended at the junction with the A858 in Barvas. The length of the section was 17510m. The second section surveyed continued from this point and ended at a cattle grid in Dell. This second section was a slightly longer at 18060m.

A new survey was then started on the road A859 from Stornoway towards Tarbert. The first section started at a roundabout in Stornoway and ended at the junction with the road to Keose. The length of this section was 15765m. The second section started at the junction with the road B8060 and ended at the Scaladale bridge. This section length was 15185m. The third, and last section, on the road A859 was on the Isle of Harris. This started at Northton and ended at the Leverburgh bridge, a length of 3130m.

A survey was then carried out on the A858 road. The section start point was at the junction with the A859 road and the end of the section was in Garynahine at the junction with the B8011 road. The length of the section was 12870m.

The last section to be surveyed was on the B8011 road. This started from the A858 at Garynahine and the section ended at the junction with the road B8059. The length of the surveyed section was 5330m.

The weather during the surveys varied. In the beginning, when the video-logging and the drainage analysis were being carried out, the weather was quite dry and even sunny. The laser scanner survey was made separately later and during that the weather got worse and rained at times.

3.2. VIDEO AND GPS

Drainage analysis in the field was carried out on one road section at a time and both sides of the road were analysed separately. The Technical Services Department of Comhairle nan Eilean Siar provided the van for the survey. A CamLink video-logging system by Roadscanners Oy was installed on the Western Isles Council van roof (Figure 3). The driving speed during the data collection was about 30 km/h and the van was driven close to road shoulder so that the video cameras had the best possible view of the ditch and roadside. An APD Communications INCA 2 GPS device was used for GPS positioning. All data was linked to GPS coordinates using Road Doctor™ CamLink software.

Two digital video cameras were used in the survey. One camera was used to record the road view, and the second camera to record the ditch.

Figure 3: The survey vehicle used in the project. Video cameras were placed in the orange CamLink box for shelter from the rain and dust.

A Panasonic Toughbook laptop with Road Doctor™ CamLink software was used to record the video data from the cameras and the classification of the drainage data. Preliminary classifications were directly recorded in the vehicle using the pc keyboard. Audio comments were also recorded to assist data interpretation in the office. These audio comments were mainly about soil type, presence of ditches and their condition, and to correct any mistakes in classifications made with the keyboard.

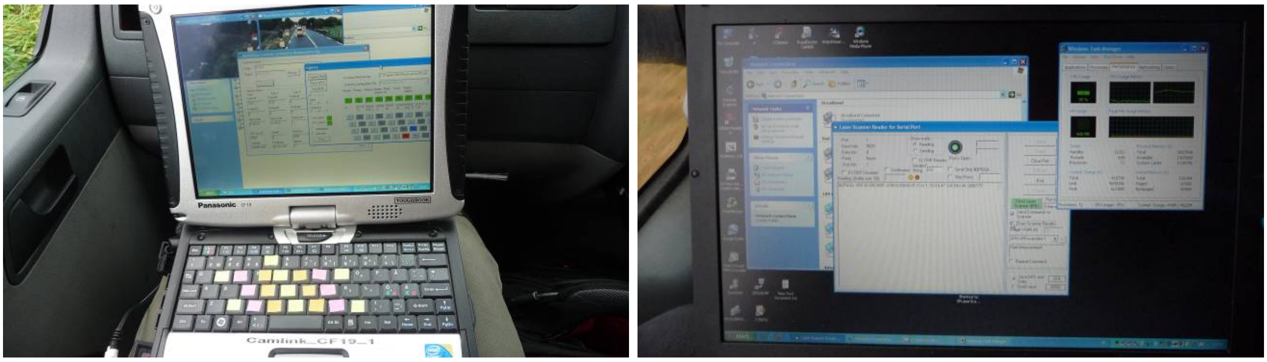


Figure 4 (left): The laptop used for drainage analysis, coloured pieces of paper helped to choose the right keys during the survey. (right): A view of laptop collecting the laser scanner data on the road.

The preliminary analysis was adjusted later in the office. This was made with the help of data from the road camera, and supplemented by data from the ditch camera view which was very useful in having a closer record of the ditches.

3.3. LASER SCANNER

In recent years the greatest developments in all of the NDT techniques used in road surveys have been made with the laser scanner technique and it is a fact that these systems will fast become a standard tool fo a variety of tasks in road condition management.

Laser scanning is a technique where the distance measurement is calculated from the travel time of a laser beam from the laser scanner to the target and back. When the laser beam angle is known and beams are sent out to different directions from a moving vehicle with known position, it is possible to make a 3d surface image, a "point cloud", from the road and its surroundings. In the point cloud with millions of points, every point has an x, y and z coordinate and a number of reflection or emission characteristics.

The accuracy of the laser scanner survey can be reduced by different factors reducing visibility, such as dust, rain, fog or snow. Also high vegetation can prevent information being obtained from the actual ground surface.

Laser Scanner is composed of three parts, the laser canon, a scanner and a detector. The laser canon produces the laser beam, the scanner circulates the laser beam and the detector measures the reflected signal and defines the distance to the target. The distance measurement is based on the travel time of light, or phase shift, or a combination of both.

The quality and price of mobile laser scanner survey systems vary but they can be roughly classified into two categories a) highly effective high accuracy systems and b) cheaper "everyman´s" laser scanner system that have reduced distance measurement capability and accuracy.

Laser scanner results can be used in several different ways in low volume road surveys. A road cross section profile can provide good information on the shape of the rutting and if there are verges preventing water flow away from the pavement. A map presenting surface levels in colour codes can be prepared to identify the places with debris filled ditches and clogged culverts. The changes in width of the road can also be easily seen from the maps. When other road survey data is combined with laser scanner data it can provide excellent basic information for analysing permanent deformation and road diagnostics.

In this project the data collection was collected using a SICK LMS151 laser scanner mounted on a survey van as shown in Figures 3 and *5.* The analysis was made with the new Road Doctor Laser Scanner module (RDLS) of Road Doctor software. This module facilitates integrated analysis of the laser scanner data together with other road survey data.

Figure 5: The laser scanner was installed behind the survey vehicle at the height of 3m.

4. DRAINAGE ANALYSIS

4.1. GENERAL

Road drainage arrangements in the Western Isles differ fairly significantly from Nordic countries where the ROADEX drainage survey method was originally developed. The main difference is that verges are quite common on older road sections. In some sections the removal of the verges could be expensive and difficult because there are cables placed inside the verge here and there.

The terrain differed significantly across the surveyed roads. In the northern part of of the Isle of Lewis the common subgrade soil type was peat. For example the surveyed section on the road A857 from Stornoway to Barvas had several peat sections. At the south side of the surveyed area towards Isle of Harris on the road A859 the terrain varied a lot. It was much drier, rocky and hilly.

The drainage in newly upgraded sections of road seemed to be working well. The ditches were deep enough and the verges had been removed.

A typical feature of the section of the A859 road in the Stornoway urban area was the use of special drainage systems like French drains and storm water piped drains. These special drainage structures appeared to be working well in the main, but in some cases they were blocked or just inadequate.

The great part of the severe drainage problems in the Western Isles appear to occur in the same kind of circumstances as in Nordic countries. A good example of this is where the road located on side sloping ground. If the ditch in the upper side of the road is not in good condition, problems will most likely occur.

4.1.1. A857 Stornoway – Barvas

The beginning of the section, from the roundabout in Stornoway to the cattle grid at 3700m, is within the urban area. Water outlets are available to take the water away from the road surface. There are additionally a couple of short sections with problematic verges inside this section.


Figure 6: An example of water outlets in the Stornoway urban area, marked with red circles (left) and an example of problematic verge (right).

Outside the urban area the road passes through uninhabited land until Barvas village. The terrain is treeless and mostly the road is located in side sloping ground (61,5%). Peat sections occurred along the road. The drainage deficiencies were typical for these kinds of road profiles. There are several sections where the ditch in the upper side of the side sloping ground was not good enough to take the water away. In some peat sections there were a few obvious drainage problems, where the ditches should be cleaned. It should be noted however, that making the ditches deeper in peat areas can cause other problems, such as retriggering settlement, and these should be taken into account. Verges were also causing problems at times by blocking the surface water from the road and preventing it running unrestricted to the ditch. The photographs below show some of the typical drainage problems on this road section.


Figures 7: Examples of problematic verges


Figures 8: Drainage deficiencies on the upper side of the side sloping ground.

4.1.2. A857 Barvas – Dell cattle grid

This section commenced in the village of Barvas. On the left side there was a footway up to chainage 1700m. The right side had short sections with verges. There was also a short section with offlets, which were partly lined with concrete.

Figure 9: "Special" offlets in the village of Barvas (marked with red circles). The concrete offlets were working well.

From chainage 3000m to 4000m the presence of verges was again creating drainage problems at times. Here there were numerous offlets available that appeared to be open but surface water was still lying at the edge of the pavement (Figure 10). Later along this same section a couple of weak outlet ditches were noted.

Figures 10: Photograph showing that even with sufficient offlets the surface water was still running along the edge of the pavement

The road from chainage 4100m to the village of Baile an Truiseil had been upgraded. The structure appeared thicker and the verges had been removed in the upgrading process. This section was in good condition and the drainage was working well (Figure 11).

Figures 11: Upgraded section of road close to the village of Baile an Truiseil

There were stone walls to the rear of the verges on the left side of the road on the approach to Borve village with the result that there was little room for a ditch. The ditch present was clogged with vegetation (Figure 12).

Figures 12: Stone wall close to the road near the Borve village.

After the bridge in Borve there was a short section of road with a very high verge on the left side and a damaged road edge (Figure 13).

Figures 13: Problematic verge in the village of Borve

Also in this section there were many examples of drainage problems that correlated with damages in the road surface correlate, especially where the road was in side sloping ground and the upper ditch was not functioning well.

Figures 14: Inadequate drainage located in the upper side of the road

From Loch Barabhat to the end of the section at Dell cattle grid there was a long section with inadequate drainage. The section was located on peat and the road profile was mostly in side sloping ground. The most of the road damage was on the upper side of the side slope.

Figures 15: Shallow ditches and also problematic verge

4.1.3. A858 A859 - Garynahine

The road profile of this section of road was mostly (90%) in side sloping ground. The drainage deficiencies noted were quite typical for the road profile. Drainage problems mainly occurred mainly on the right hand side of the road, i.e. the upper side of the side slope. Drainage difficulties were compounded by the presence of verges.

Figures 16: Example photographs of typical drainage deficiencies on Road A858

4.1.4. A859 Stornoway - Keose

The beginning of this section was located in an urban area. Typical features for this part of the road were water outlets and drains from the beginning until chainage 1800m. Within the urban section there were several sections with damages which correlated well with drainage deficiencies. In some places the water outlets did not appear to be working efficiently enough. Also in some sections the high verges were blocking the surface water from reaching the drains.

Figures 17: Drainage deficiencies in Stornoway at the start of the surveyed section.

Several severe drainage deficiencies occurred immediately after leaving the urban area. The road profile had been constructed on side sloping ground and the ditch on the upper side of the road did not appear to be functioning well. Stone wall was very close to the road on the left side, and the ditch between the road and the wall was partly missing or too shallow.

Figures 18: Problems caused by the proximity of the stone wall to the road.

At chainage 4250m there was a clear outlet ditch problem; water was lying in the ditch on the left side of the road (figure 19). This might be difficult to improve as the landscape is flat. For this reason it may be very difficult to ensure that water can flow freely away from the area.

Figure 19: Problematic outlet ditch on the left side of the road.

The condition of the pavement varied greatly along the remainder of the surveyed section. There were several sections with new pavement and also sections with old and weak pavement surface. The terrain also varied towards the end of the section. The end section was much drier compared to the beginning of the section. Most of the drainage deficiencies were due to problematic verge sections but there were also a few sections with clogged ditches. These ditches should be cleaned and deepened where appropriate. (Figure 20)

Figures 20: Problematic verges and damages they have caused.


Figures 21: Drainage deficiencies in the upper side of the side sloping ground

4.1.5. A859 Junction of B8060 - Scaladale

In this section the majority of the offlets were made of concrete. Most of the offlets were working well but some were broken. In some cases, especially in the middle part of the section, the concrete offlets were clearly open and looking fine, but the surface water was still lying in the edge of the pavement.


Figures 22: Offlets made of concrete, an example of broken concrete offlet on the right figure


Figures 23: Good concrete offlets, but it still appears that the water has stayed in the edge of the pavement

In the village of Arivruach the road profile was steeply side sloping. On the right (upper) side of the road there were drainage deficiencies and sections with problematic verges. The drainage deficiencies noted were typical for this kind of road profile.

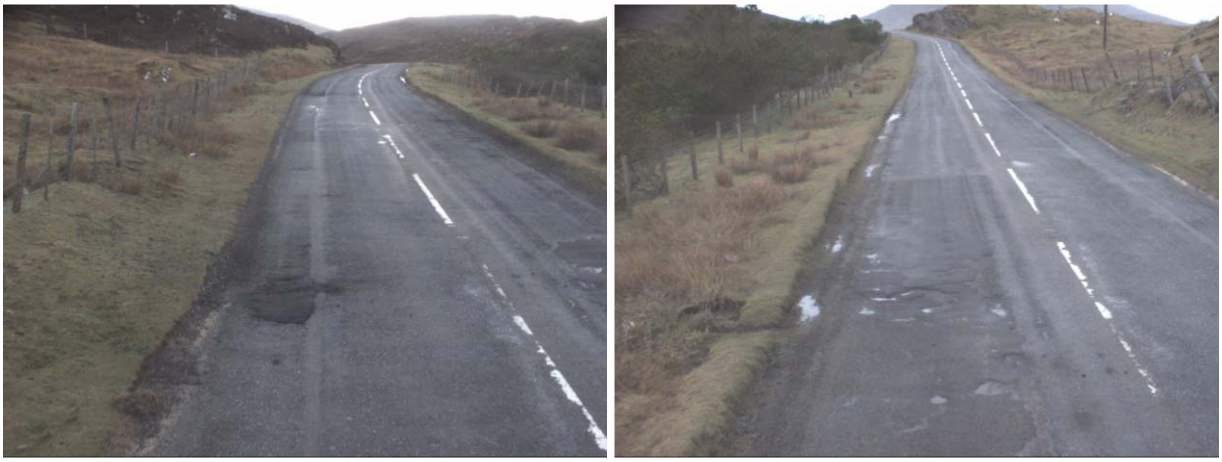
Figures 24: Drainage deficiencies on the upper side of the side sloping ground

An upgraded section of road commenced at chainage 11550m and ended near the bridge at chainage 14800m. In this renewed section drainage has been well maintained: the verges have been removed and the ditches are deep enough. The section is located on side sloping ground and it will be important in the future to keep the ditches in the upper side in good condition. A special drainage structure has been used in this section. Long offlets lead the water from the road surface to the ditch which is located further from the road. This solution appeared to be working well.

Figures 25: On the left picture there are long offlets to lead the water to the ditch at Bowglass. On the right picture unstable soil is blocking the ditch.

4.1.6. A859 Northton – Leverburgh

This section started as two lane road but changed to a single-lane road within the surveyed length. The quality of the pavement varied significantly; the section in the middle was in quite poor condition. The end of the section in Leverburgh was in good shape. The ditch in the upper side of the road was missing from chainage 700m to chainage 800m.



Figures 26: The ditch in the left side of the road is missing

4.1.7. Road B8011 Garynahine to B8059 junction

This section contained a number of road cuts with drainage problems. In some cases unstable material and stones had fallen to the bottom of the ditch prevent the free flow of water (figure 29).

Figures 27: Stones are blocking the ditch

Another typical problem in some road cuts in this section was the absence of a ditch. This lack of ditch appeared to correlate with adjacent pavement damages. Where the ditch was missing, there were more damages in the pavement surface.

Figures 28: The ditch is missing in a road cut

4.2. DRAINAGE CLASSIFICATION

The drainage classification of the surveyed roads was carried out using the principles that will be presented in this chapter. A complete description of the ROADEX drainage analysis classification is given in the ROADEX report "*Drainage Survey Method Description*".

4.2.1. Class 1; Drainage in Good Condition

Drainage Class 1 means that the drainage condition is faultless. The cross-section of the road has preserved its form well and water flows unrestricted from the pavement to the ditch. Water has also a clear passage in the ditches. Where a verge is present it has enough offlets to let the water flow to the ditch.

Figures 29: Examples of road sections with drainage Class 1 in the Western Isles

4.2.2. Drainage Class 2; Drainage in Adequate Condition

In drainage Class 2 there can be some visible changes to the road cross-section. The road shoulder has narrow verges or vegetation growth that is preventing the free flow of surface water from the road surface into the ditch. There is some vegetation in the ditch that restricts water flow and creates damages. Some soil is sliding from the road side slope into the ditches and raising the bottom of the ditch. This hinders water flow and raises the ground water level.

Figures 30: Examples of road sections with drainage Class 2 in the Western Isles.

4.2.3. Drainage Class 3; Drainage in Poor Condition

Drainage Class 3 covers those road sections with severe drainage problems. The road shoulder has a high verge and/or dense vegetation that are causing ponding on the traffic lane or on the shoulder. Vegetation is growing in the ditches and restraining the flow of water creating dams in the ditches. Unstable soil is flowing from ditch slopes into the bottoms of ditches and blocking the flow of water. Clogged culverts or outlet ditches is preventing the flow of water in the ditch. All of these situations lead to the development of deformation and damage in the road cross-section.

Figure 31: Examples of road sections with drainage Class 3 in the Western Isles.

4.3. VERGE CLASSIFICATION

Earlier research in the ROADEX project indicated that verges can have a substantial negative impact on road drainage. Statistical results of the Irish drainage demonstration project showed a correlation between the verges and the IRI and Rutting data. In the Western Isles demonstration survey the verges were classified into three classes to see if the correlation would work the same way. The classification was made according to the principles below:

4.3.1. Verge Class 1; No verges

Class 1 verges cover those road sections where there is no verge and water can flow freely from road surface. Figure 33 presents two examples of verge Class 1 road sections.

Figure 32: Two examples of verge Class 1, i.e. road sections without verges.

4.3.2. Verge Class 2; Minor verges

Class 2 verges cover all road sections with minor verges and adequate offlets. The number of offlets is enough to ensure proper drainage and they are in good condition. The water can flow freely from the road surface. Verges do not restrict the water flow or the workings of the road drainage system. Figure 33 shows a few examples of road sections with verge Class 2.

Figure 33: Two examples of verge Class 2, roads with a verge which has minor effect on the workings of the road drainage system.

4.3.3. Verge Class 3; Significant verges

Class 3 verges cover those road sections with significant verges restricting the water flow away from the pavement causing ponding and other problems. There are no offlets or they are in poor condition. Figure 34 shows a few examples of road sections belonging to verge Class 3.

Figure 34: A few examples of verge Class 3, roads with a verge that has a significant negative impact on the workings of the road drainage system.

,

5. DRAINAGE ANALYSIS RESULT

5.1. STATISTICAL RESULTS OF THE SURVEY

5.1.1. Summary of the Roads

Overall, for all of the roads surveyed, the road profile was classified as being in side sloping ground in no less than two-thirds of the surveyed length (Figure 35). Figure 36 shows that the average drainage class was the best in road sections classified as embankment. The average drainage class in these sections was 1.3. The drainage was in the worst condition in road cuts. There was only a minor difference in average drainage class between 0-level and side sloping ground.

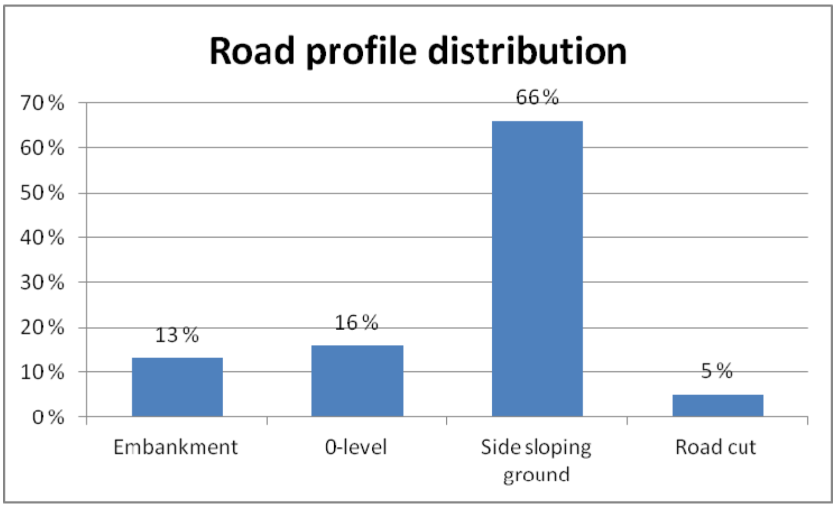


Figure 35: Distribution of the road profile

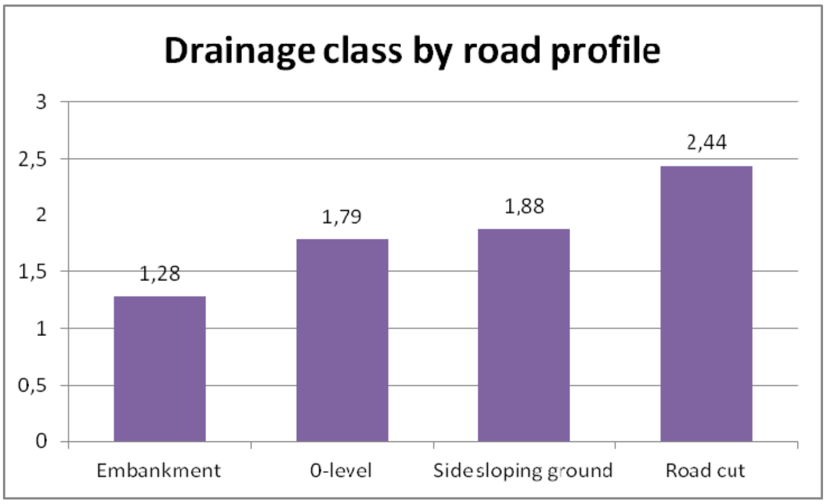


Figure 36: The average drainage class in different road profiles

5.1.2. Summary of Drainage and Verge Classes

As already mentioned the drainage condition on the surveyed roads was divided into three different classes: Class 1 (Good condition), Class 2 (Adequate condition) and Class 3 (Poor condition). The verges were also classified into three classes: Class 1 (No verges), Class 2 (Minor verges) and Class 3 (Significant verges). The distribution of the drainage classes and verge classes are shown in Figures 37 and 38. The majority of the surveyed sections had a drainage class of Class 1 (54%), whilst the main verge class was Class 3 (59%).

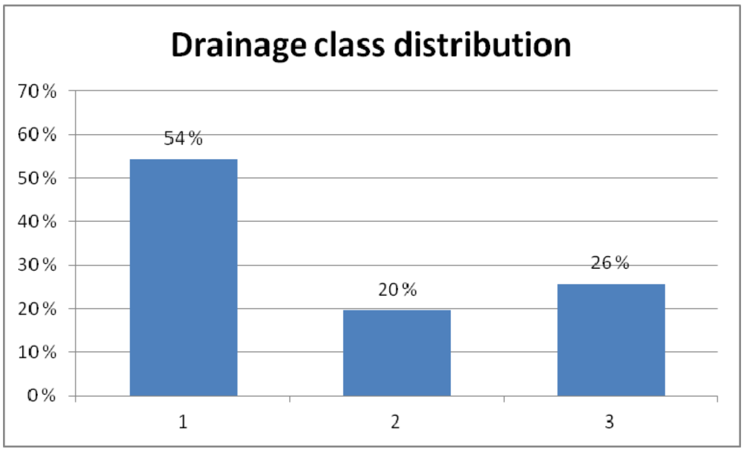


Figure 37: Distribution of drainage class distribution

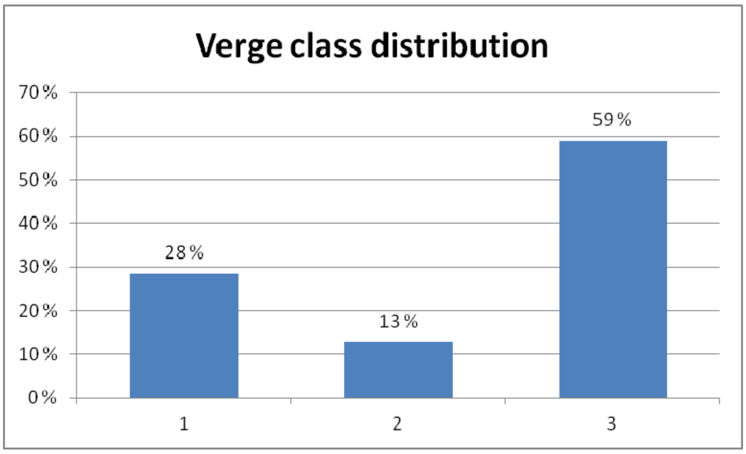


Figure 38: Distribution of verge class distribution

5.1.3. Drainage Condition and Verge Severity in Surveyed Sections

The drainage and verge classes of each section were examined statistically. The distribution of average drainage classes in each surveyed section is presented in Figure 39. The worst sections for drainage class from a statistical point of view were the A857 section from Barvas to Dell and the A859 section from Stornoway to Keose.

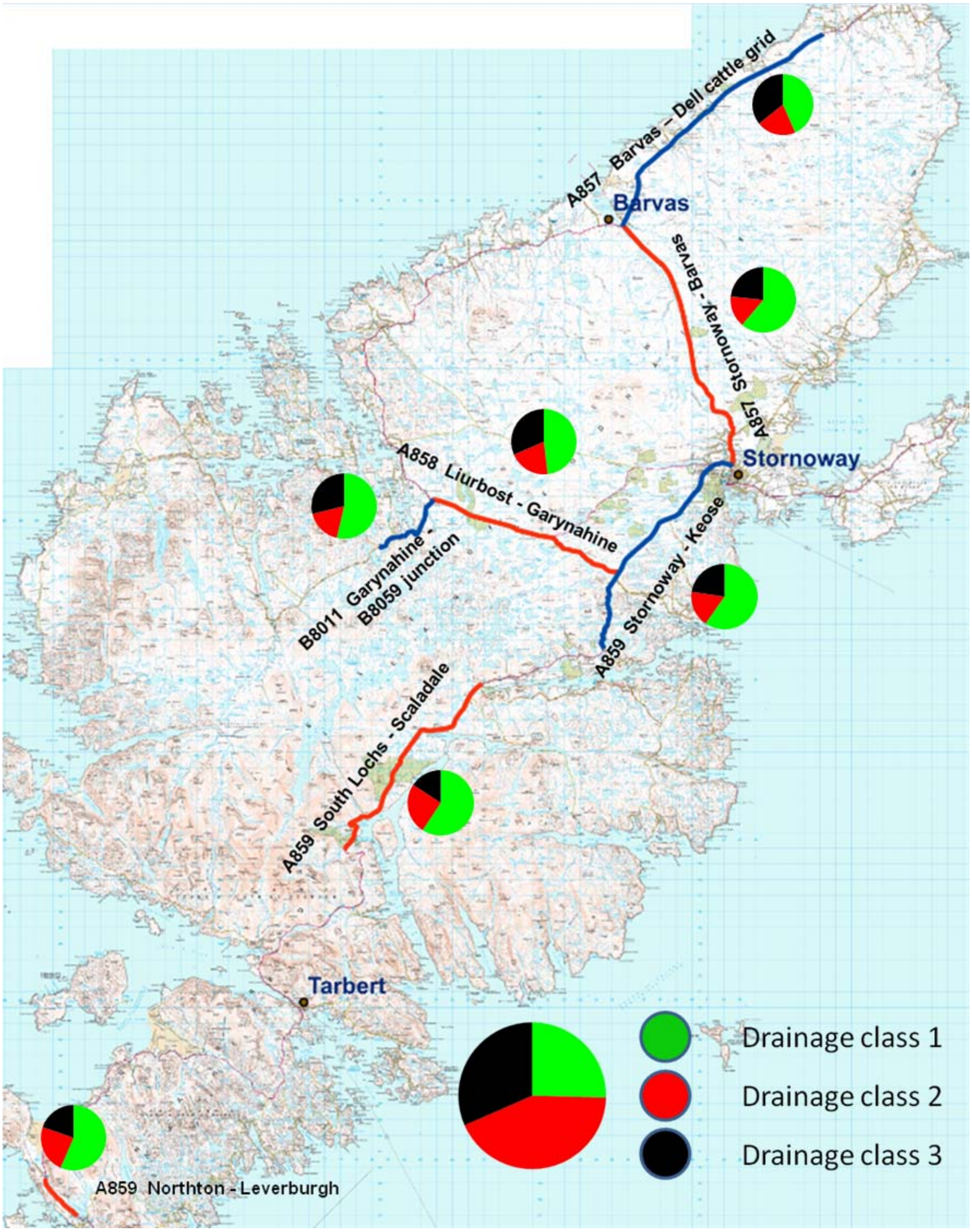


Figure 39: Distribution of average drainage classes in the surveyed roads

The distribution of average verge classes in each surveyed section is presented in Figure 40. The sections with the highest percentage of verge Class 3 were the A859 section from Stornoway to Keose and the A858 section from Cameron Terrace to Garynahine. The best section for verge classification was the A859 section from Northton to Leverburgh.

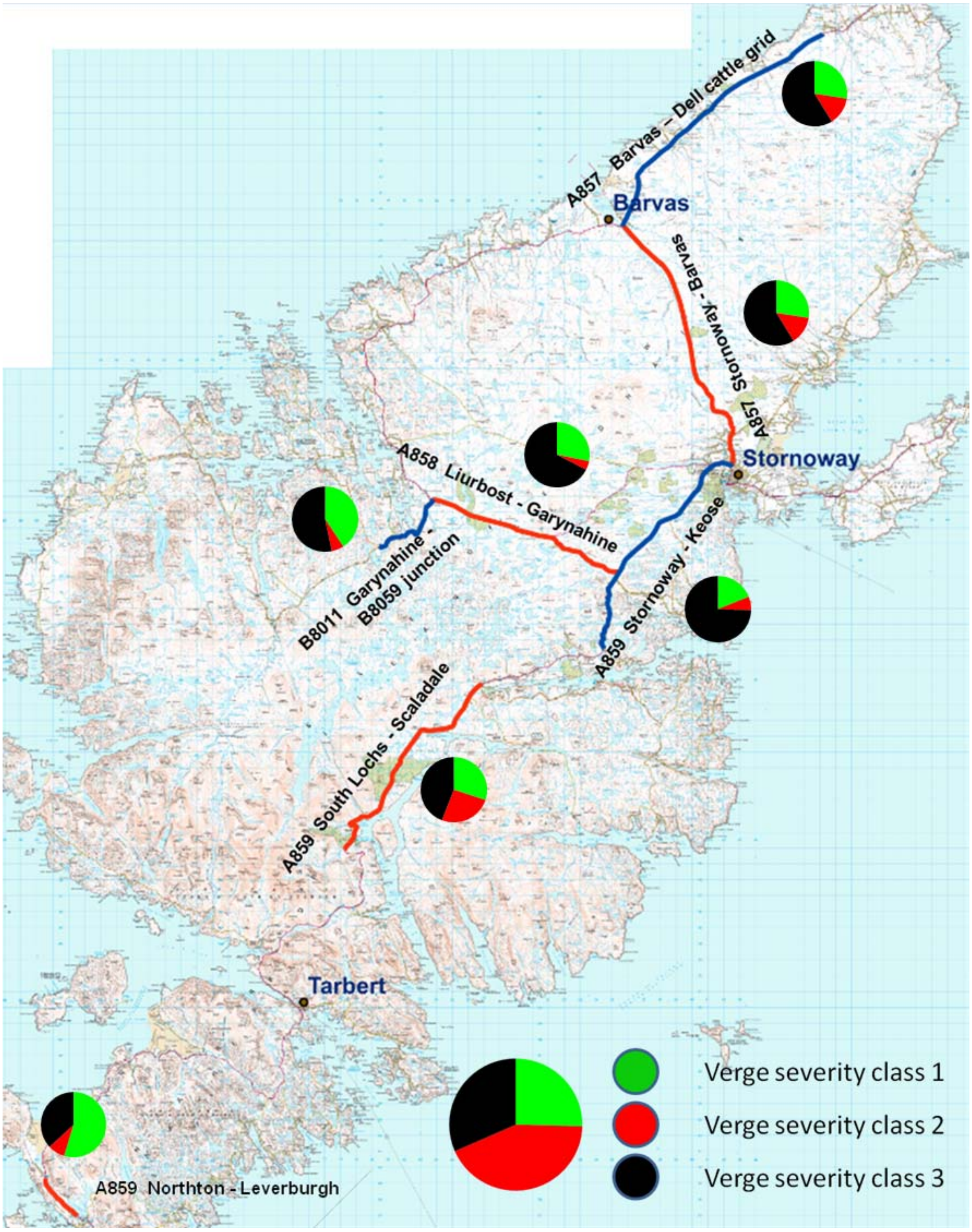


Figure 40: Distribution of verge severity in the surveyed roads

The detailed statistical maps for each road section surveyed are presented in Figures 41-47. These maps are printed from Road Doctor project trees to show the drainage and verge classification of each section. From these detailed maps it can be seen that in many cases where severe verge problems were observed there were also problems with the ditches.

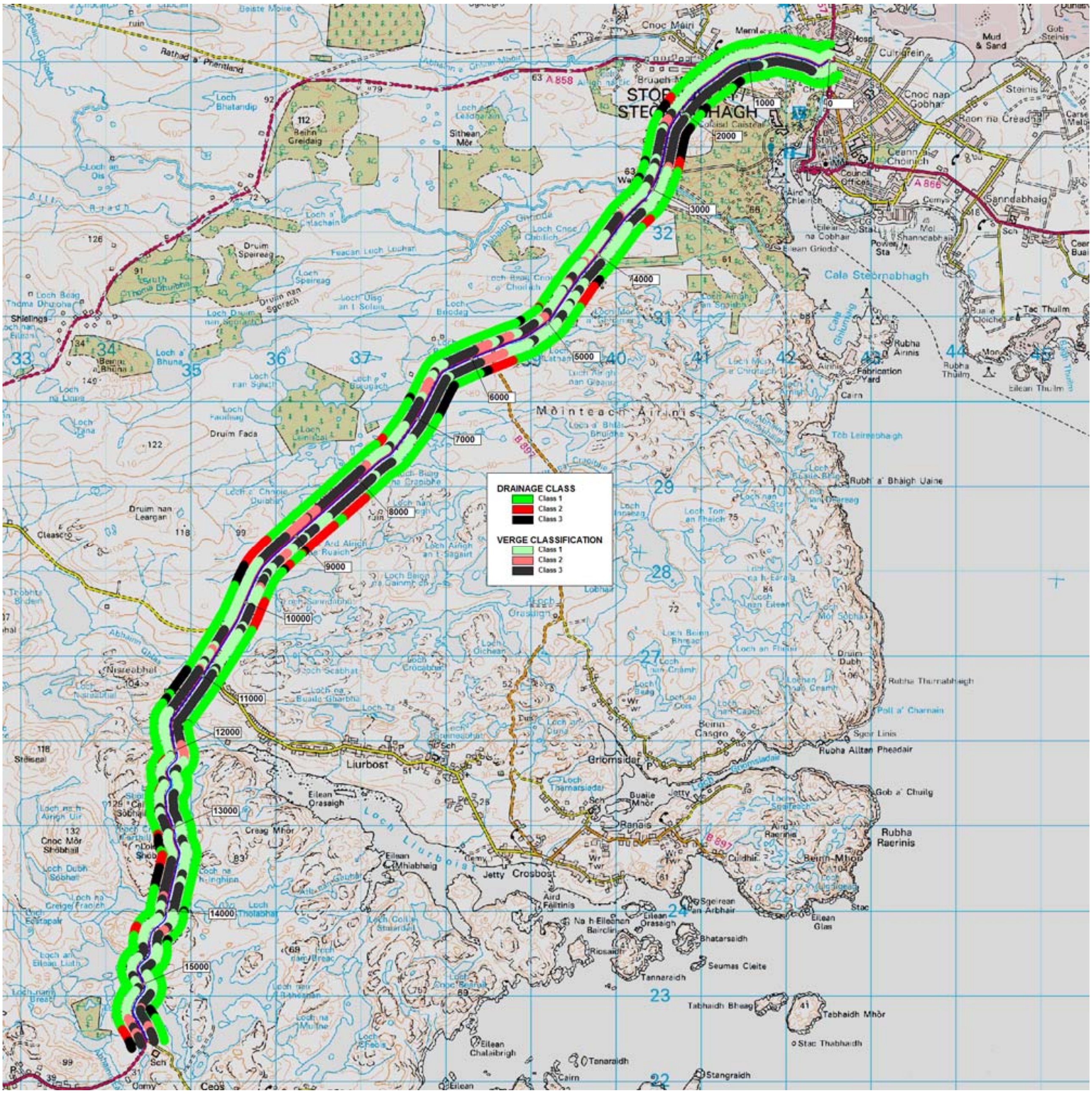


Figure 41: Drainage and Verge classification in road A859, section Stornoway – Keose

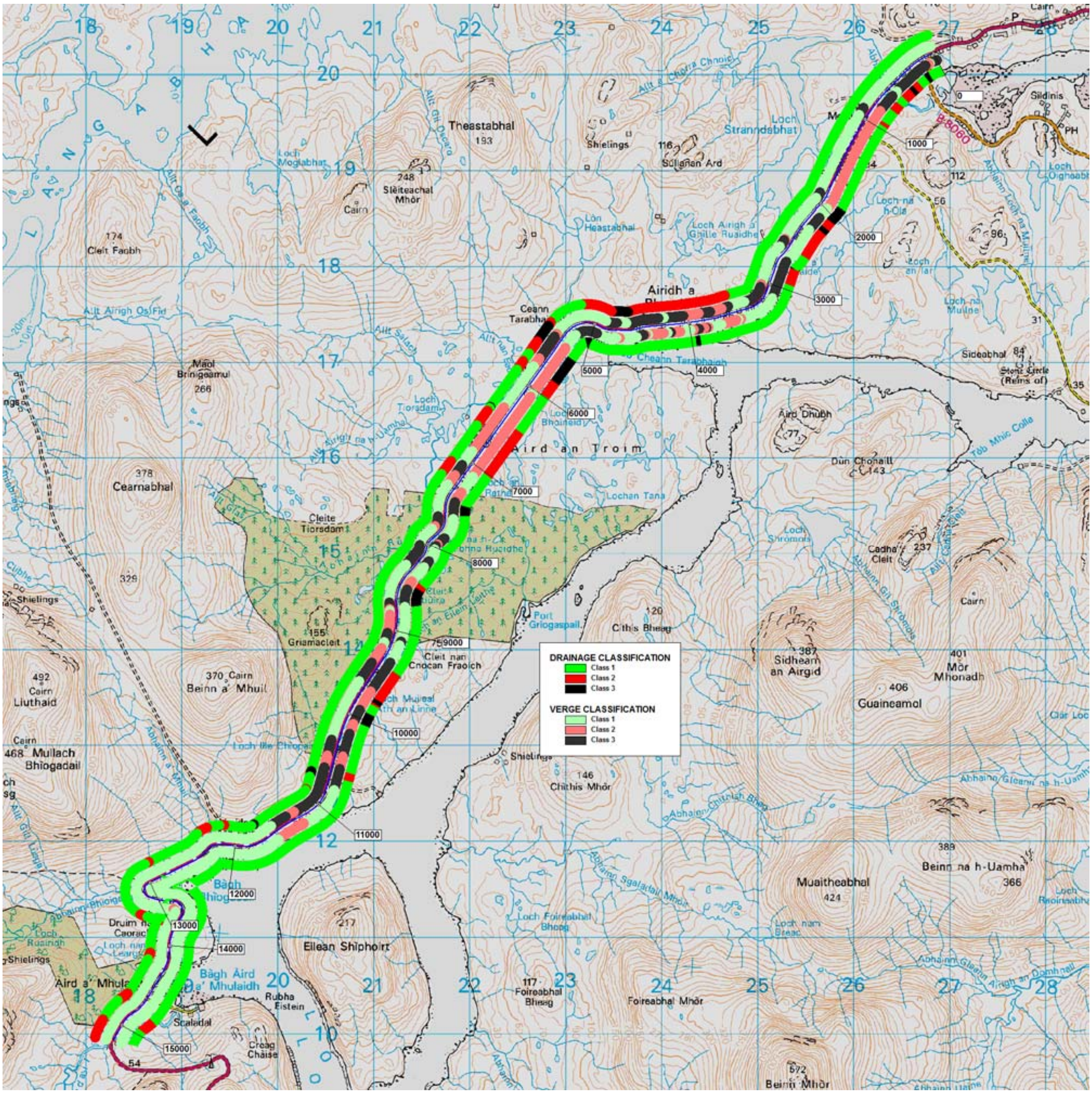


Figure 42: Drainage and Verge classification in road A859, section B8059 – Scaladale

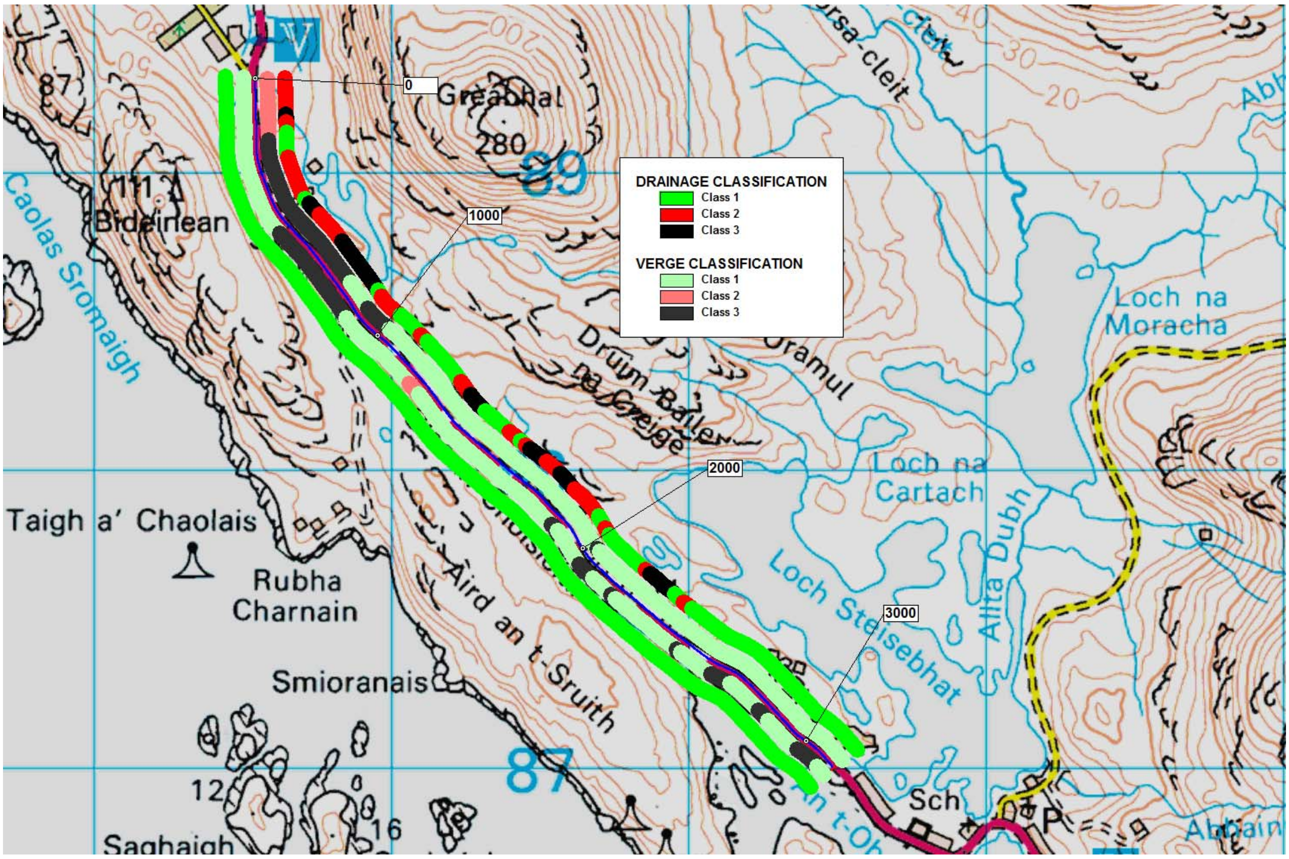


Figure 43: Drainage and Verge classification in road A859, section Northton – Leverburg

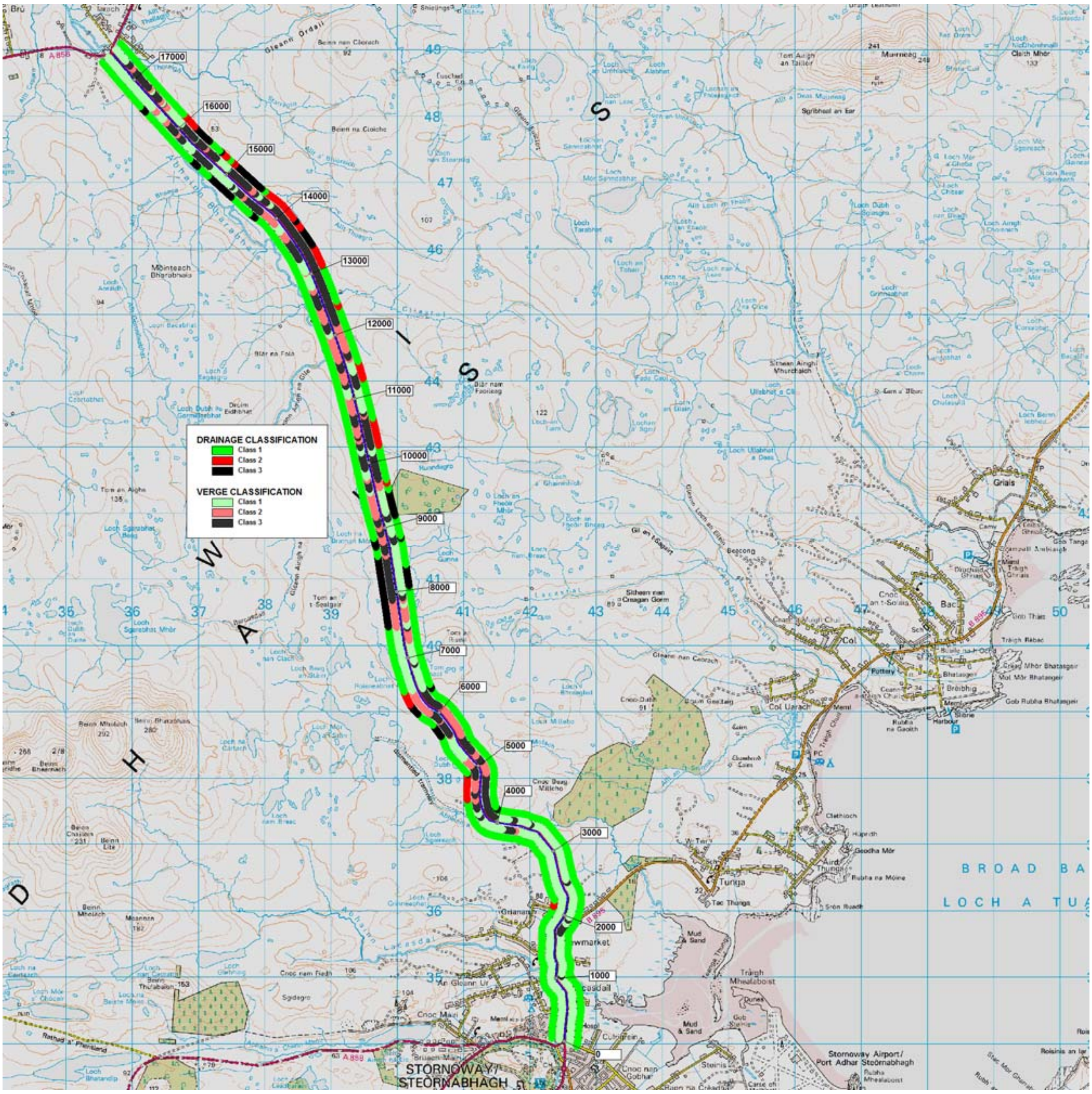


Figure 44: Drainage and Verge classification in road A857, section Stornoway – Barvas

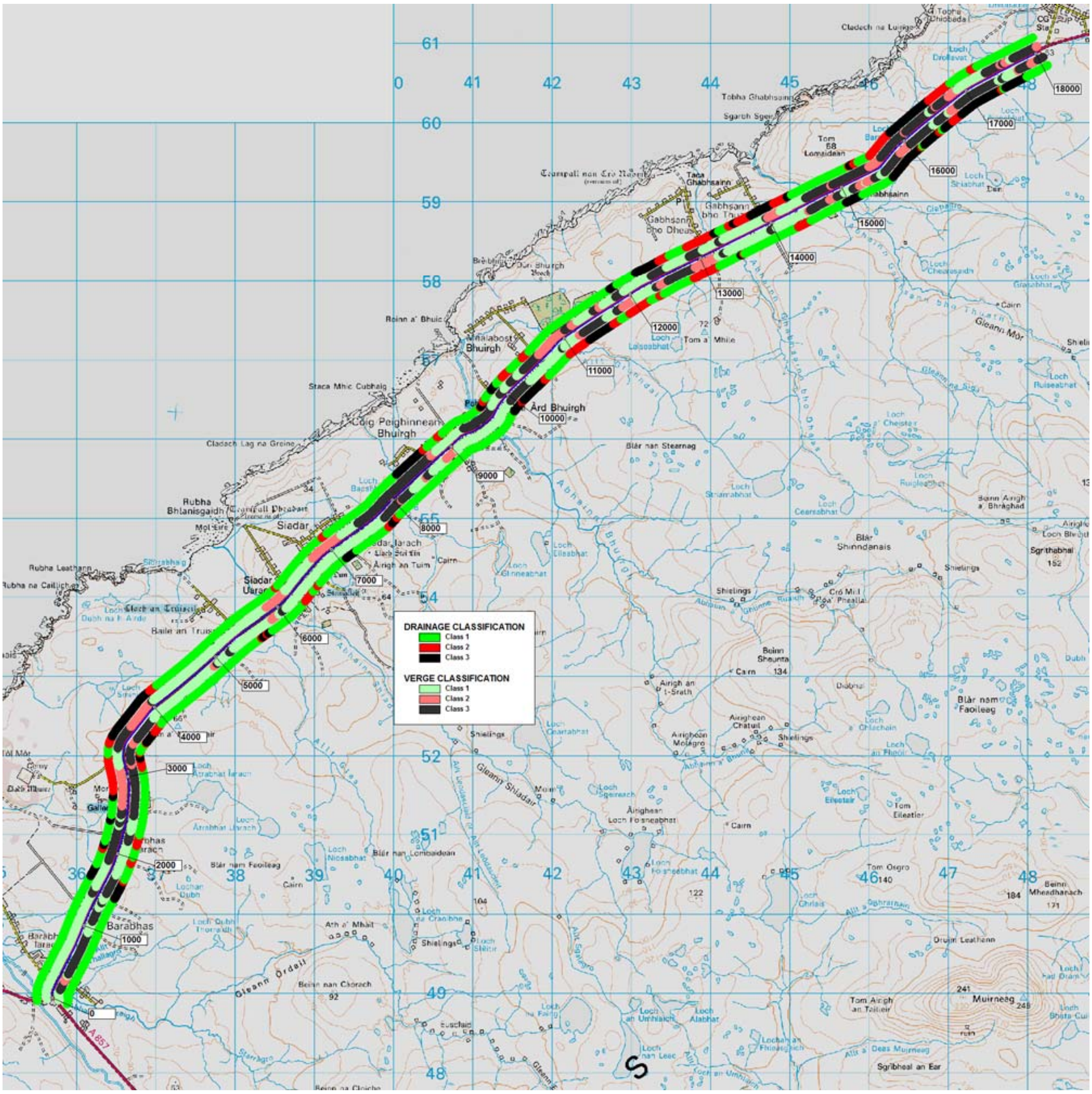


Figure 45: Drainage and Verge classification in road A857, section Barvas – Dell

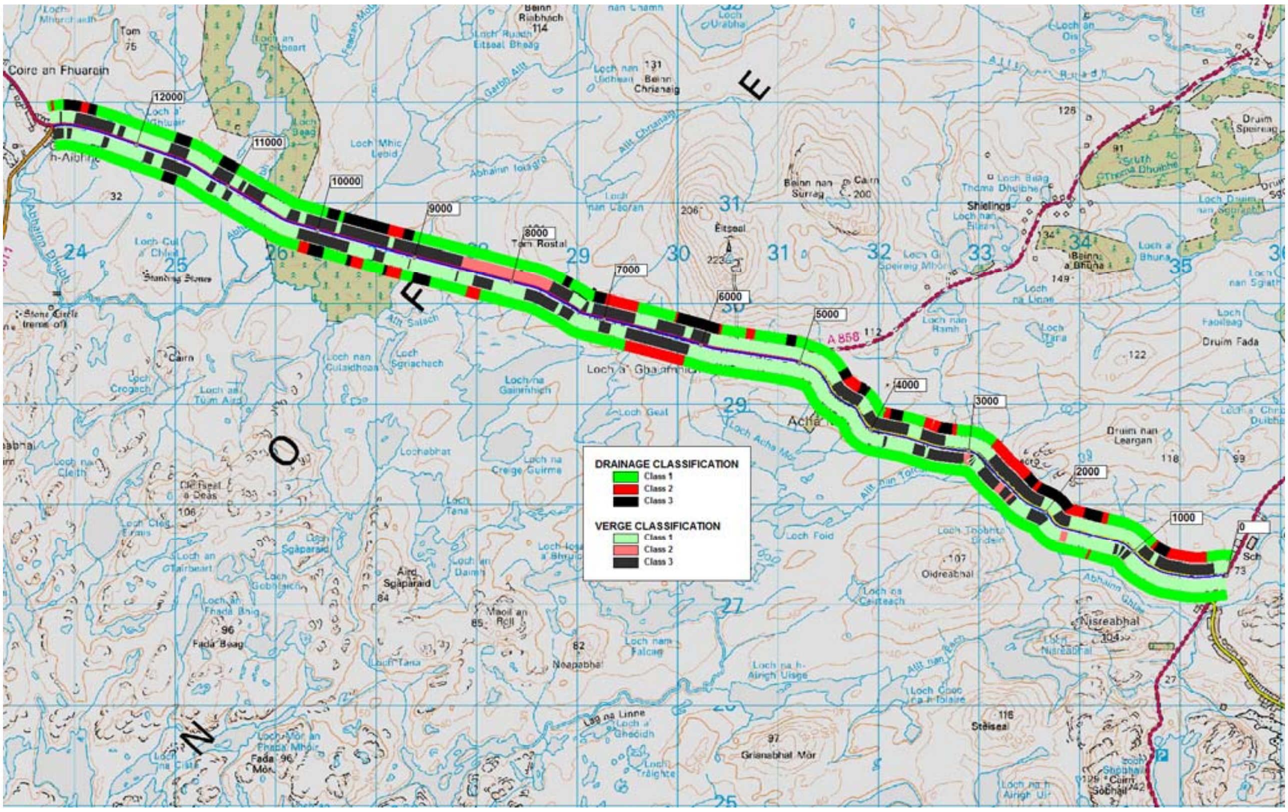


Figure 46: Drainage and Verge classification in road A858, section A859 – Garynahine

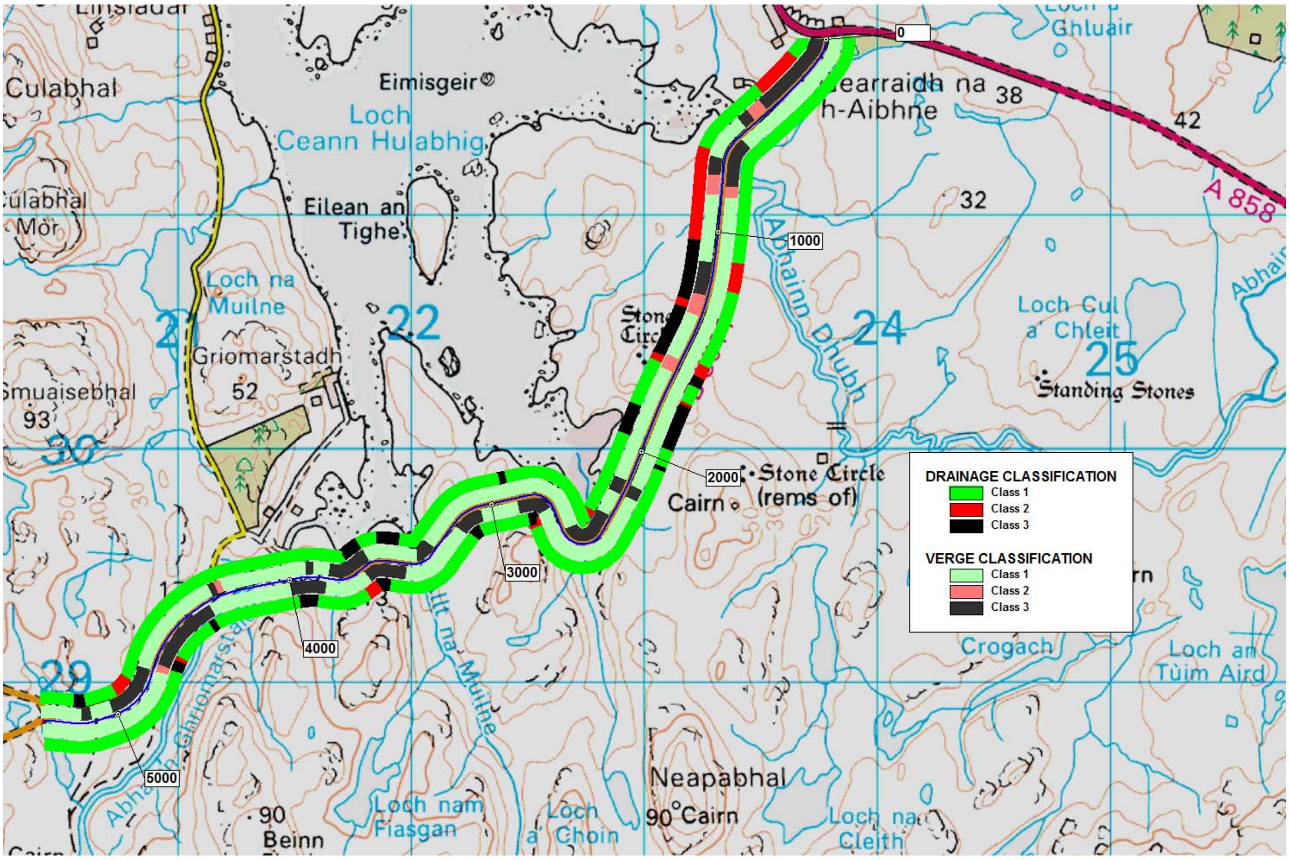


Figure 47: Drainage and Verge classification in road B8011, section Garynahine – B8059

5.2. DRAINAGE AND ROAD PERFORMANCE

5.2.1. Effect of Drainage on Rutting

As already mentioned two-thirds (66%) of the surveyed chainage was in side sloping ground. Unfortunately from the statistical point of view most of the rutting data was collected from the "wrong" side of the road in nearly all of the sections. The direction of the rutting data is from Stornoway outwards and because of the coastal terrain the two sections of roads A857 and A859 south of Stornoway were measured on the lower side of the side slope. Similarly the surveyed sections in road A857 from Stornoway to Barvas, and the section in road A858, mainly side slope in the same way and the rutting data again is unfortunately from the lower side of the slope.

It is usually the case is that the most of the problems on roads on side sloping ground take place in the upper side of the side slope and the lower side usually has less damage (Figure 48). That is because in side sloping ground the water wants to flow "through" the road using the shortest possible path. If the drainage in the upper side of the side slope is not in good condition the water will stay in the ditch causing problems which are usually visible and measurable in that side of the road. This might have had some effect on rutting depth calculations by drainage classes.

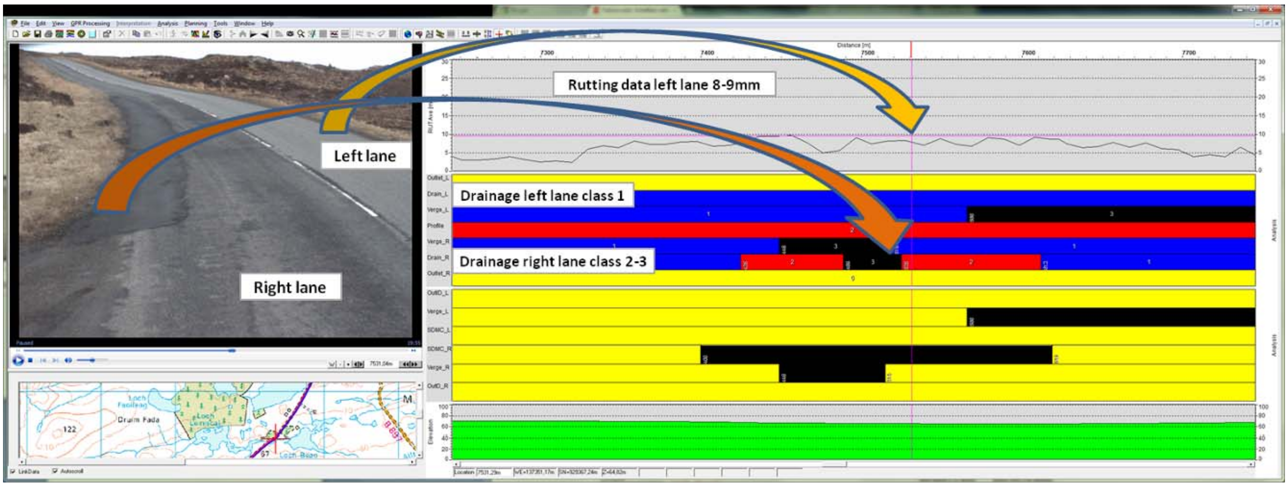


Figure 48: Road Doctor view from direction 2. Drainage problems and severe damages on the pavement on the right lane. Rutting data is from left lane which is in much better condition. Also the drainage is Class 1 on the left lane.

The data provided by Technical Services Department did not include IRI data which meant that it was not possible to carry out an IRI correlation analysis. However, in similar drainage projects the IRI has usually correlated well with any drainage deficiencies.

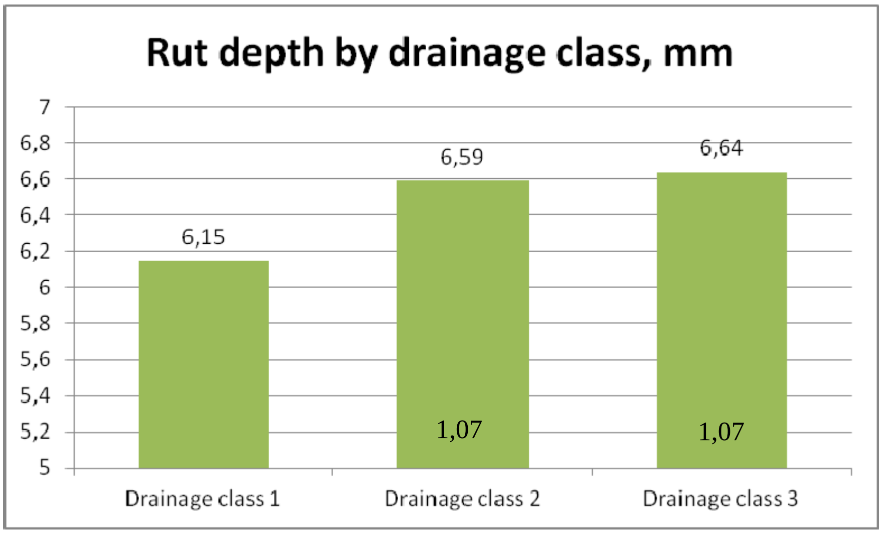


Figure 49: The average rut depth value for each drainage class. The value on the top of the column shows the average rut depth value on each drainage class. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

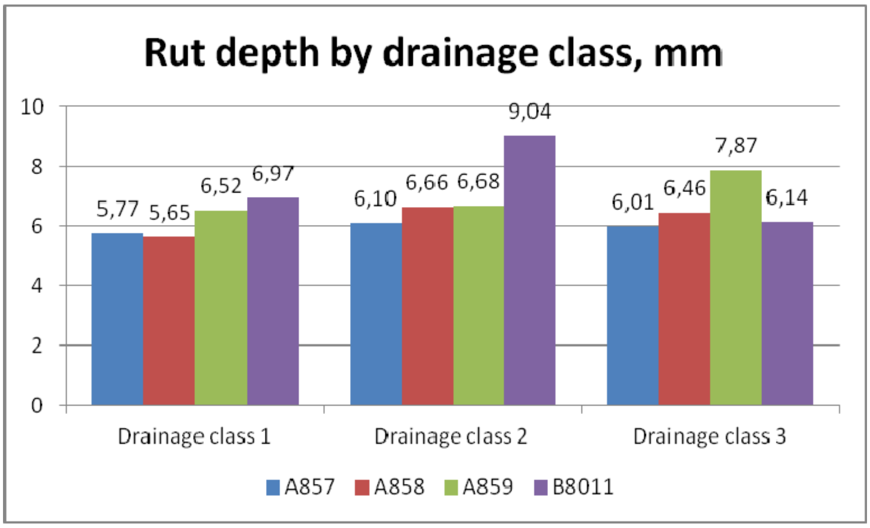


Figure 50: The mean rut depth values classified by drainage classes in surveyed roads.

In the surveyed sections there was one section where the side slope happened to be the "opposite way" compared to normal rutting data collection. This section was on the A859 from Northton to Leverburgh Bridge. Nearly all this section was in side sloping profile and the upper side of the slope was on the left side of the road which was the lane where rutting data was measured. In this section the correlation between the drainage classification and rutting was much stronger than the average. On the other hand there was no correlation between verge class and rutting values in the section. (Figures 50 and 51).

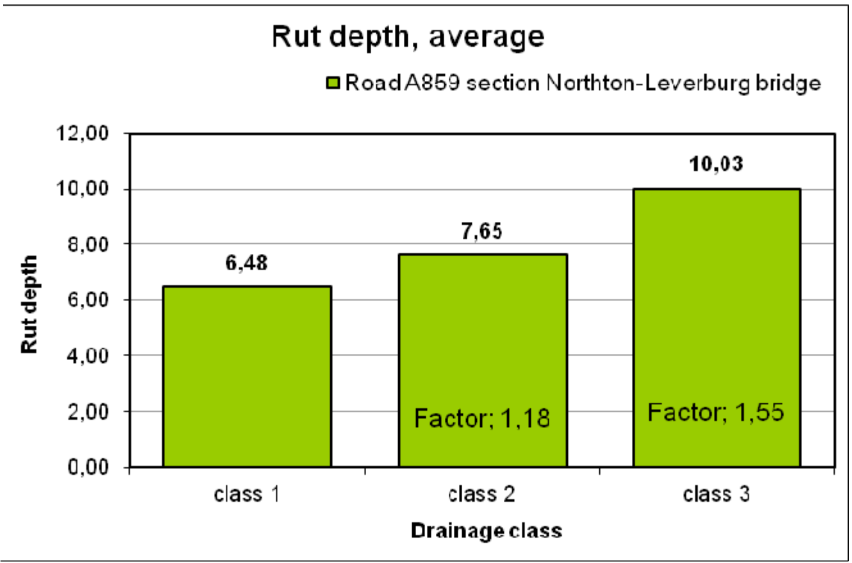


Figure 51: Rut depth classified by drainage classes in road A859, section Northton – Leverburgh Bridge. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

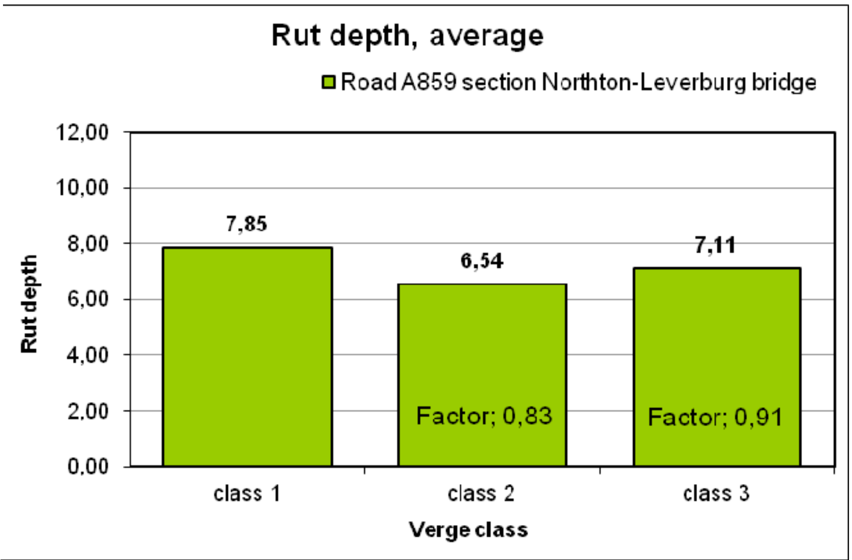


Figure 52: Rut depth classified by verge classes in road A859, section Northton – Leverburgh Bridge. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

5.2.2. Effect of Verges on Rutting

Verges also have an effect on the roughness and rutting of a road. In this project it was not possible to examine the affect of the verges on roughness as data on roughness was not available. Overall, for the particular circumstances of the Western Isles, it appears that the presence of roadside verges has even a bigger affect on rutting values compared to drainage problems. It was noted that there were cables inside the verges in some locations. Lowering or removing these verges could be difficult and expensive.

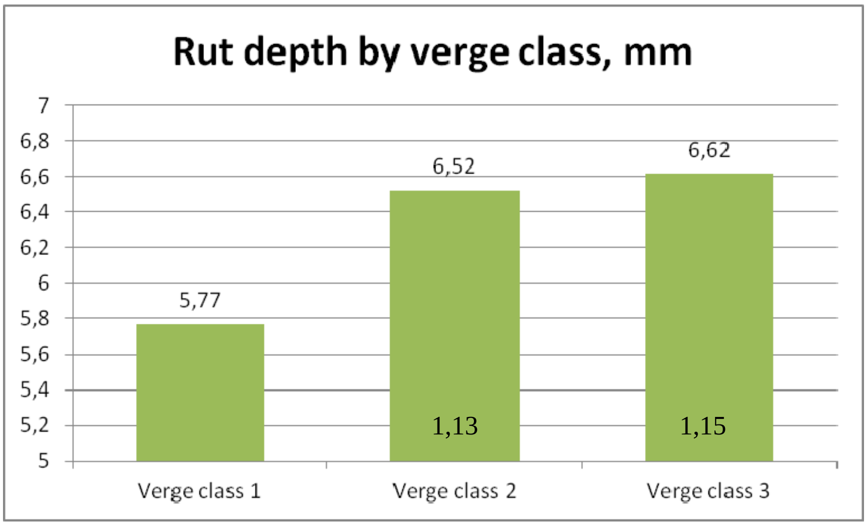


Figure 53: The average rutting value compared to verge classes. The value on the top of the column shows the average rutting value in each drainage class. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

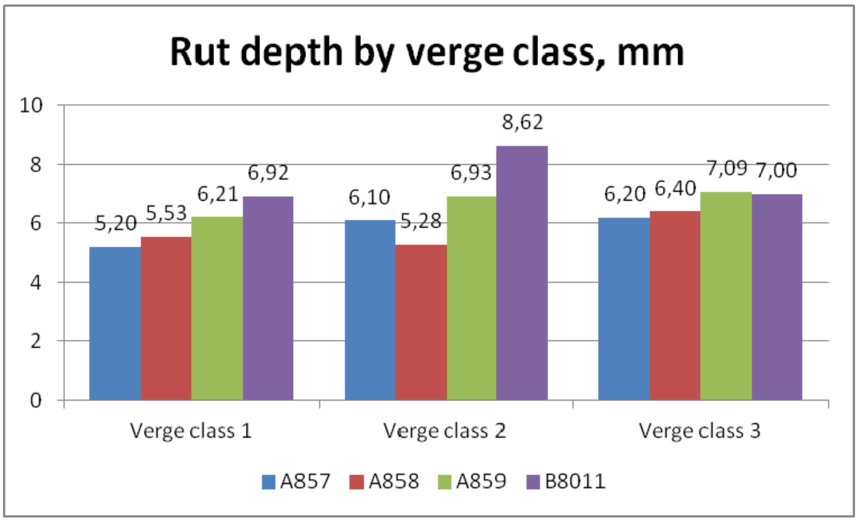


Figure 54: The mean rut depth values classified by verge classes in surveyed roads.

6. LASER SCANNER SURVEY RESULT

Laser scanner surveys in drainage analysis have been previously tested by the ROADEX project in Umeå Södra area in Sweden in 2009 with promising results. The Western Isles survey was the second ROADEX drainage demonstration survey which also included a laser scanner survey. The aim of the task was to measure the depths of the ditch bottoms.

The circumstances in roads in Western Islands appeared to be a challenge for the laser scanner due to the presence of verges and vegetation on the road sides. Verges and vegetation cause disturbances to the laser scanner beams in reaching the bottom of the ditch which could give inaccurate results for ditch depths. More information on the principles of laser scanner method and possible errors are given in Chapter 3.3. Despite this however the actual laser scanner survey results on Western Isles road network were very promising, considering the challenging circumstances mentioned earlier.

6.1. DATA ANALYSIS

The analysing methods of laser scanner data have been further developed since the Umeå Södra project. At that time, the points had to be picked up manually, but for the Western Isles surveys it was possible to do this automatically by using Road Doctor Laser Scanner software module. Five points are usually selected from the road cross section; the level of both ditch bottoms, the level of both road edges and the level of the centreline (figure 55).

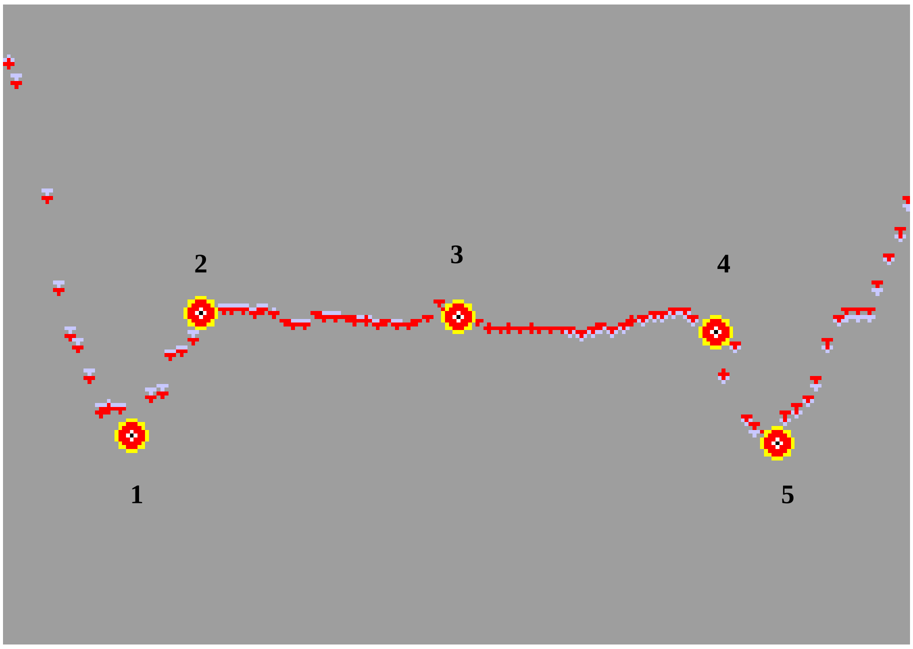


Figure 55: Diagram showing the points selected from the cross-section, from left to right: 1.The bottom of the left ditch 2.left road edge 3.centreline 4.right road edge 5.the bottom of the right ditch

The data from the laser scanner surveys was processed with the Road Doctor Laser Scanner module. According to the guidelines in the Nordic countries the bottom of the ditch should be more than 20cm deeper than the bottom of the road structure. Unfortunately GPR data was not available for the roads surveyed for drainage analysis, so the bottom of the road structure could not be determined.

6.2. ANALYSIS OF DITCH DEPTHS

Figure 56 and 57 show examples of the analysis of ditch depths using the data from laser scanner surveys. The depth of the ditch is calculated from the difference in level between the road centreline and the bottom of the ditch. As already mentioned the verges and the vegetation in the ditches can affect the accuracy of the data laser scanner data.

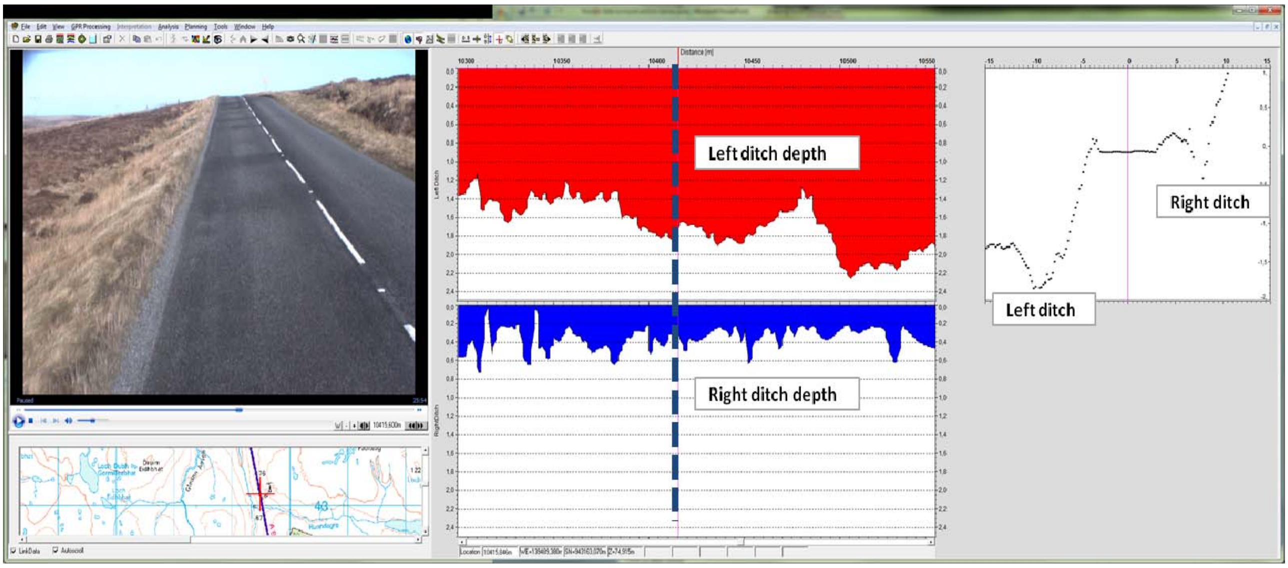


Figure 56: Example of the data view where the road profile is in side sloping ground from right to left. The top panel shows a profile of the left ditch depth from 10300 to 10550, and the bottom panel shows the depth of the right ditch over the same distance. The blue dashed line indicates the position of the cross section. It will be seen that the right ditch is very shallow over this length..

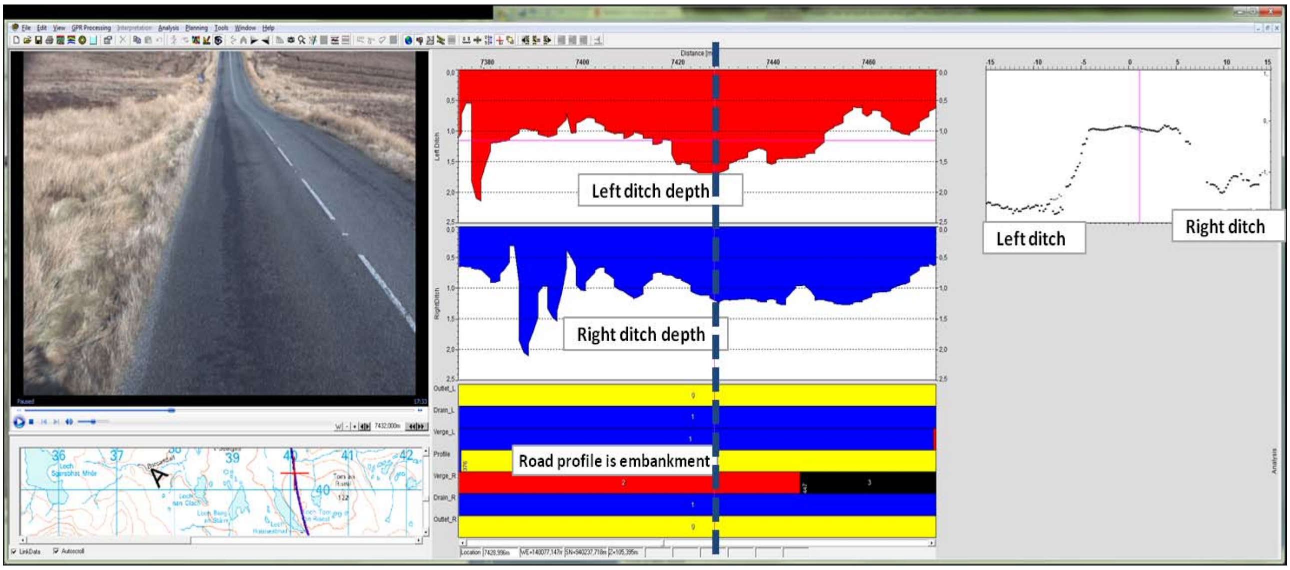


Figure 57: Example of a section in embankment. There are no real ditches on this section but the program sees the toe of the embankment as the depth of the ditch.

When GPR data is available it is possible to interpret the bottom of the road structure and compare the level to the level of the ditch bottom from the laser scanner data. For the Western Isles surveys there were some road sections where GPR data was available from previous road surveys. In order to demonstrate the calculation this GPR data was linked to the drainage analysis survey so that the project road structure thickness could be interpreted. When this was done an example was prepared to show what the results would have been if it had been possible to combine the GPR and laser scanner surveys (Figure 58). This example taken is from the A857 Stornoway to Barvas section at chainage 14600m. The road profile is side sloping and on the right side the drainage is Class 3. The ditch is shallow and full of vegetation. The grey panel in the screendump is the bottom of the road structure interpreted from the GPR data and the coloured lines are the ditch depths from the laser scanner data. From this figure it can be clearly seen that the bottom level of left ditch is too high and water is flowing from the ditch to the road structure causing failures. In this case the left ditch should be excavated deeper.

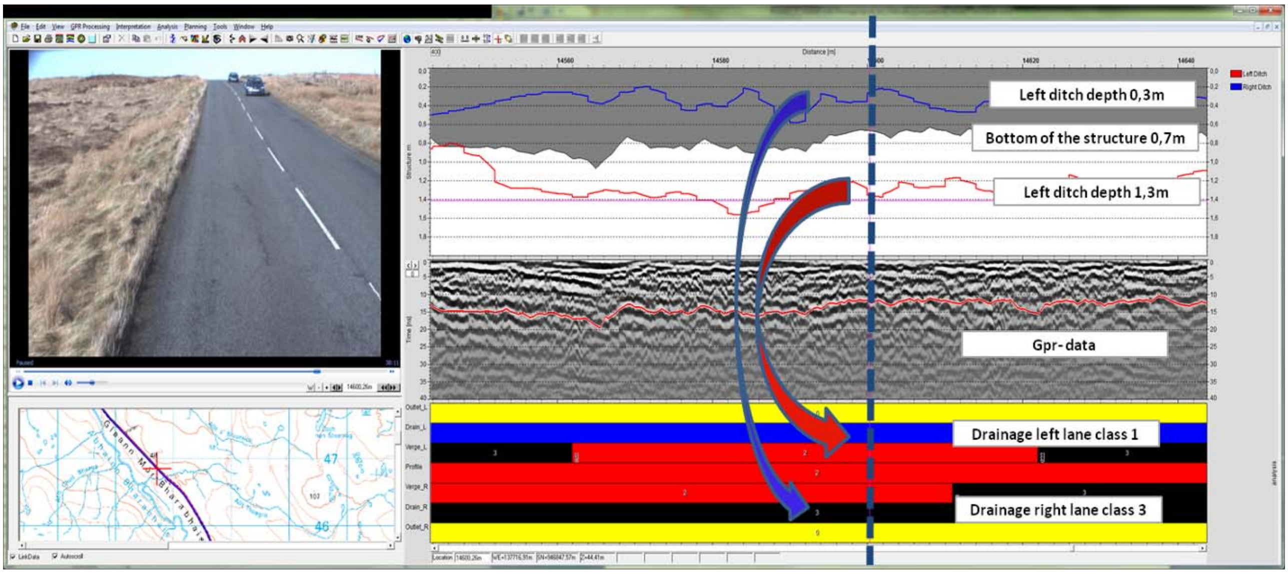


Figure 58: An example of the integrated analysis of GPR data and laser scanner information in drainage analysis. The data is from A857 Stornoway - Barvas.

6.3. COMPARISON TO DRAINAGE CLASSES

Figures 59-61 present typical cases of correlation between the ditch bottom depth and drainage class in the Western Isles. In most cases the correlation between the ditch depth and the drainage condition is clear. In some cases, e.g. in dry terrain, the ditches were shallow yet the drainage still worked well. On the other hand there were cases where water was standing in the ditches, possibly due to a clogged outlet ditch or some other reason. In these cases the ditch could be deep enough but drainage problems were still evident.

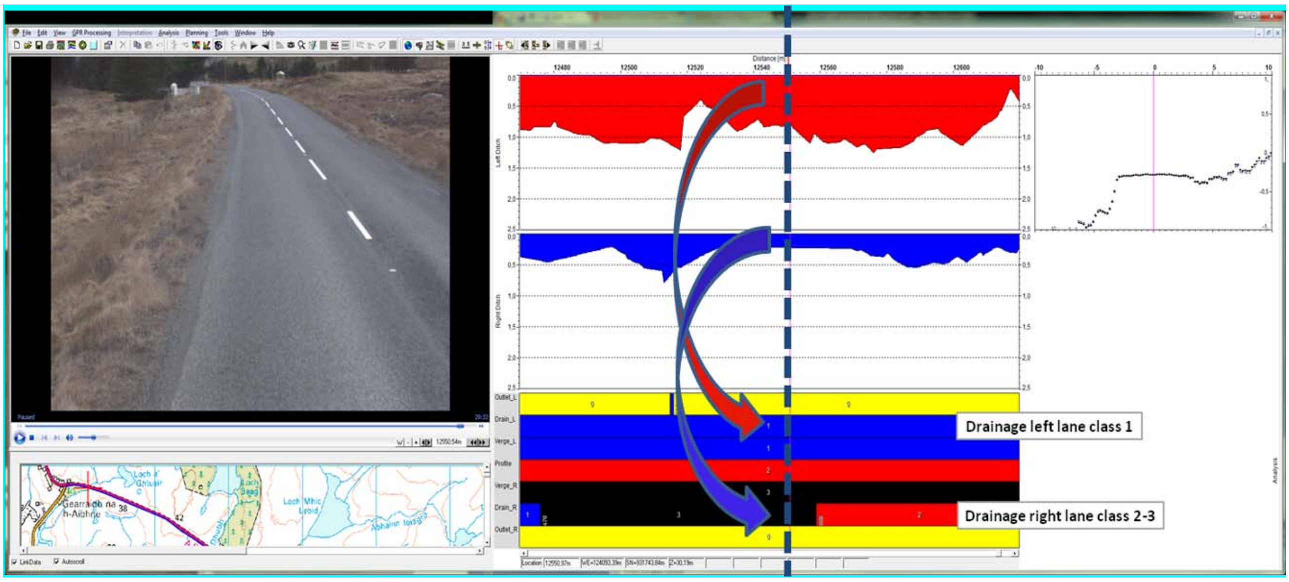


Figure 59: The drainage on the right has been classified as Class 2 and Class 3 as the ditch (blue field) is nearly non existent. Left side the drainage is classified as Class 1 (red field). There is not a dtch on this side but the program has detected the toe of the high embankment as a deep ditch.

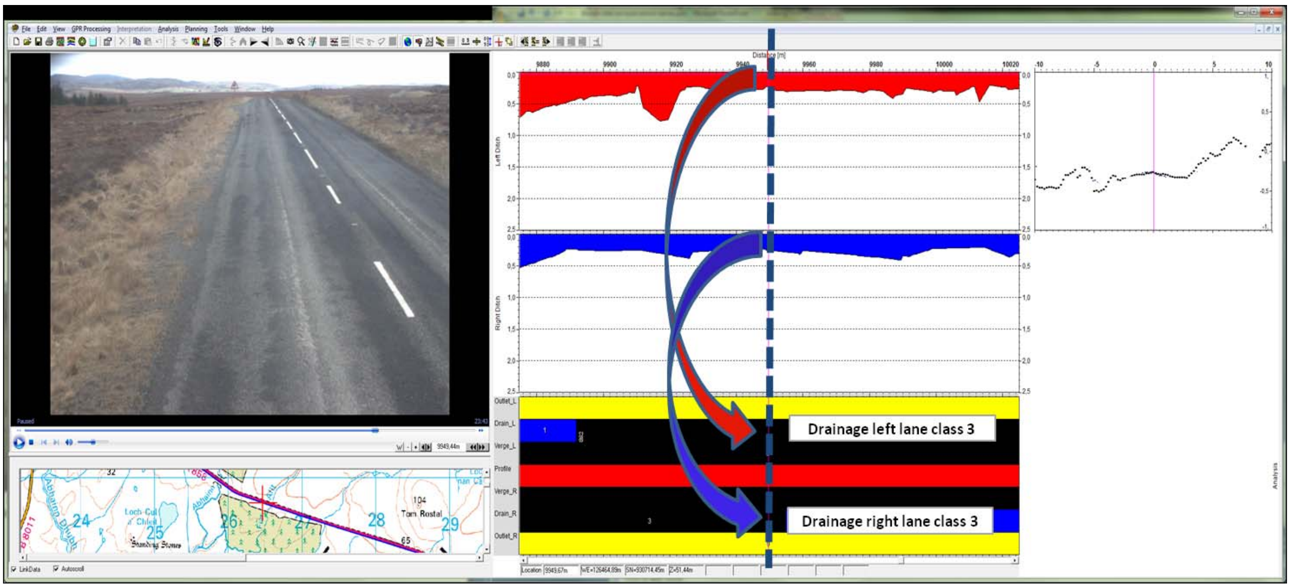


Figure 60: Drainage deficiencies on both sides of the road. The drainage has been classified as Class 3. The ditches on both sides are full of vegetation.

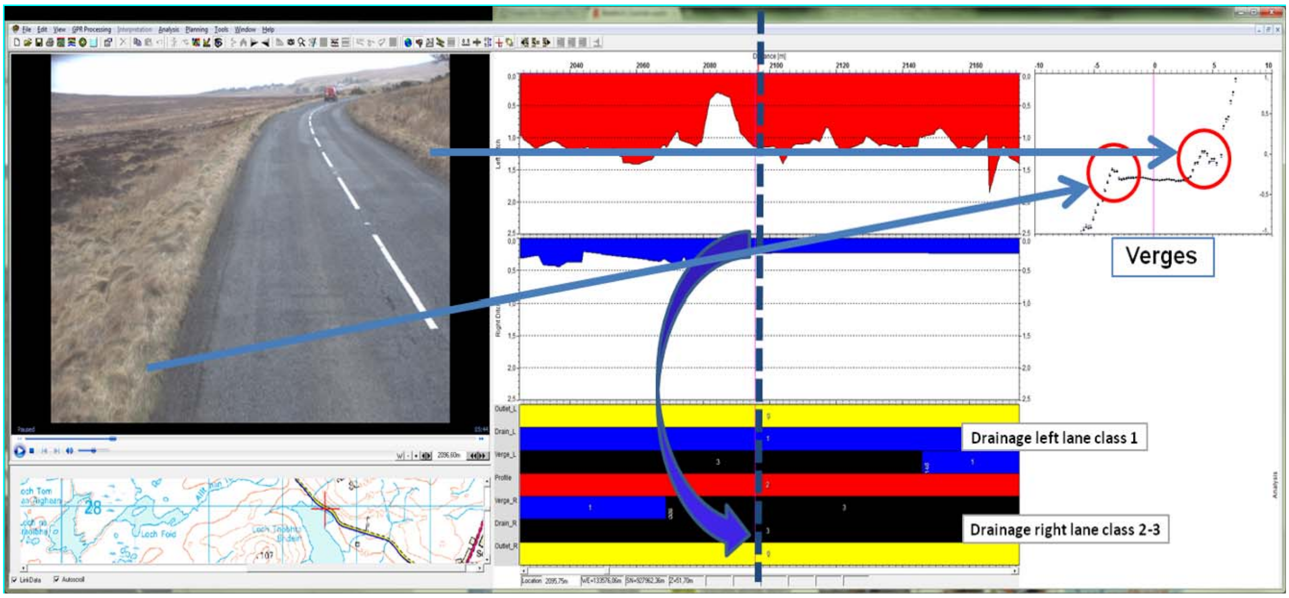


Figure 61: Drainage deficiencies on the right side where the ditch is shallow. The road profile is side sloping from right to left. In the cross section the verges are clearly visible.

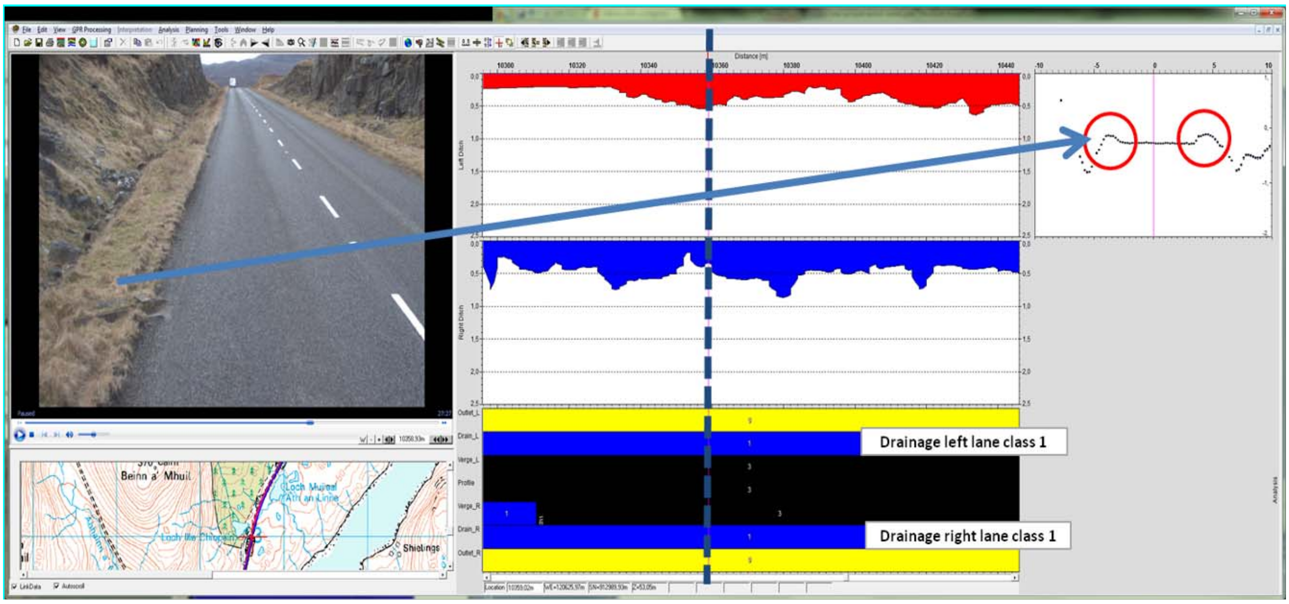


Figure 62: Shallow ditches in a road cut in dry terrain. The drainage has been classified as Class 1 on both sides but there are verges present on both sides.

7. DRAINAGE AND PAVEMENT LIFE TIME

The lifetime of a road section is determined by its worst 10 % sub-sections. In the case of the Western Isles the available profilometer surveys (rutting) had mostly been carried out on the "better" side of the road and as a result the correlation between drainage class and rut depth was not as good as it has been in other the ROADEX partner countries. However, based on pavement distress data and A859 results, it can be stated that improving the drainage condition in critical sections, and maintaining it in good condition, will increase the pavement lifetimes in the Western Isles by at least 1.2 - 1.5 times. The conclusion is that if rehabilitation and drainage maintenance can be carried out together in an economic fashion they can lead to major savings in annual paved road network costs.

In order to calculate how much a well-functioning drainage system can affect the life cycle costs of a pavement it is important to know the costs of improving the drainage. Normally the costs of drainage maintenance are much smaller than repaving. In some surveyed sections it is likely that the drainage solutions will be challenging and in some places expensive, due to the local constraints involved, but the pay-back time is expected to be short. If the drainage can be improved, the potential savings in annual paving costs could be up to 30% according to calculations made in earlier ROADEX projects.

Figure 61 shows the results of pavement lifetime factor calculations (the ratio of the worst 10% rutting class) for the roads surveyed in the Western Isles. These factors varied from <1.5 for road A859 to >1.5 for the Northon to Leverburgh road. The other roads (A857, A858 and B8011) appear to have better lifetime factors, even when their drainage is worse than A859, but this can probably be explained by the rut depth survey lane as explained earlier.

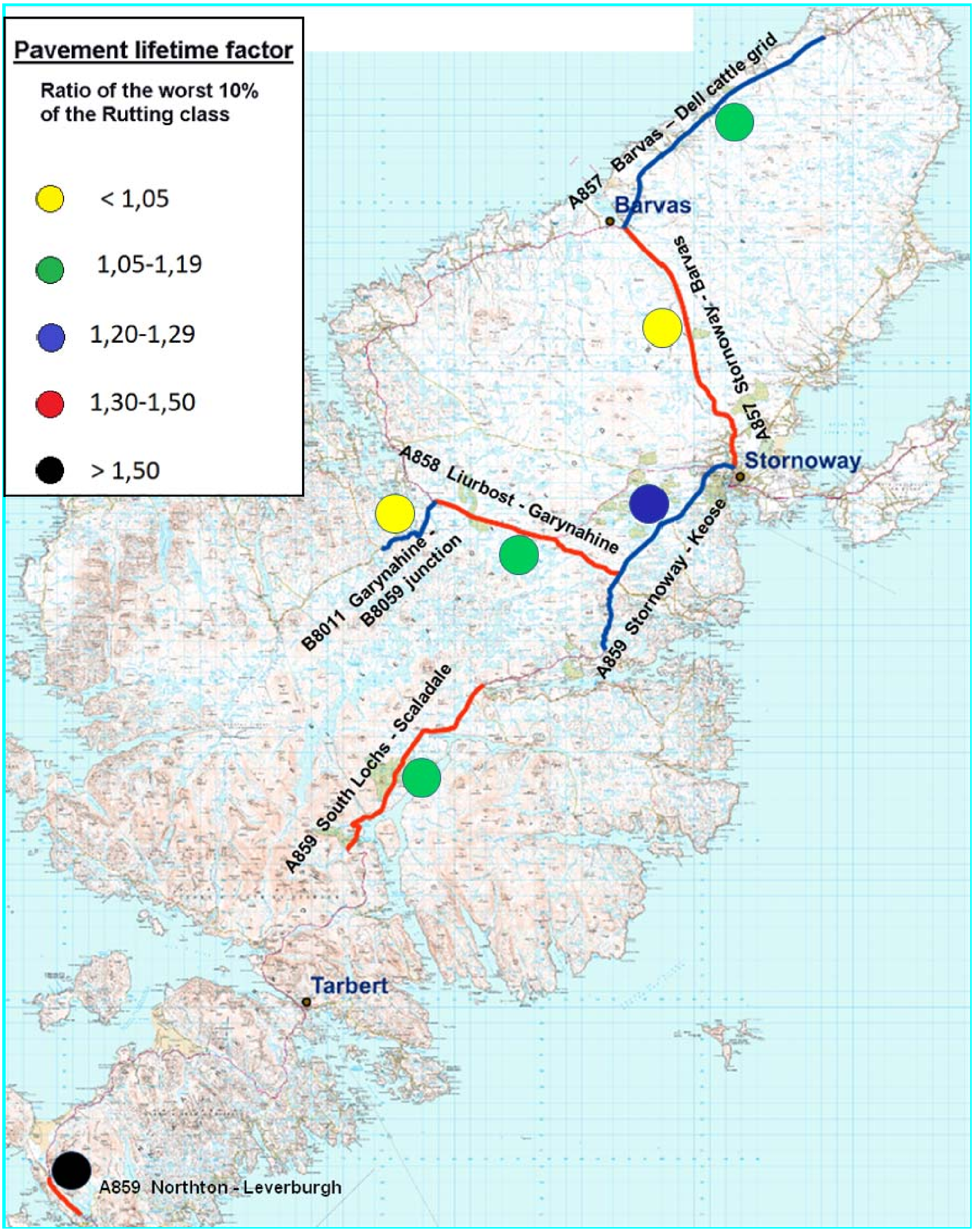


Figure 63: Pavement lifetime factor for the roads surveyed in the Western Isles

8. DRAINAGE IMPROVEMENT DESIGN

In many ROADEX countries drainage, and drainage improvement, has a low priority despite research proving that it is important that road drainage should be kept in good condition. At present a number of issues have to be addressed when planning drainage work. What is the best way to organise it? Should the work be the responsibility of the maintenance or pavement contractor? Etc.

It is not just enough that problematic sites are improved, it is vital that the improved sections are also kept in a good condition. Constant monitoring and maintenance of the improved drainage is vital to ensure that good drainage work remains effective.

When a drainage improvement is carried out the work should be done carefully. It is more important to pay attention to the longitudinal gradient of the ditch and the removal of obstacles blocking the water flow (big stones, flowing soil, etc.), than to dig the ditch deeper. Ditches that are dug too deep increase the risk of side slope erosion. It is recommended that the bottom of the ditch should be 20-30cm deeper than the bottom of the road structure and that the longitudinal gradient of the side ditch should be at least 4 ‰ (4 mm/m).

If the ditch has steep side slopes, it is better to carry out the improvement works in the early summer so that the local vegetation has enough time to grow back before winter to reduce the risk of erosion.

The most noteworthy feature of the surveyed sections in the Western Isles is the presence of verges in the sections that have not been upgraded yet. Removing these verges will be challenging as in many cases there will be cables inside them. The solution for road sections where verges are producing problems is to remove the verge or make more offlets.

As part of the project in the Western Isles suggestions were also made for improving the drainage in some road sections. These sections were identified for “special maintenance” measures and this information has been sent separately to the respective road maintenance managers. A special maintenance section means that drainage improvement measures are needed for both ditches and verges, or if the design only mentions the verge, it means that only the verge needs some operations (e.g. removal of verges or making more offlets).

9. CONCLUSIONS

The drainage condition of the tested roads in Western Isles varied greatly. Good road sections with faultless drainage systems were seen but there were also road sections where poor drainage was compromising road pavement performance. Despite the problems with the profilometer data the overall drainage classes and verge classes correlated reasonably well with rut depth values. On average the rutting values in drainage Class 2 and 3 were both about 7% higher than the rutting value in drainage Class 1. The calculated pavement life time factors varied between 1.2 and 1.5 which indicates that substantial saving can be gained if the drainage can be improved.

One of the main problems on the Western Isles road network was the presence of verges. Calculations within the project show that the correlation between verges and the rutting value is strong. Additionally verges, where they existed, did not perform well. Only 13% of the verges surveyed were classified as Class 2. A verge Class 2 means that the verge does not restrict the water flow or the workings of the road drainage system. Further problems could be related to roads on side sloping ground. In these areas the drainage in the upper side of the road did not work well. Ditches were missing, or too shallow, or they were clogged with vegetation, and this was causing pavement failures. A distinctive problem area lay in road cuts, but these accounted for only a small proportion of the sections surveyed (5%).

In recent years the greatest advancements in all of the NDT techniques used in road surveys have been made with the laser scanner technique. It is inevitable that these systems will become a standard tool for a variety of tasks in road condition management. In the Western Isles the laser scanner provided useful information about the level of ditches compared to the road surface. The data collected in the project shows that in many cases water was flowing from the ditches to the road structures when it should be vice versa. It is very important however to pay attention to the local conditions during laser scanner surveys. The accuracy of the laser scanner survey can be reduced by a number of factors that affect visibility, such as dust, rain, fog or snow. High vegetation can also prevent the system from obtaining data on the actual ground surface.

In this survey the conditions were challenging for laser scanner analysis. During the survey there was some rain at times. Because of the time of year the main vegetation had not started to grow, but there was a thick brown growth in the bottom of the ditches in some locations. These factors when taken together may have skewed the ditch depth results somewhat in some parts of the surveyed sections.

It is recommended that in future laser scanner surveys should be done together with GPR data collection. This will ensure that the bottom of the road structure can be measured at the same time. A demonstration project carried out earlier in Sweden showed that if the ditch was 20-30cm deeper than the bottom of the road structure, the road should function relatively well.

In summary, the ROADEX drainage analysis guidelines have been proven to be suitable for use on Western Isles roads. It is however important that verges should be analysed also in areas where they are typical as they will have a major impact on the efficient working of the road drainage system.

ROADEX

Implementing Accessibility

ROADEX PROJECT REPORTS (1998–2012)

This report is one of a suite of reports and case studies on the management of low volume roads produced by the ROADEX project over the period 1998-2012. These reports cover a wide range of topics as below.

- Climate change adaptation
- Cost savings and benefits accruing to ROADEX technologies
- Dealing with bearing capacity problems on low volume roads constructed on peat
- Design and repair of roads suffering from spring thaw weakening
- 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.