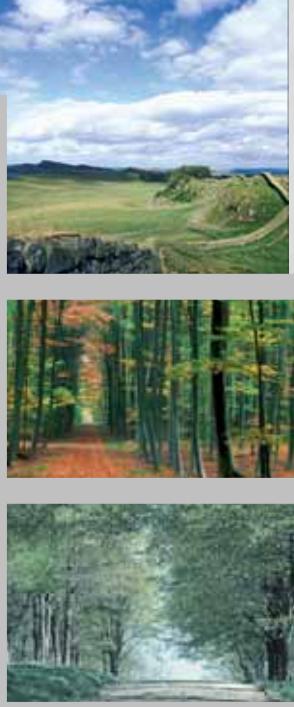




ROADEX III
NORTHERN PERIPHERY

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Timo Saarenketo

**DEVELOPING
DRAINAGE
GUIDELINES FOR
MAINTENANCE
CONTRACTS**

Results of a ROADEX III pilot
project in the Rovaniemi
Maintenance Area in Finland

**Developing Drainage Guidelines for Maintenance Contracts –
Results of a ROADEX III pilot project on the Rovaniemi Maintenance
Area in Finland**

RESEARCH REPORT
November 2007

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Roadscanners Oy

PREFACE

This is a final report from Task B2 of the ROADEX III project, a technical trans-national cooperation project between 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 Road Administration and the Swedish Forest Agency; The Savo-Karjala Region of The Finnish Road Administration; the Icelandic Road Administration; and the Municipality of Sisimiut from Greenland. The lead partner in the project is The Northern Region of The Swedish Road Administration and project consultant is Roadscanners Oy from Finland. ROADEX III project Chairman is Per-Mats Öhberg from The Northern Region of The Swedish Road Administration and project manager is Ron Munro of Roadscanners Oy.

The report was prepared by Timo Saarenketo of Roadscanners Oy. The field data collection and preliminary analysis has mainly been carried out by Seppo Tuisku and Jani Riihiniemi from Roadscanners. Great help in solving technical and software problems has been provided by the Roadscanners software crew: Pekka Maijala, Timo Saarenpää and Tapios Inkeröinen. The drainage data statistical analysis for this report has been made by Paula Tiainen. She has also prepared most of the GIS maps for this survey and drafted some text for this report. Paula, as a young student in civil engineering, showed great skill in quickly learning this difficult issue and preparing excellent analysis results. The report has been edited by Leila Hannula, the language has been checked by Kent Middleton and Jaakko Saarenketo has helped with graphics, all of them are from Roadscanners. Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout.

All the work done in this project was made in close cooperation with the personnel of Lapland Region of the Finnish Road Administration. The author would like to thank and acknowledge especially district chief Tapani Pöyry, Procurement Chief Jukka Jääskö and engineers Kari Parikka, Eero Kenttälä and Kalervo Niva, without their help and support it would not have been possible to complete this work.

Finally the author would like to thank the ROADEX III Project Partners and the Project Steering Committee for their guidance and encouragement in this work.

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ABSTRACT

The European Union ROADEX Project 1998 – 2007 is a trans-national roads co-operation aimed at developing ways for interactive and innovative management of low traffic volume roads throughout the cold climate regions of the Northern Periphery Area of Europe. Its goals have been to facilitate co-operation and research into the common problems of the Northern Periphery. This report provides new solutions for one of the major problems, shared by all the partners, which is poorly performing drainage.

A well performing drainage system has received general acknowledgement, but data which demonstrates the economic effect of drainage on pavement lifetime has yet to be produced. In this work, the condition of the drainage of the paved roads of the Rovaniemi maintenance area was classified. The goals for this study were to assess the status of the current drainage condition, compare rutting and roughness values with the drainage condition and, based on these results, calculate the effect of poor drainage on pavement lifetime and annual paving costs.

This paper will present the results of this survey. The analysis showed that rut development on main roads was 1.52 times faster in sections with the poorest, class 3, drainage than in sections with good quality, class 1, drainage. On local roads with thinner pavement structures the same pavement lifetime ratio was 2.32. Poor drainage had a similar effect on the roughness (IRI) values. The cost benefit calculations showed that, by improving the drainage of paved road networks to a class 1 level, it would be possible to save almost 12 % of the annual paving costs. In terms of the Rovaniemi maintenance area, a network that includes 645 km of paved roads, a savings of approximately 335.000 € could be achieved. The results of this analysis demonstrate the economic benefits of investments in improving drainage and maintaining it in good condition.

Finally, an important goal in this work was also to test, through its inclusion in the tendering process for the Rovaniemi maintenance contract, how the new policy of better drainage maintenance could be put into practise.

Chapter 1. INTRODUCTION

1.1 ROADEX -PROJECT

The ROADEX Project is a technical co-operation between roads organisations across northern Europe that aims to share roads related information and research between the partners. The Project was started in 1998 as a 3 year pilot co-operation between the roads 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 and a third, ROADEX III, from 2006 to 2007.

The partners in ROADEX III "The Implementation Project" comprised public road administrations and forestry organizations from across the European Northern Periphery. These were the Highland Council, Forestry Commission Scotland & Comhairle Nan Eilean Siar from Scotland, the Northern Region of the Norwegian Public Roads Administration, the Northern Region of the Swedish Road Administration and the Swedish Forest Agency, the Savo-Karjala Region of the Finnish Road Administration, the Icelandic Road Administration and the Municipality of Sisimiut from Greenland.



Figure 1. Northern Periphery Area and ROADEX III Partners

A priority of this Project was to take the collected ROADEX knowledge out into the Partner areas and deliver it first hand to practising engineers and technicians. This was done through a series of 14 seminars across the Partner areas to a total audience of 800. The executive summary reports were translated from English into the 6 other partner languages of Danish, Icelandic, Finnish, Greenlandic, Norwegian and Swedish. ROADEX research continued through 5 projects: measures to improve drainage performance, pavement deformation mitigation measures, health issues caused by poorly maintained roads, road condition management policies and a case study of the application of ROADEX methodologies to roads in Greenland. All of the reports are available on the ROADEX website at www.ROADEX.org.

1.2 DRAINAGE – A SHARED PROBLEM IN THE NP AREA

It is a well known fact that a high amount of water in road structures and subgrade soils decreases the bearing capacity of the road. Since the first ROADEX project was established drainage has been acknowledged as being one of the most important problems shared by all the road authorities in the Northern Periphery area.

The results of the ROADEX pilot project 1998-2001 showed that drainage problems were especially great on road sections located on side sloping ground (Saarenketo 2001). The benchmarking results of the pilot project also showed that Scotland had even bigger problems with drainage of their low volume roads due to a history of using high grass verges on road shoulders.

In the ROADEX II drainage project (Berntsen and Saarenketo 2005, see also Aho and Saarenketo 2006) a literature review was first made concerning seasonal changes in moisture content of the road structure and subgrade soils. Also the research regarding the relationship between moisture content and strength and deformation behaviour for unbound granular materials and subgrade soil was reviewed. The review showed that increased moisture content reduces the bearing capacity and reduction is greatest with materials having high fines content. Theoretical calculations following the Swedish Design Guide showed that by improving the drainage the lifetime will increase by a factor of 2.2-2.6 times. The report also introduced a new system for classifying drainage problems on roads and presented new solutions to these problems.

The ROADEX II project also analysed some field data from Norway and Finland that verified the observation that there were big differences in rut depth and roughness on the road cut side of the road compared to the embankment side. In the worst 20 % of the analysed road sections the rut depth in the road cut lane was 1.5 times deeper than the other lane. Since in PMS systems the worst 10-20 % of the rutting and roughness values in each road section are those which trigger the need for a new pavement, poor drainage also becomes an economic issue for road owners. This was further verified through the life cycle cost analysis made by the authors.

1.3 PROJECT GOALS

As stated above, the ROADEX I and II project results confirmed the importance of ensuring a well working drainage system in road condition management. However the ROADEX Steering Committee felt that the greatest challenge was to implement these findings into everyday practise in a low volume road network. The current policies in road maintenance do not fully support the implementation of better drainage maintenance strategies, this is mainly due to organizational issues. A big problem is also that the procurement policies of new administration-production organizations do not have implementation models. That is why there was a need to develop and pilot new procurement practises and policies which could then be used in the new maintenance contracts.

The goal of this pilot project was to analyse the status of the drainage condition in the Rovaniemi maintenance area in Finland, which represents a typical road network in the northern part of the Northern Periphery of Europe. This area was selected to be a pilot survey area because the procurement documents for the new maintenance contract 2007 – 2012 were being prepared during the ROADEX research period and new ideas could easily be tested in the contract documents. Another goal was to calculate the effect of poor drainage on pavement lifetime of paved roads and the general performance of gravel roads. The results of this analysis would demonstrate the benefits of investing in improving drainage condition and keeping them in good shape. Finally, a very important goal was also to test new ideas in the procurement process with the goal of better drainage maintenance in the Rovaniemi maintenance contract.

Chapter 2. DRAINAGE CONDITION DIAGNOSTICS AND CLASSIFICATION

2.1 GENERAL

The drainage condition analysis tested and used in this project consists of collection, classification and analysis of information about the condition of drainage system in general on paved and gravel roads. The effect of poor drainage on rutting and on roughness on paved roads and on spring thaw weakening on gravel roads was also studied. In addition, the condition of drainage in different road cross section profiles was examined.

Drainage analysis methods for both paved and gravel road networks needed to be developed for several reasons. First of all there was a need to define the current drainage condition of the road network before setting up new and reasonable goals for drainage standards in the Rovaniemi maintenance contract 2007-2012. A systematic drainage analysis was also needed in order to locate critical places where poor drainage was causing early deterioration of the road. Furthermore, this drainage analysis method needed to be a simple and clear method, with distinct rules and definitions for each drainage class, to be used in the analysis before the maintenance contract but also later in the follow up of the contract to verify if the contractor has succeeded in meeting the standards required.

The survey methods, data analysis and the classifications used in this analysis are described in the sections that follow.

2.2 SURVEY METHODS

Drainage condition analysis in this project was done first in 2005 by making a visual analysis of the drainage system on both sides of the road. This analysis was based on digital video which was captured by a digital video camera mounted on the roof a car (figure 2). This camera, which was aimed at the road shoulder and the ditch, was linked to a laptop PC inside the car where a technician provided commentary concerning both the drainage class and the road profile class (see chapter 2.3 and 2.4) while the vehicle was moving at a speed of 20-30 km/h. The condition of the outlet ditches was also assessed if they could be observed. The data was positioned using a differential GPS system and all the collected data was linked and stored in a database using RoadDoctor Cam Link software developed by Roadscanners.

Doing the drainage classification in the office, based on the video and audio commentary, required a large amount of labor with the 2005 survey data. That is why, in 2006, the complete analysis was done, using an improved system where, during the data collection, the technician could make a preliminary classification directly to the RD Cam Link data. This was done using laptop PC keyboards and afterwards this data was later confirmed or corrected in the office. In

2006, the RD Cam Link system had also two video cameras and other camera was now recording the road surface (figure 3).



Figure 2. RD Cam Link system used in the drainage analysis data collection in 2005



Figure 3. A two camera RD Cam Link system used in the drainage analysis data collection in 2006

2.3 DRAINAGE CLASSIFICATION – PROPOSAL FOR PAVED ROADS

As mentioned in the previous chapter, drainage condition was classified in this survey using three different classes as is generally used in Sweden and in Finland. The classes are, in order of superiority, good (class 1), adequate (class 2) and poor (class 3). A description of each class is presented below:

Figure 4. Class 1: good drainage condition. The drainage condition of class 1 is faultless. The cross-section of the road has preserved its form well and water flows from the pavement to the ditch unrestricted. Water also has a clear passage in the ditches.

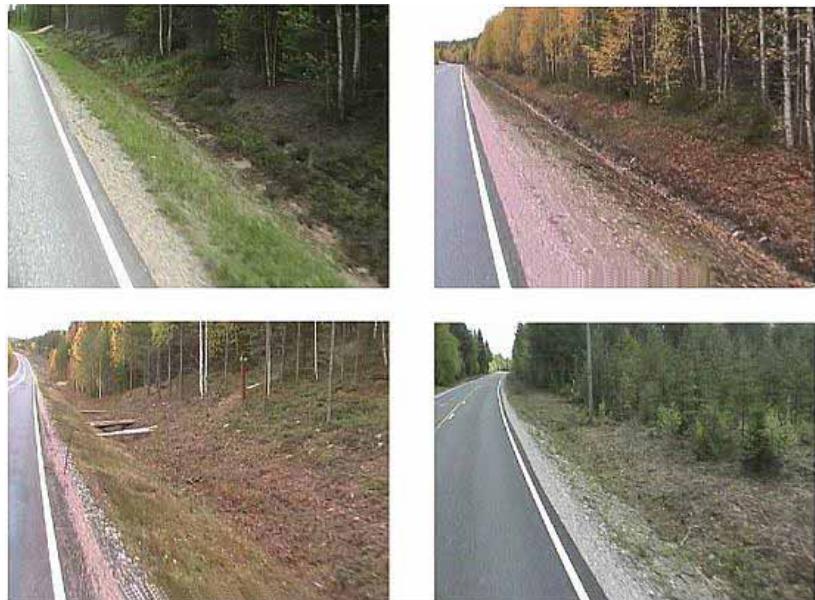


Figure 5. Class 2: adequate drainage condition. In drainage class 2 there can be some visible changes in the road cross-section. Road shoulder has small verges or vegetation that prevents good water flow from the pavement into the ditch. Vegetation in ditch restricts water flow and creates dams. A small amount of soil flows from the road slopes into the ditches and raises the bottom of the ditch. This hinders water flow and raises the ground water level.



Figure 6. Class 3: poor drainage condition. There are many severe problems with roads that are classified into drainage class 3. Road shoulders can have high verges and / or dense vegetation that cause ponding on the traffic lane or on the shoulder. Vegetation in the ditch restrains water flow and creates dams in the ditch. Unstable soil flows from ditch slopes into ditches and blocks the water flow. Clogged culvert or outlet ditch prevents the water from flowing in the ditch. All of the situations described above lead to the development of deformation and damage in the road cross section.



2.4 DRAINAGE CLASSIFICATION – PROPOSAL FOR GRAVEL ROADS

The classification of drainage of gravel roads is basically the same as with paved roads. The following figures and figure texts present the drainage classes for gravel roads.

Figure 7. Class 1: good drainage condition. The drainage condition of class 1 is faultless. The cross section of the road has preserved its form well and water flow from the road surface into the ditch is unrestricted. Water also has a clear passage in the ditches.



Figure 8. Class 2: adequate drainage condition. In drainage class 2 there can be some visible changes in the road cross section. Road shoulder has small verges or vegetation that prevents good water flow from pavement to the ditch. Vegetation in the ditch restricts water flow and causes damming. Small amounts of soil flow from the road slopes into the ditches and raise the bottom of the ditch, slowing water flow and raising the ground water table.



Figure 9. Class 3: poor drainage. There are many severe problems concerning gravel roads with drainage class 3. Road shoulder can have a high verge and / or dense vegetation that cause ponding on the traffic lane or on the shoulder. Vegetation in the ditch restricts water flow and cause damming in the ditch. Unstable soil flows from ditch slopes into ditches and blocks the water flow. A clogged culvert or outlet ditch prevents water from flowing in the ditch. All of the situations described above lead to the development of deformation and damage in the road cross section.



2.5 CLASSIFICATION OF THE ROAD PROFILE

The classification of road cross section profiles was done in order to analyse if drainage and road condition problems could be related to certain terrain conditions such as a road being located on a side sloping ground. Road profile classification helps especially in drainage analysis but the results can also be used in designing drainage improvement strategies and maintenance class requirements. For instance, drainage class can be slightly worse on roads located on high embankments compared to when they are in road cuts with thinner structures.

In this survey, roads were classified into four different cross section profile types (figure 10). A description of each class follows below:

Road in a road cut

A road is in a road cut, when the foundation level is beneath the surrounding ground. Both sides of the road have ditches – or are supposed to have ditches

Road on side sloping ground

A road is on side sloping ground when ground water flows – or tries to flow – under the road. The upper side of the road has a ditch, but the lower slope side is normally at surrounding ground level or it is built on embankment. Locally lower side of the road can also have a ditch.

Road is at 0-level

A road is at 0-level (zero-level), when the foundation level is roughly at the level of the surrounding terrain. Road surface is not higher than 1 m from the surrounding terrain. Ditches are normally on both sides of the road.

Road on embankment

A road is on embankment when the pavement structure bottom is clearly above the surrounding terrain (road surface is higher than 1 m from the surroundings). In embankments there can also be a ditch on one side or both sides of the road.

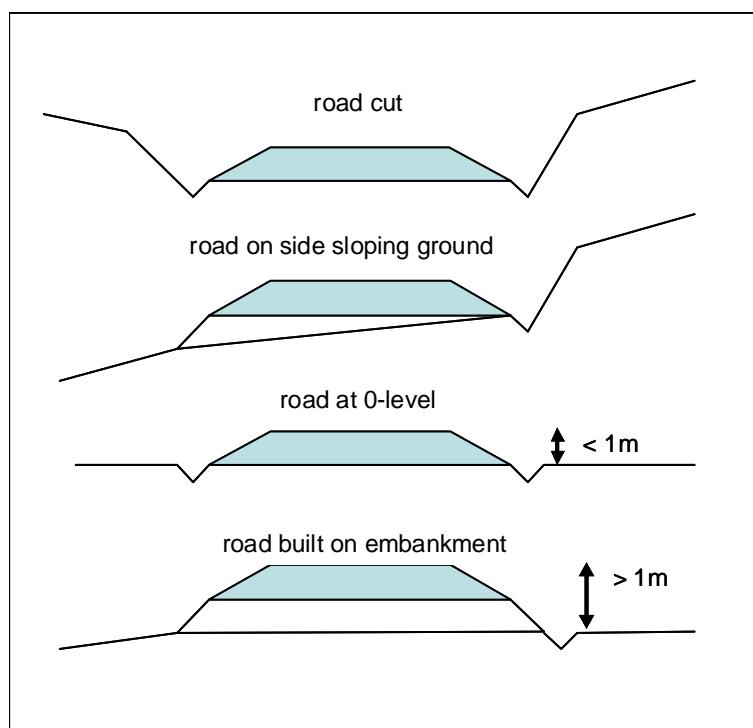


Figure 10. Illustrations of the different road cross section profiles.

2.6 DATA ANALYSIS

Data analysis was made using Road Doctor Designer™ software developed by Roadscanners. First a project was established for each road section. After that the drainage analysis data and road cross section profile data and digital videos were linked to the established project. The profilometer data, including rut depth measurement results and IRI measurement results from different years, was also linked to the project.

After the data was linked, the average annual rut depth increase was calculated from the profilometer history data using a linear fit model. In this analysis, the paving year and initial rut depth values were used only if there were one or two years of measured 10 m rut depth values available in the Finra database. In that case linear regression would not have been reliable.

After the annual rut increase value was calculated the results were compared with the drainage analysis results as figure 11. shows. Rutting was considered to be normal if the rut increase values were less than 1.0 mm/year. In the analysis, maps of each road section (figure 12) were drawn in order to locate places where drainage condition was influencing the permanent deformations in the road and thus rut depths.

However, because there was no reliable rutting and paving history data available for the entire paved road network in the Rovaniemi area, the final analysis was done using a statistical method where average rut depths were calculated for each drainage class in each road section.

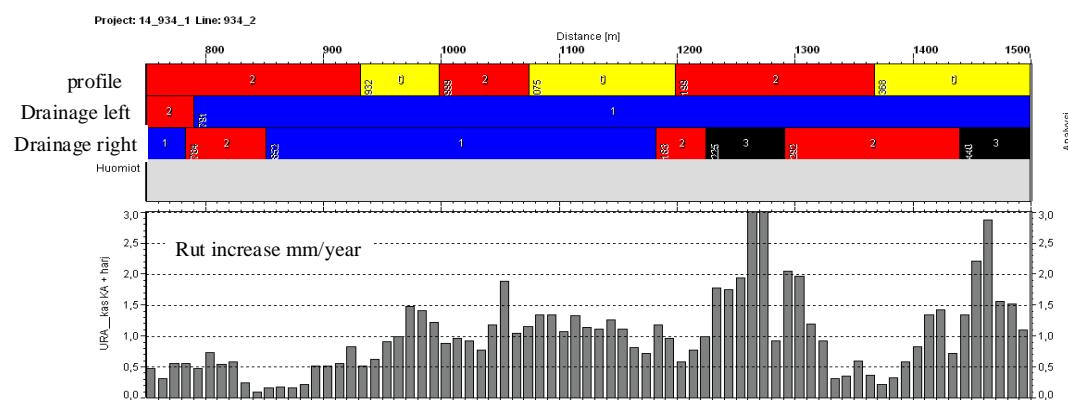


Figure 11. An example of rutting analysis data from road 934 section 1. The top part presents the results of road cross section profile classification and the drainage class on both sides from the road. The lower part presents the results from the annual rut increase calculations.

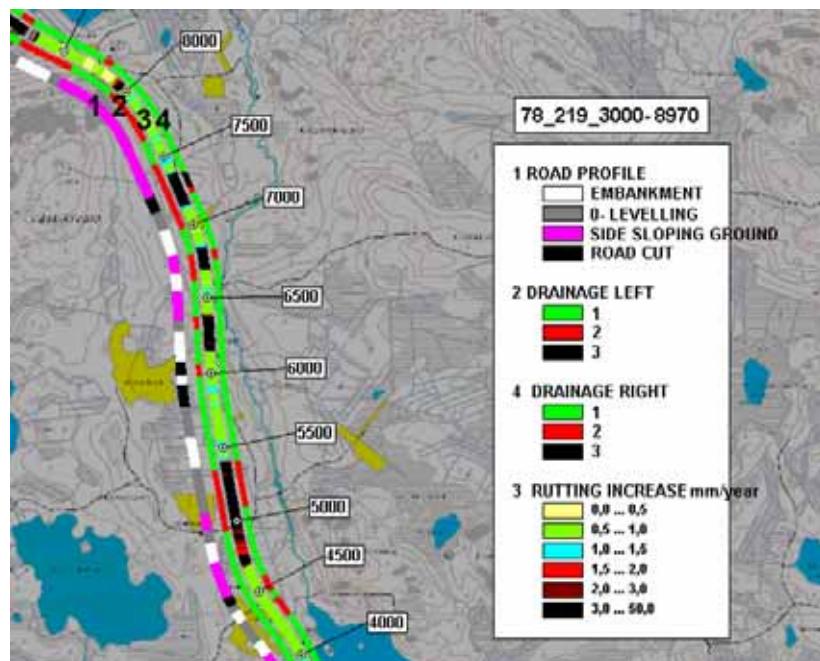


Figure 12. An example of a map presentation of drainage analysis. The map has been prepared from road 78, road section 219.

With gravel roads the basic analysis procedure was the same except that instead of rut increase calculations the historical data of the locations of spring thaw weakening damage. Also FWD and winter IRI survey results were linked to the Road Doctor project (figure 13). In the analysis these data sets were then compared with the drainage analysis results.

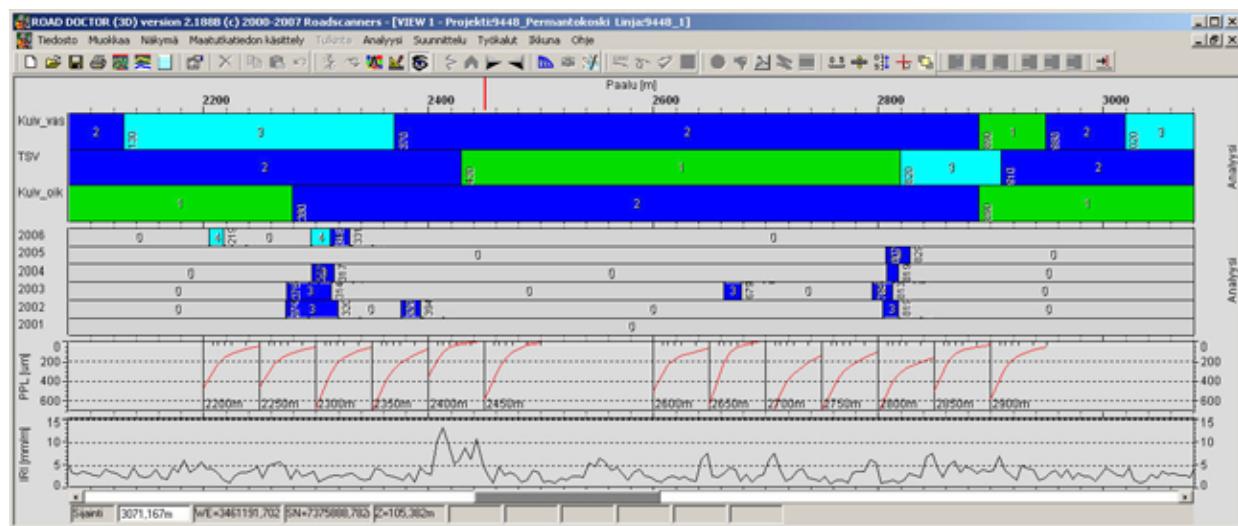


Figure 13. An example of drainage analysis from a gravel road. The top bars present drainage classification and road profile (in the middle). Beneath is spring thaw weakening history, FWD deflection bowls and IRI profile.

3. CONDITION OF DRAINAGE ON PAVED ROADS ROVANIEMI MAINTENANCE AREA

3.1. GENERAL

This chapter presents the results of the drainage analysis of the paved roads in the Rovaniemi maintenance area. The purpose of this work was to present the drainage condition of the road network before the new maintenance contract started in 2007 and also to demonstrate how poor drainage affected the lifetime of the road network.

3.2. ROVANIEMI MAINTENANCE AREA ROAD NETWORK

The Rovaniemi maintenance area is geographically the same area as the area of the municipality of Rovaniemi (figure 14). The length of the public road network is 1060km and it consists of 645 km of paved roads and 415 km of gravel roads. The most important road in the area is highway 4 (E4) that traverses the maintenance area from South West to North East. Other important roads are 79 and 81 in the southern half of the area and roads 79, 82 and 83 in the northern half. Roads 79 and 81 follow the river valleys of the Ounasjoki and the Kemijoki and are located mainly on side sloping ground with silty subgrades. Outside the river valleys the subgrade is mainly glacial till (moraine) or peat. In this area, frost normally penetrates 1.4 – 3 m below the road surface.

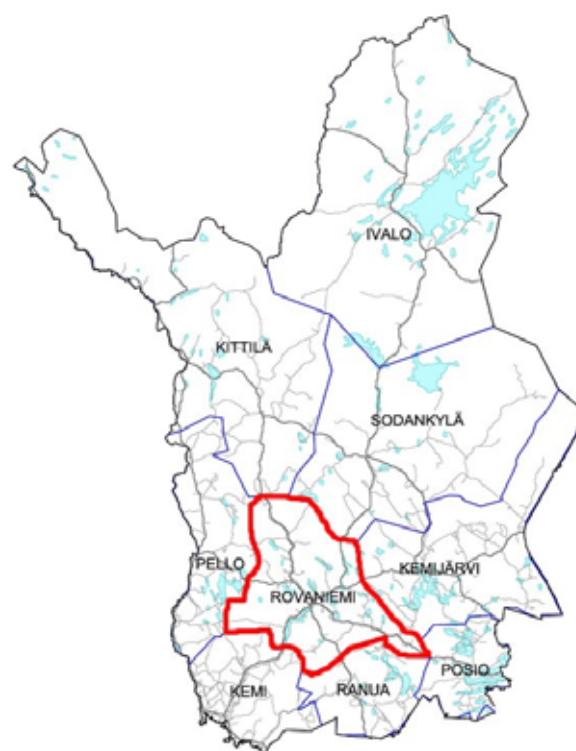


Figure 14. Rovaniemi maintenance area in Finnish Lapland.

3.3. GENERAL DRAINAGE CONDITION ON PAVED ROADS

Figure 15 presents drainage condition distribution of the paved roads in the Rovaniemi area. It shows that the majority of paved roads in the Rovaniemi maintenance area are in good condition in terms of drainage, with 62.6 % of the road network classified as drainage class 1 and only 2.9 % in class 3. The figure also shows some differences between different road classes. Regional roads differ from main roads with only a slightly higher amount of class 3 drainage. The drainage condition of local roads, however, is much worse and only 46.9 % have class 1 drainage.

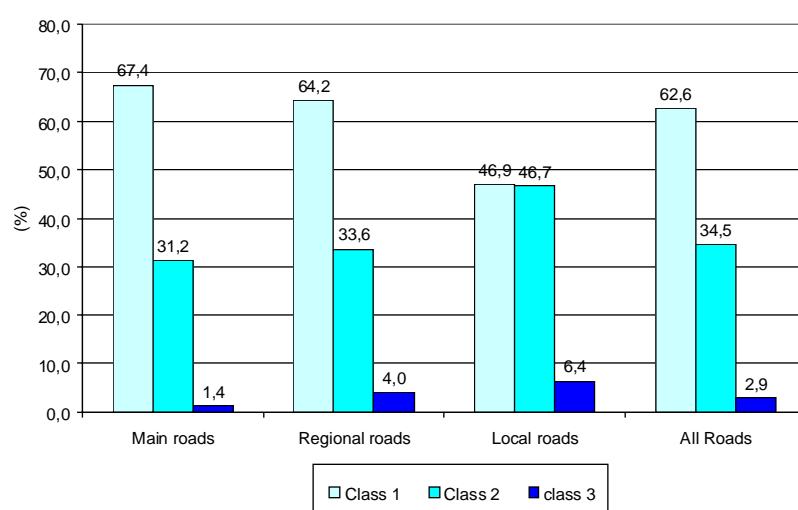


Figure 15. Percentage of each drainage class in the Rovaniemi maintenance area paved road network.

3.3.1. Main roads

The main roads include sections of class I main road 4 and class II main roads 78, 79, 81, 82 and 83. The condition of drainage on these roads is naturally better than average due to higher maintenance standards (see figure 15). Only 1.4 % of main roads were classified as having poor drainage class 3.

The percentage of problem drainage classes 2 and 3 in each road section is presented on a GIS map shown in figure 16. This map clearly shows the sections with the biggest drainage problems. The drainage condition of main roads is at its worst in the north-eastern part of the region on roads 4 and 82. Also, sections 7 and 9 from road 81 are also in poor condition. Road 81 is situated in the Kemijoki river valley and is constructed mainly on side sloping ground with silty subgrade and the ground water table is relatively high. There are also sections on this road where the problems are caused by grass verges (figure 17). However the same road also has several road sections with well working drainage and these sections are mainly located in areas of sandy or gravel subgrade (figure 18).

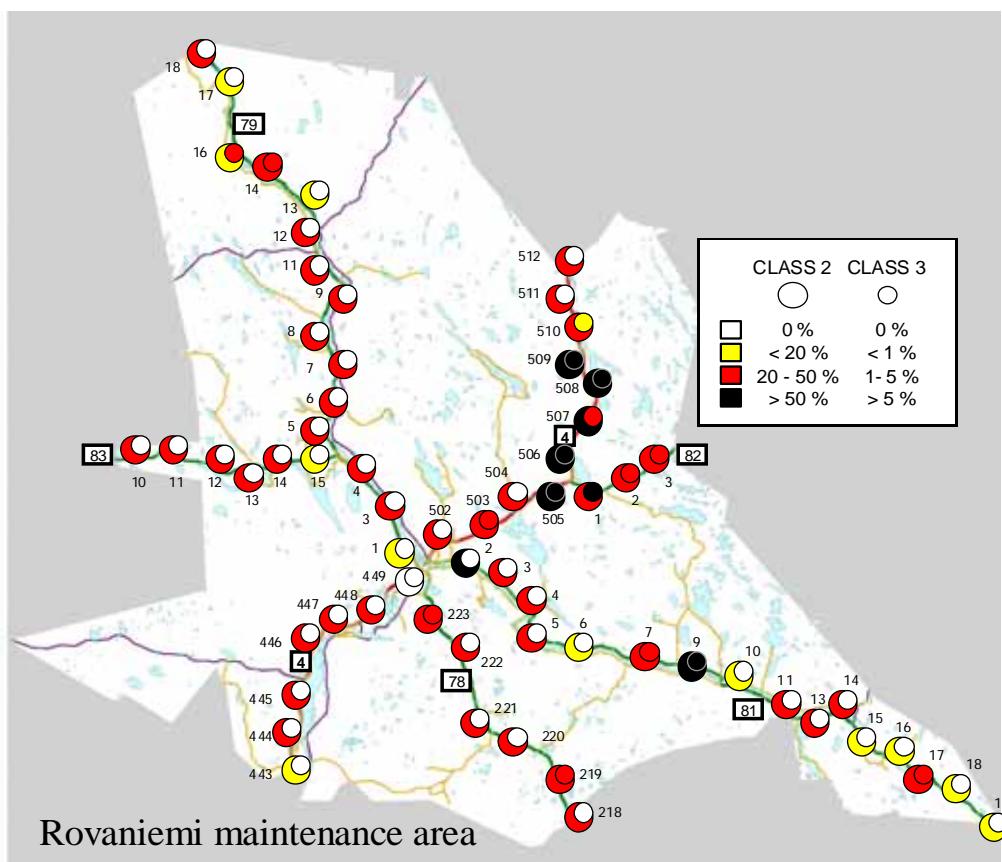


Figure 16. Drainage class distribution and percentage of each drainage class in each road section. Big sphere represents drainage class 2 and small sphere represents class 3.



Figure 17. Grass verges preventing water from flowing away from the pavement on road 81.



Figure 18. Class 1 drainage section on sandy subgrade on road 81.

3.3.2. Other roads

Figures 19 and 20 present the distribution of drainage classes 2 and 3 on regional roads and local roads in the Rovaniemi area. This GIS map and the previous figure, 15, showed that on regional roads and especially in the local road network the condition of the drainage is worse than that of main roads. Many reasons can be used to explain this difference. The most obvious one is the amount of maintenance measures: roads with higher traffic volume demand more care and due to a lack of resources the drainage condition of the low volume rural roads has been neglected. Regional and local roads also have a smaller amount of roads built on embankments and this can also partly explain the difference.

As was the case with main roads, the road sections with the poorest drainage lay in river valleys. The subgrade in those regions is silt or sandy silt, which flows easily into ditches and causes drainage problems and consequently permanent deformation (figure 21). In addition, the maintenance of outlet ditches has often been neglected and they are in bad shape (figure 22).

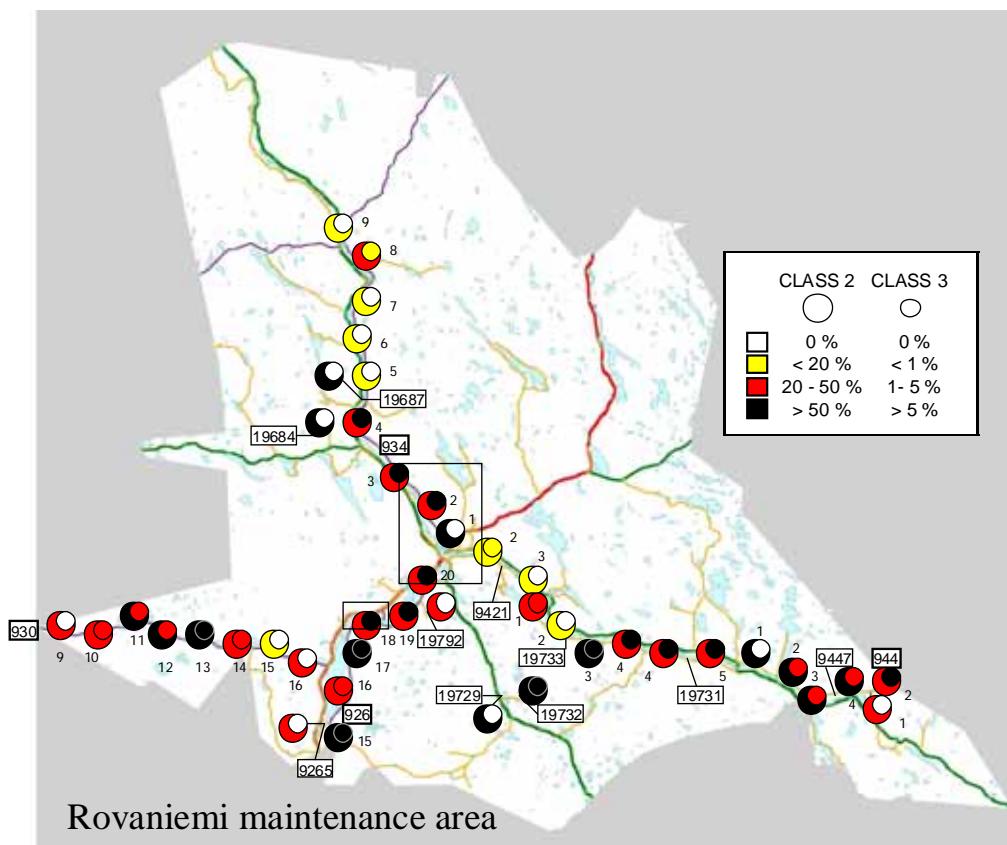


Figure 19. Distribution of drainage classes 2 and 3 on other (regional and local) roads. The big sphere represents class 2 and the small sphere represents class 3.

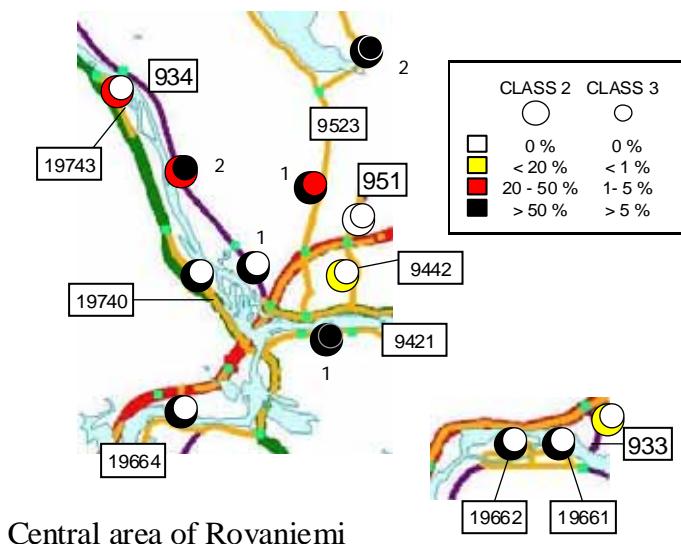


Figure 20. Drainage class distribution in the area around Rovaniemi and in a lower area of the Kemijoki River.



Figure 21. Permanent deformation problems on road 19731 the ditches in these sections are almost entirely filled.



Figure 22. Clogged outlet ditch (arrow) causing drainage problems also on road 19731.

3.4. DRAINAGE AND RUT DEVELOPMENT

In the research in which rutting speed was compared to drainage condition, the latest rut values measured with a profilometer along with the worst drainage class from either side of the road were used. In the analysis, the problem was that reliable rut increase values (mm/year) were not available from all the roads and so absolute values had to be used to compare the effect of the drainage to rutting. Because the age of the pavement could vary within each road, the researchers ended up using relative rut development ratios, where the average rut depths of drainage classes 2 and 3 were compared with average rut depths on road sections with drainage class 1.

Figure 23 presents the relation between rut depth values on different road types and drainage classes. Quite surprisingly the smallest average rutting value was measured from regional roads with drainage class 1. Higher average rutting values on main roads can be explained however by rutting due to studded tires. Figure 23 indicates that the rut depth average is increasing in each road class along with drainage class which verify the earlier results that there is a direct relationship between poor drainage and rutting. This problem was identified in all road sections so the theory that poorer drainage would only be found on roads with old pavement is therefore eliminated. Another interesting result was that the rut depth ratios on main roads in drainage class 1 and 2 were higher than on regional roads. This can be explained by the much higher amount of heavy traffic on main roads which accelerates permanent deformation during the spring thaw season in road sections with poor drainage and consequently higher frost heave.

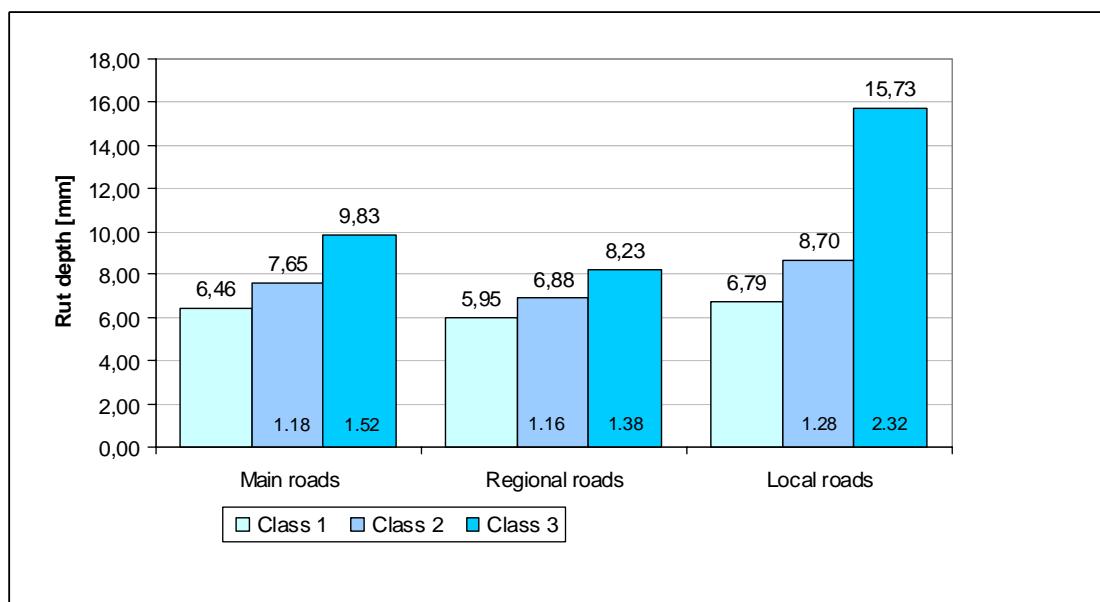


Figure 23. Rut depth average values on each road type and drainage class. The values on top of columns are absolute, in the middle of bars the values are relative to class 1.

As could be predicted, both absolute and relative rutting values are at their highest on local roads. The average rut depth is 2.32 times higher on drainage class 3 than on class 1. The reason for this is that local roads have the thinnest structures and the poorest drainage and, in combination, these create the greatest drainage related problems even though the traffic volume is low.

However, these values gave only an indication of the importance of good drainage to pavement lifetime and the risks if drainage maintenance is neglected. When looking at pavement lifetime, there must be a relatively high number of poorly drained road sections in order to trigger the need for new pavement and thus reduce pavement lifetime (although a small number of bad sections can still pose a risk for traffic safety). That is why a special parameter, "pavement lifetime factor", was developed in order to describe the effect of poor drainage on pavement lifetime in each road section.

This "lifetime factor" was defined by calculating an average for the worst 10 % rut depth ratios. The ratio is both or either 3rd and 2nd class drainage compared to 1st class. If the percentage of drainage class 3 is 10% or higher, then the ratio used is the direct ratio of average rut depths of 3rd and 1st class drainage sections. If there is 0 % class 3 drainage on the road section, then the same method applies with drainage class 2. In a case where there is less than 10 % of class 3, for example 8 %, then that 8 % represents 80 % of the whole 10 % and is completed with 20 % of 2nd class (and 1st class, if necessary). In brief, the 10 % pavement lifetime factor is compiled with ratios starting from the poorest drainage class using weighted averages that depend on the amount of each drainage class.

The results from main roads are presented in figure 24 and other roads in figures 25 and 26.

The map in figure 24 shows that the greatest number of road sections, where poor drainage has the biggest effect on pavement lifetime, are located on road 81 and also in the northern part of road 4. These sections also have the highest amounts of drainage class 3 sections and the pavement lifetime is reduced 5 – 20 % because of these poor drainage sections. A third road with poor pavement lifetime values caused by drainage was road 78 southeast from Rovaniemi. The map also shows that good drainage conditions correlate with minor rutting.

Figures 25 and 26 demonstrates equivalent pavement lifetime information about regional and local roads. All of the worst road sections are located in the Kemijoki river valley where the road is lying mainly on side sloping ground and the subgrade is in many places silt or silty moraine. In these roads, the worst 10 % average drainage class is often higher than 2.5 and this clearly affects the pavement lifetime factor resulting in 30 or even 50 % shorter lifetimes.

It is quite apparent that the same road sections that were criticized in the drainage condition chapter are also the ones with rutting issues. Road sections 3-4 from road 19733, sections 4-5 from road 19731 and sections from road 926 were all at the top of the list of the poorest drainage.

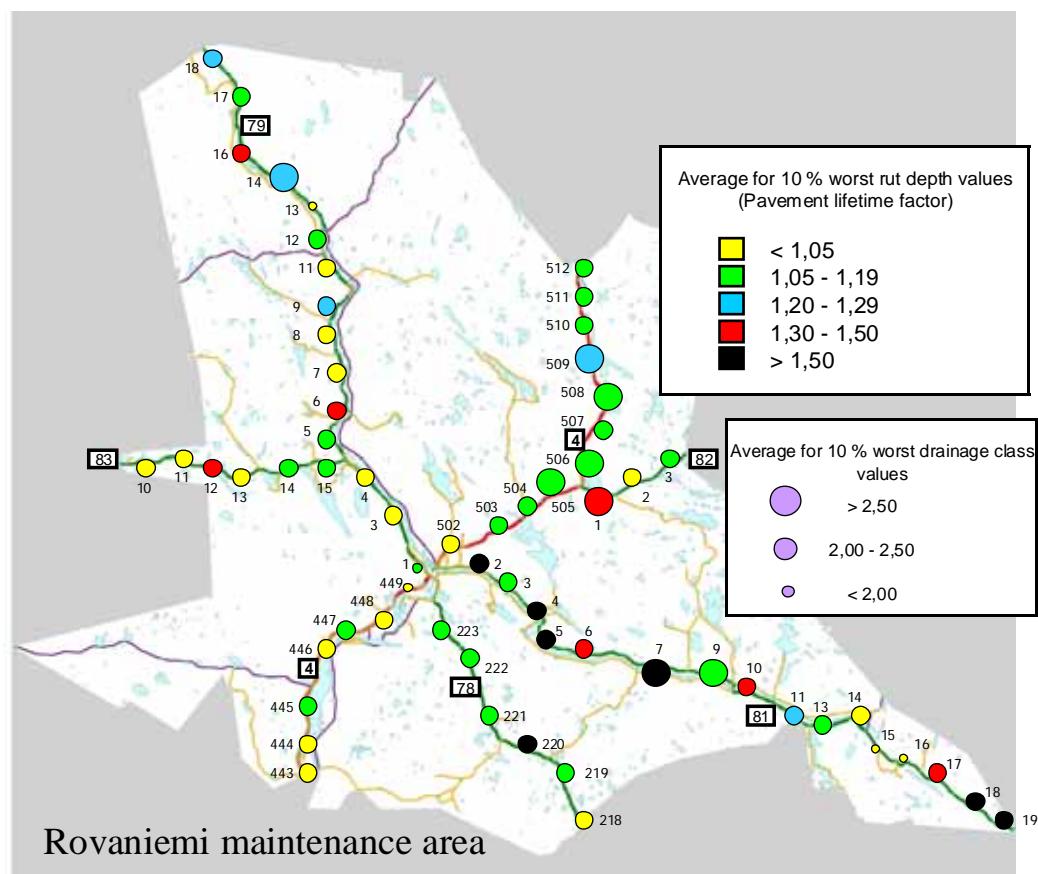


Figure 24. Pavement lifetime factor a.k.a. average for the worst 10 % rut depth ratio values and drainage classes on main roads. Rut depth ratios are presented in colours and drainage classes with sphere size.

In spite of the great amount of poor drainage and rutting problems, there are also good sections on regional and local roads. For example in the middle of very poor sections on road 19733, there is section 2 where there seems to be no drainage-related rutting. Road 944 is also in good condition, as well as most of the small village roads, e.g. road 19661 which has the best 10 % rutting ratio of all the roads in the whole maintenance area. The best 10 road sections also have something else in common: all of them are located mainly on sand or gravel subgrade.

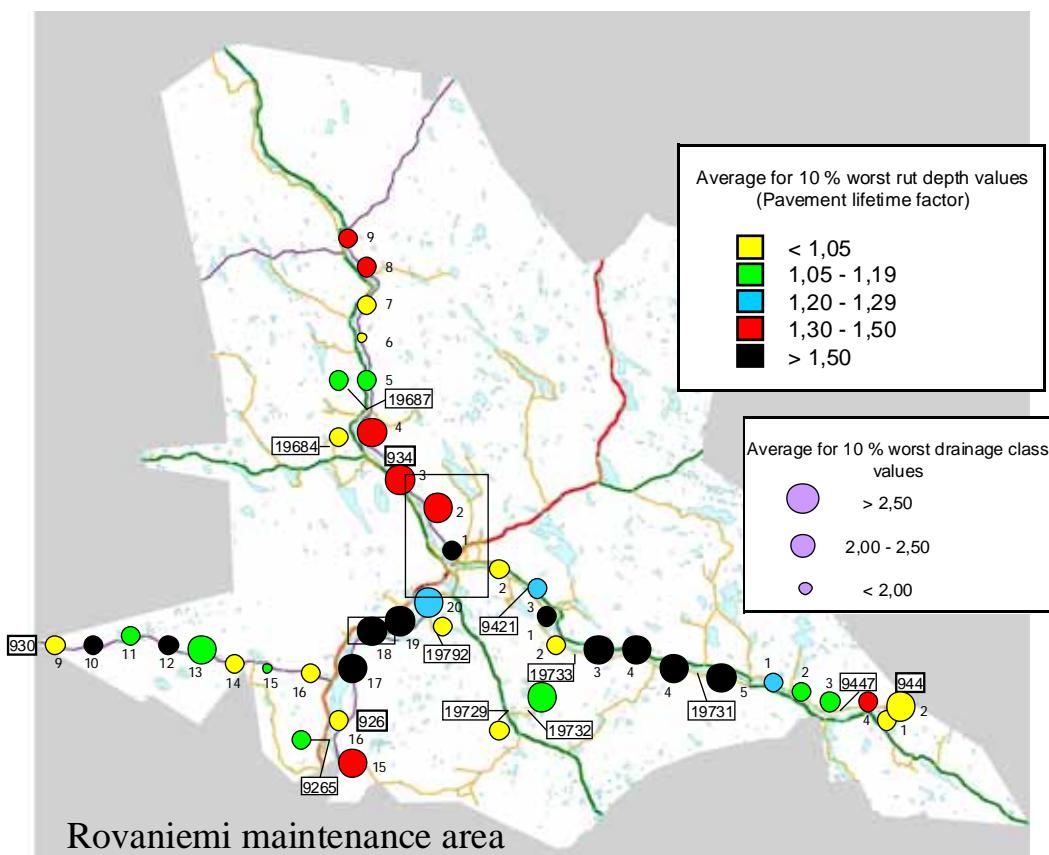


Figure 25. Pavement lifetime factor a.k.a. average for the worst 10 % rut depth ratio values and drainage classes on other (regional and local) roads. Rut depth ratios are presented in colours and drainage classes with sphere size.

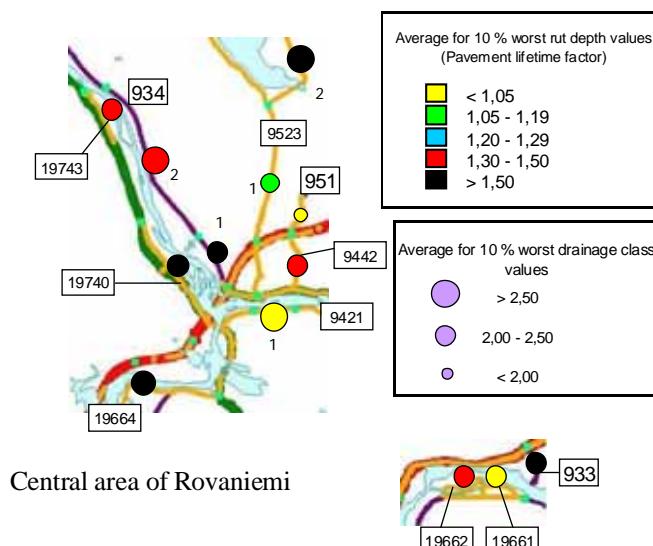


Figure 26. Pavement lifetime factor a.k.a. average for the worst 10 % rut depth ratio values and drainage classes in the area around Rovaniemi and an area along the Kemijoki River.

3.5. DRAINAGE AND ROUGHNESS

The effect of the drainage condition on roughness values was tested using the same principles used in the rut development analysis. The results appear to be also quite similar even though the process causing these problems is different. In the Rovaniemi area, high IRI values are mainly caused by differential frost heave problems on the roads. Poor drainage increases the moisture content in frost susceptible subgrade soils and thus their segregation potential will be increased resulting in higher frost heave values from road surfaces.

According to figure 27 the relationship between roughness and drainage is obvious. In these results, the effects of the thicker road structures in higher category roads, with smaller frost heaves and thus reduced frost fatigue and smaller IRI values, is easy to see. The difference in average IRI values becomes clearer in the lower class road with thinner structures: on main roads the ratio between drainage classes 3 and 1 is 1.28, on regional roads 1.42 and on local roads it is 1.85. The average IRI (International Roughness Index) values from class 3 drainage sections on rural roads are so high that according to standards they would already require some rehabilitation measures.

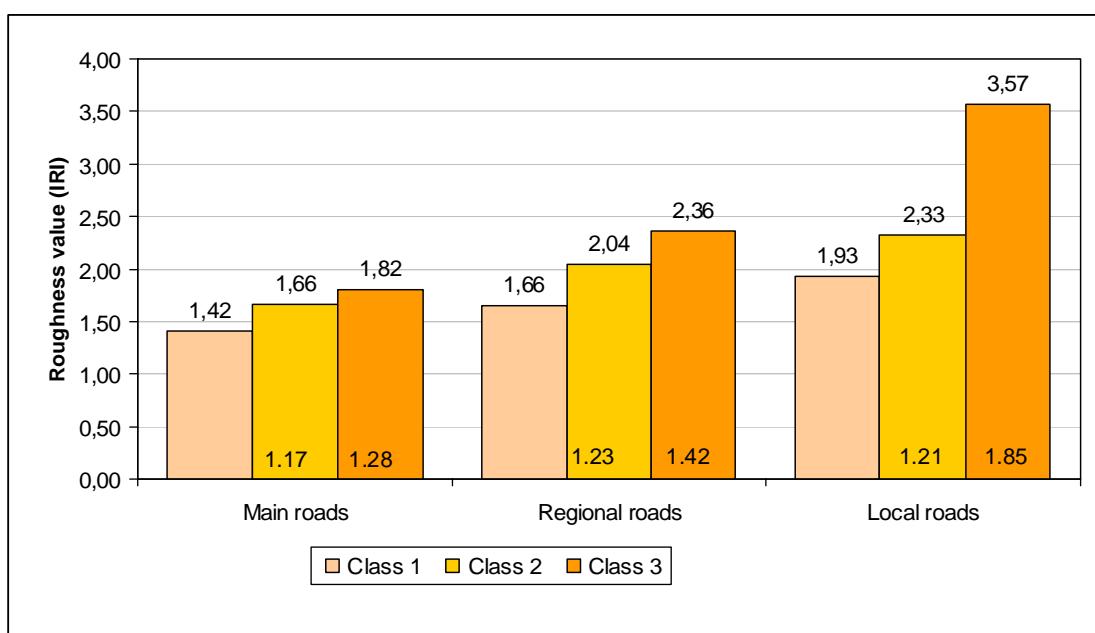


Figure 27. Roughness (IRI) average values on each road type and drainage class. The values on top of the columns are absolute, the values at the bottom are relative to class 1.

The results from tracking the problem spots on main roads are presented in figure 28. As in rutting, the 10 % average is used in roughness calculations as well. Compared to rutting values,

the roughness ratios are more moderate and there are fewer sections where the worst 10 % average is extremely poor.

An interesting finding, when comparing the IRI and rutting maps, is that, especially on roads 78, 83 and the northern part of road 4, the IRI ratio is higher than the rutting ratio. All these roads are located away from the Kemijoki river valley and are located mainly on morainic formations. This shows that in these areas with morainic formations the frost action and differential frost due to poor drainage can be more critical to the pavement lifetime than permanent deformation. Naturally the fatigue of the road in this area is a combination of both of these problems.

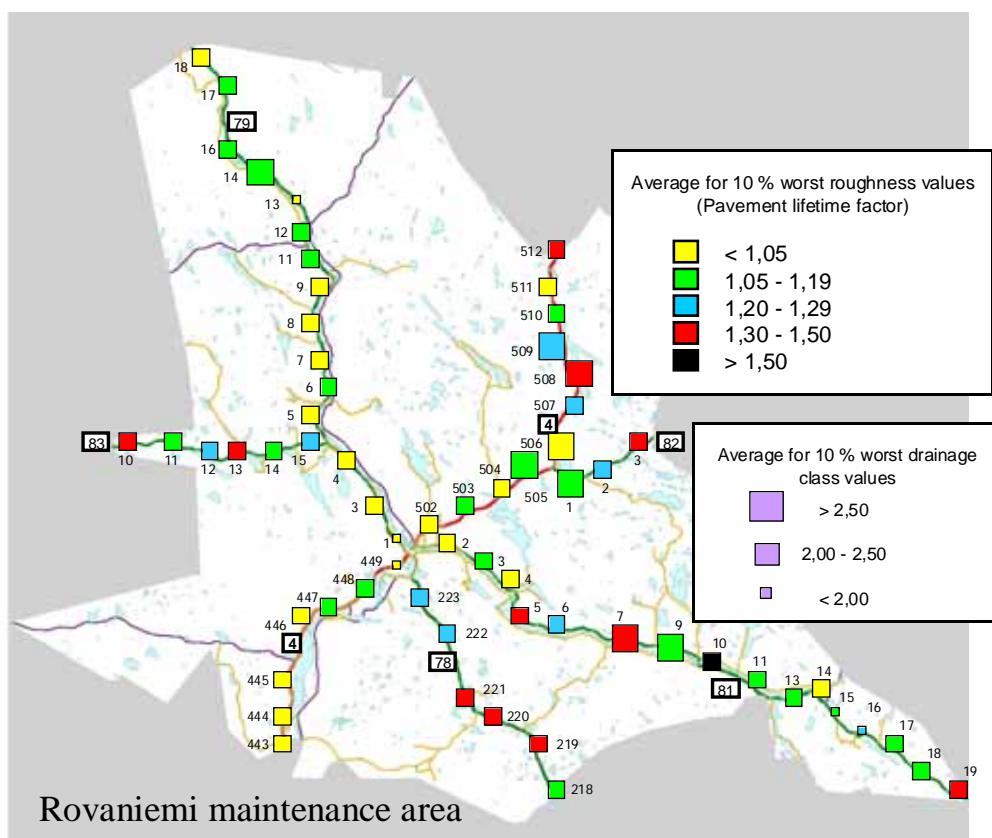


Figure 28. Pavement lifetime factor a.k.a. average for the worst 10 % roughness (IRI) ratio values and drainage classes on main roads. Roughness ratios are presented in colours and drainage classes with square size.

The maps in figures 29 and 30 show the corresponding results from regional and local roads. It can be seen that the 10 % worst roughness ratios are much higher on regional and local roads compared to rutting results. Almost all roads in these categories had high ratios indicating again the correlation between poor drainage and frost problems. The worst road sections were

identified from roads 19731, 934 (see figure 30), 944 and 926. All of them had a high amount of class 3 drainage sections. Actually the average amount of class 3 drainage on the worst 10 road roughness ratio road sections was as high as 7.9 %. The poorer the drainage class is the more roughness problems occur. Road sections with high roughness values also have problems with fast increasing pavement distress problems as figure 31 shows.

The road sections that have the smallest roughness ratios are scattered randomly across the maintenance area. There is a region in the general vicinity of the city of Rovaniemi with higher traffic volumes, though roughness ratios remained low. Most of the village roads also have suitable ratios.

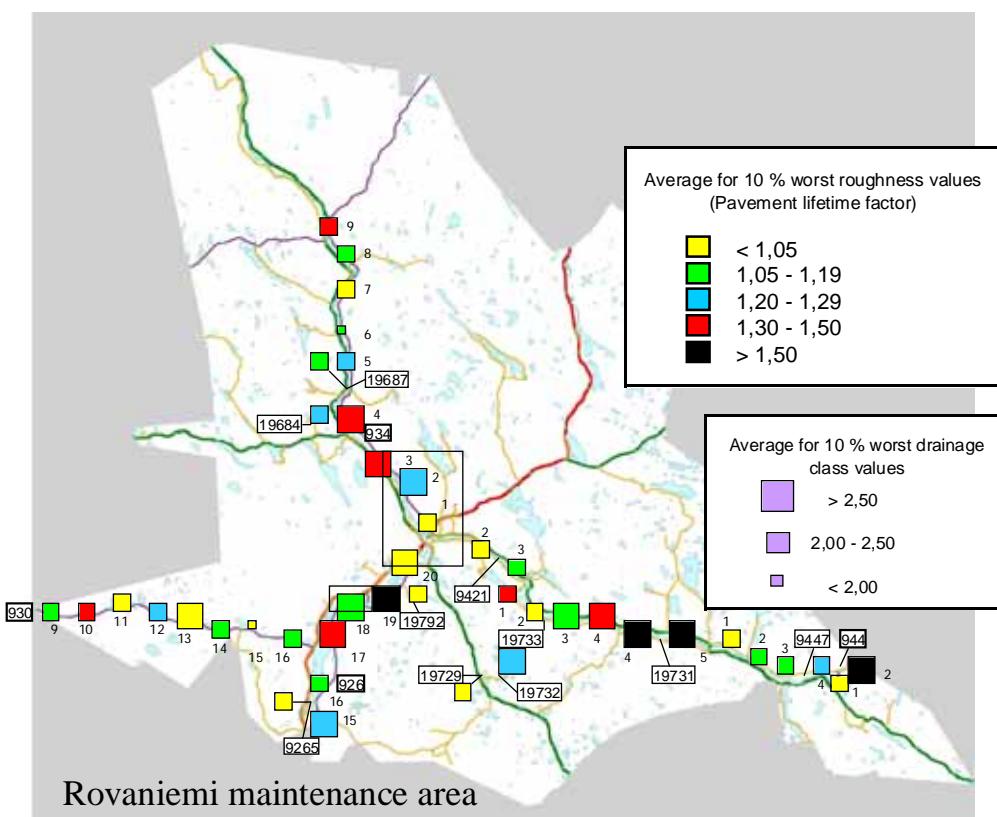


Figure 29. Pavement lifetime factor a.k.a. average for the worst 10 % roughness (IRI) ratio values and drainage classes on other (regional and local) roads. Roughness ratios are presented in colours and drainage classes with square size.

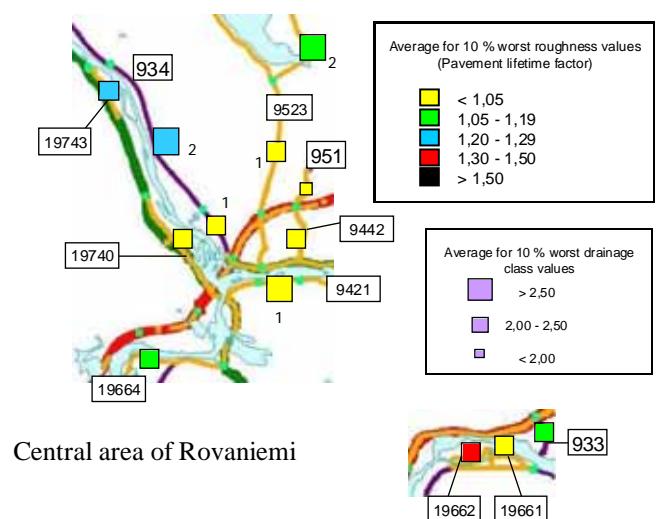


Figure 30: Pavement lifetime factor a.k.a. average for the worst 10 % roughness (IRI) ratio values in area around Rovaniemi and area along the Kemijoki River.



Figure 31. Poor drainage on side sloping ground causing differential frost heave and pavement damage along the right shoulder and increased roughness values (IRI) in road 934, section 4. Photo on the left is taken in summer 2005 and on the right in spring 2006.

3.6. DRAINAGE IN DIFFERENT ROAD PROFILES

An interesting question was could differences be found in average drainage condition in different road profiles and in different road classes? Figure 32 presents the average values of drainage condition in the Rovaniemi maintenance area and it demonstrates clearly that drainage is best on roads built on embankments. In main roads there were differences between 0-level, side sloping ground and road cut sections.

On regional roads the drainage condition was the worst in road 0-level sections and quite surprisingly even better average condition on road cuts than with main roads. On local roads the biggest problems are found in road sections located on side sloping ground. Drainage in road cuts is also much worse than with other road classes.

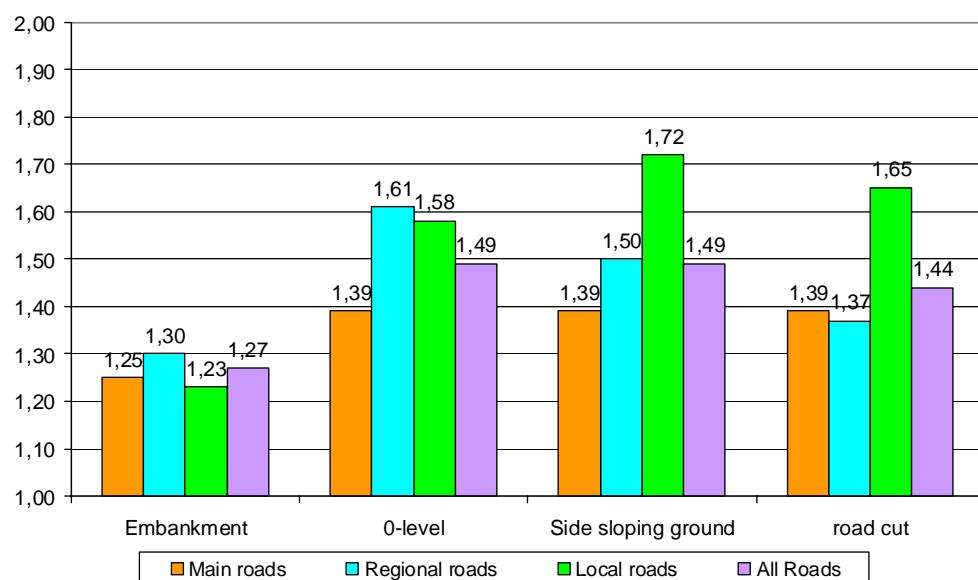


Figure 32. Average drainage class in different road profiles and road classes in the Rovaniemi maintenance area.

Figure 33 presents the relative proportion of different road profiles of paved roads and it shows that more than 35 % of the paved roads are located on embankment. The second one, representing nearly a third, are roads on side sloping ground and they have the average drainage class of 1.49 and are thereby, alongside with 0-level, the most problematic road profile class from the perspective of drainage condition.

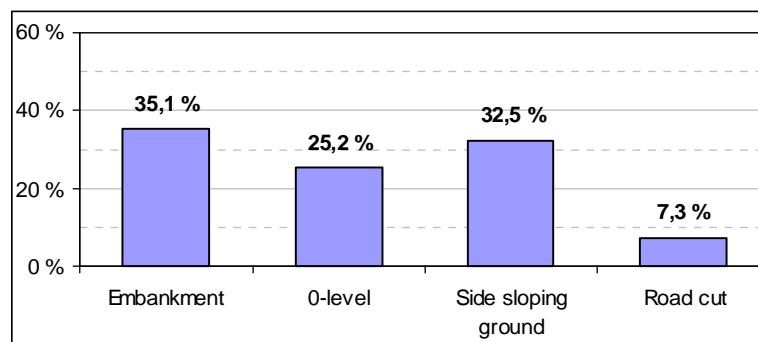


Figure 33. Percentage of each road profile on paved roads in the Rovaniemi maintenance area.

Notable differences in rutting values between road profiles (figure 34) can be found. On main roads the differences are small but on local roads it is especially noticeable that rutting is definitely least on embankments. On regional roads average rut depth is highest on road cuts where it is even higher than on main roads. On local roads the highest average rut depths were measured on roads located on flat ground (0-level) but rut depths in road cuts and on side sloping ground had values nearly as high.

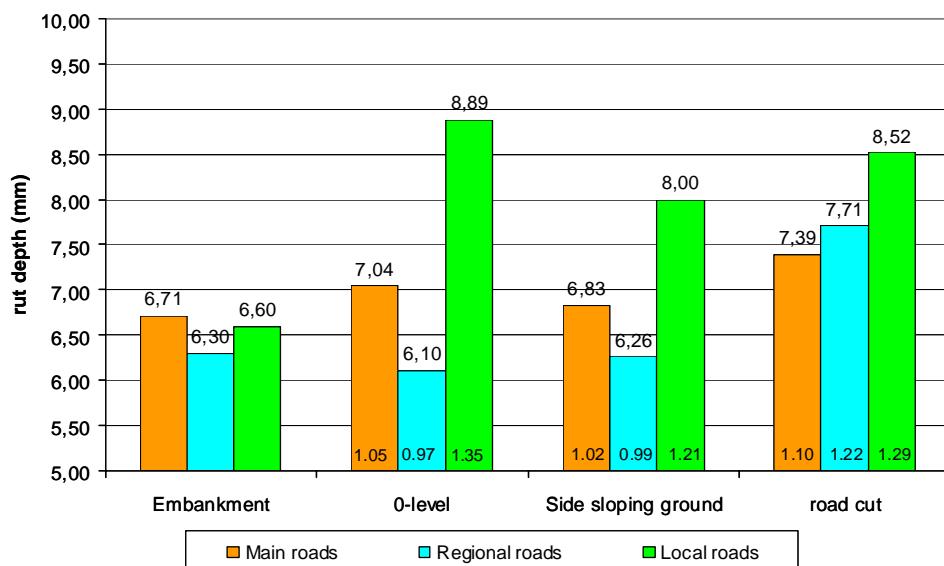


Figure 34. Rut depth average on different road profiles on paved roads in Rovaniemi area.

However when roughness values were compared to each road profile it was observed that there were no major differences in average IRI values between each road profiles class, even on local roads as figure 35 presents. The best IRI average value was in road cut sections which can be explained in that they are the "best built" structures in local roads.

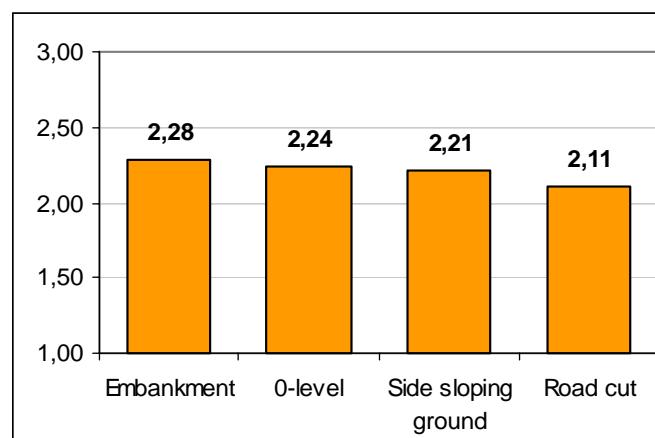


Figure 35. Roughness (IRI) average on different road profiles in local roads.

4. CONDITION OF DRAINAGE ON GRAVEL ROADS IN THE ROVANIEMI MAINTENANCE AREA

4.1. GENERAL

The condition of drainage on the entire gravel road network of the Rovaniemi maintenance area was not inspected. Only roads with a history of spring thaw weakening problems were selected for the survey. The selection of gravel roads is still representative since it consists of both regional and local roads covering a large part of the maintenance area. Road 952 in the northern part of the area is a regional road and sections 1 - 4 from this road were selected for this study. The rest of the gravel roads are local roads (9448, 19658, 19686, sections 2 and 3 from road 19688, 19742 and 19745).

The following text presents the state of drainage on gravel roads and how poor drainage affects spring thaw weakening, bearing capacity and roughness. It was also tested on gravel roads whether there are differences between drainage classes on different road profiles.

4.2. DRAINAGE CLASS DISTRIBUTION ON TESTED ROADS

Whereas drainage class distribution on paved roads was concentrated mainly in drainage class 1, with gravel roads the majority of road network had poorer drainage as figure 36 shows. On average, the proportion of drainage class 1 on gravel roads is 32.41%.

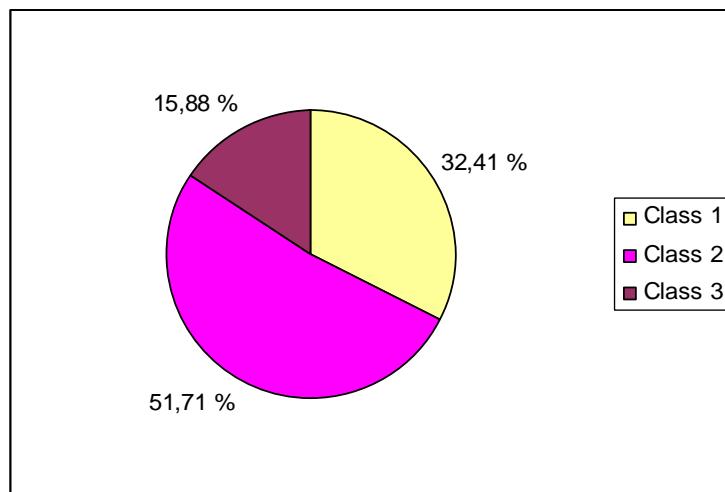


Figure 36. Drainage class distribution on gravel roads.

The average drainage class of all the tested gravel roads is 1.83 (figure 37). The worst drainage condition could be found from road 19688 from road section 3, where the average value was 2.31. There are altogether five roads/road sections where the average drainage class is greater than 2. On the other hand, there are only two sections where the average is less than 1.5: Road 952 section 2 (1.49) and road 19745 section 2 (1.36).

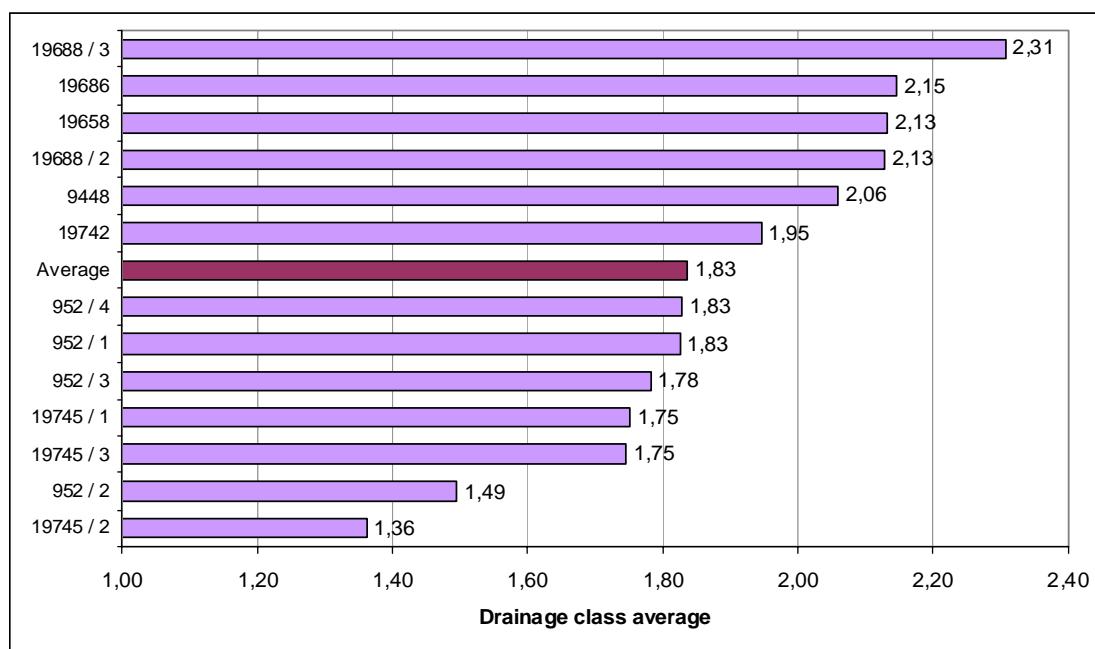


Figure 37. The drainage class average distribution on gravel roads.

An example of poor drainage is presented in figure 38. The picture is taken of a ditch from section 1 of road 19742. The ditch is clogged because material from the inner and outer slope is flowing into the ditch. This kind of problem section may require ditch cleaning, even every second year, if special drainage structures are not used.

The location of the tested gravel roads and the condition of their drainage can be found on the map in figure 39. It is remarkable that, unlike paved roads, on gravel roads there can be sections where the combined amount of drainage classes 2 and 3 is over 80 % of the whole road length. That is the case with roads 19658, 19686 and 19688. On road 19686 the proportion of drainage class 1 is as low as 7.34 %.



Figure 38. Drainage problems on road 19742 section 1. In this section, located on side sloping ground, the road has had slope stability and spring thaw weakening problems almost every year since 2001.

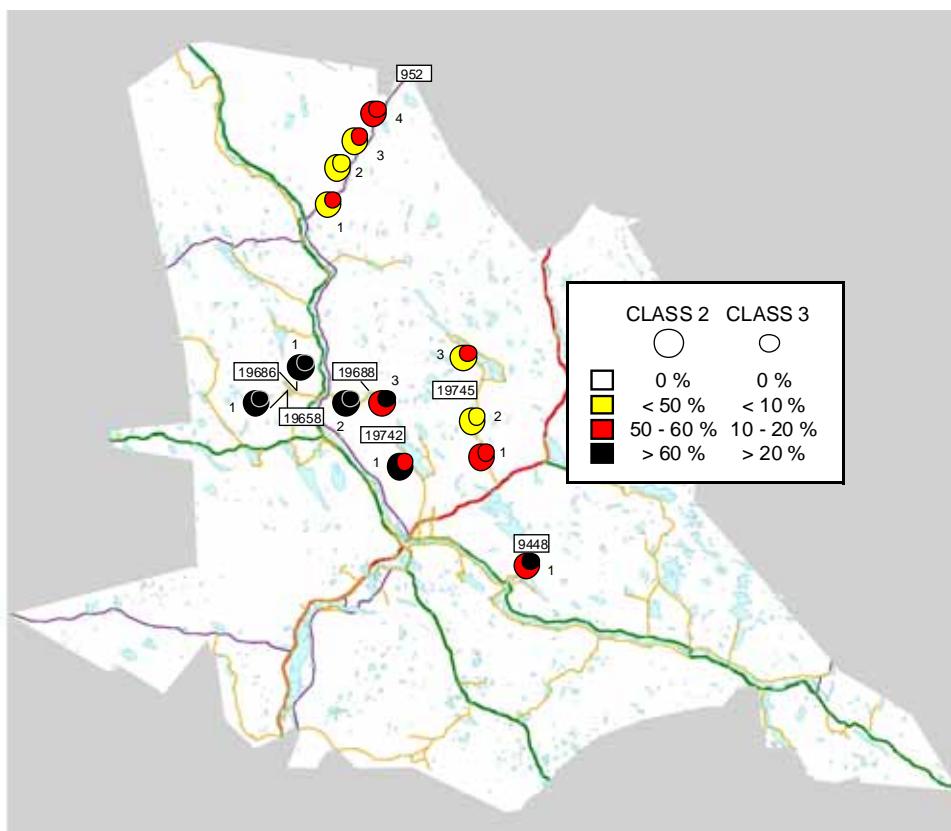


Figure 39. Proportion of drainage classes 2 and 3 on gravel roads. Sphere size represents drainage class and colour represents the proportion of it.

4.3. DRAINAGE AND SPRING THAW WEAKENING

The classification of spring thaw weakening problems that is used in this report differs a bit from the Finra spring thaw weakening classification. The categories are in reverse numerical order and the new Finra class 4 'slight problems' is not used at all because the road surveys were done before this new problem class was introduced. The equivalency of these two classification systems is presented in table 1.

Table 1. Equivalency of ROADEX and Finra spring thaw weakening problems classification

Classification	ROADEX	Finra
Extremely severe problems	Class 3	Class 1
Severe problems	Class 2	Class 2
Medium problems	Class 1	Class 3
Slight problems	-	Class 4
No problems	Class 0	

According to the field study, 92.6 % of the tested gravel road network does not suffer from spring thaw weakening. Medium weakening occurs on 6.3 % of roads and severe weakening on 1.1 % of roads (figure 40).

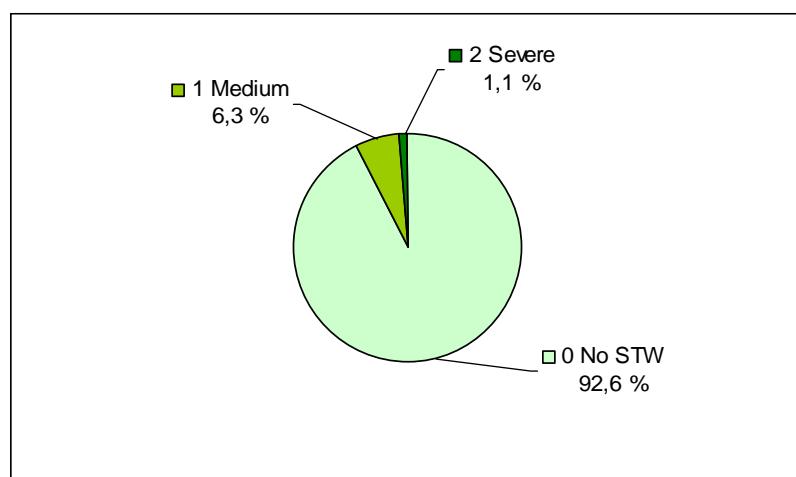


Figure 40. Spring thaw weakening problem class distribution on tested gravel roads on Rovaniemi maintenance area. The classification is done according to previous ROADEX projects.

The location of road sections with the biggest spring thaw weakening problems is very similar to the map presenting road sections with drainage problems (see figure 39). The map in figure 41 shows that the sections with greatest amount of spring thaw weakening are from roads 19658 and 19686 and section 3 from road 19688. When these sections are compared to the worst

drainage sections presented on map on figure 39 it is easy to see that these sections are the same. This demonstrates the good correlation between poor drainage and spring thaw weakening problems on gravel roads. The best sections can be found from roads 952, 9448 and 19745 (section 2).

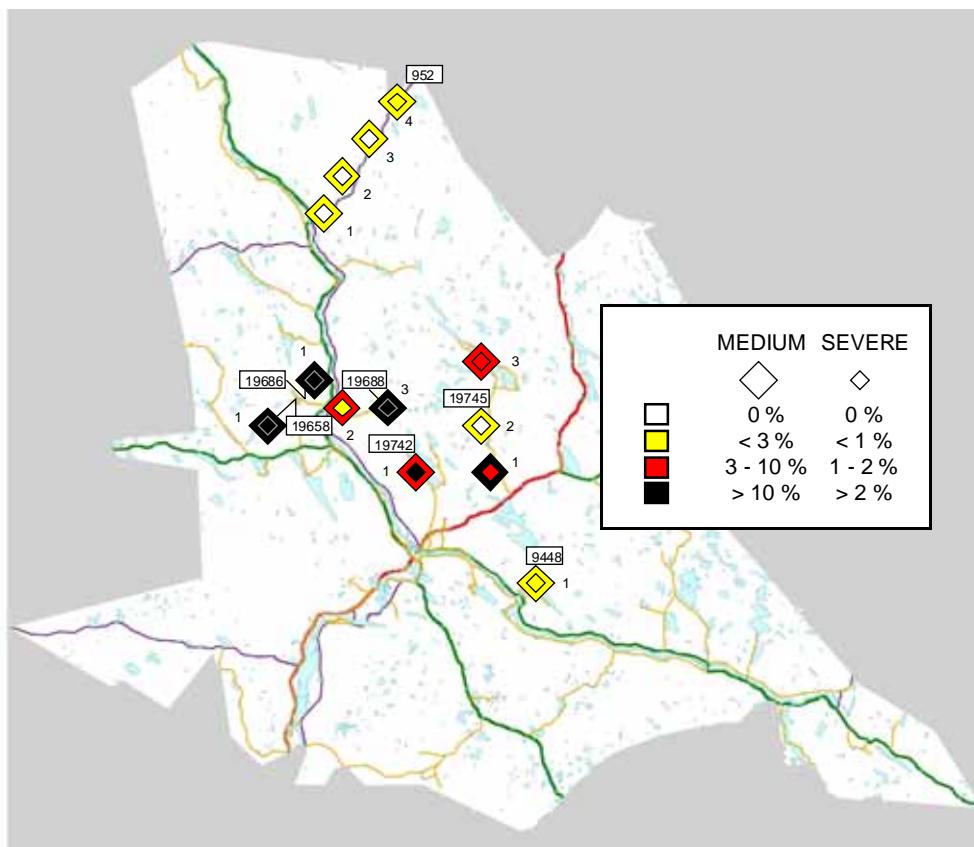


Figure 41. Proportion of medium and severe spring thaw weakening on the tested gravel roads.

The relationship between drainage and spring thaw weakening can also be seen clearly in the map in figure 42. The road section presented is section 3 from road 19688 where the relative amount of spring thaw weakening is high. According to the figure, severe spring thaw weakening only occurs on sections where drainage class is poor (figure 43). Also, spring thaw weakening in good drainage sections is minor compared to weakening on classes 2 and 3.

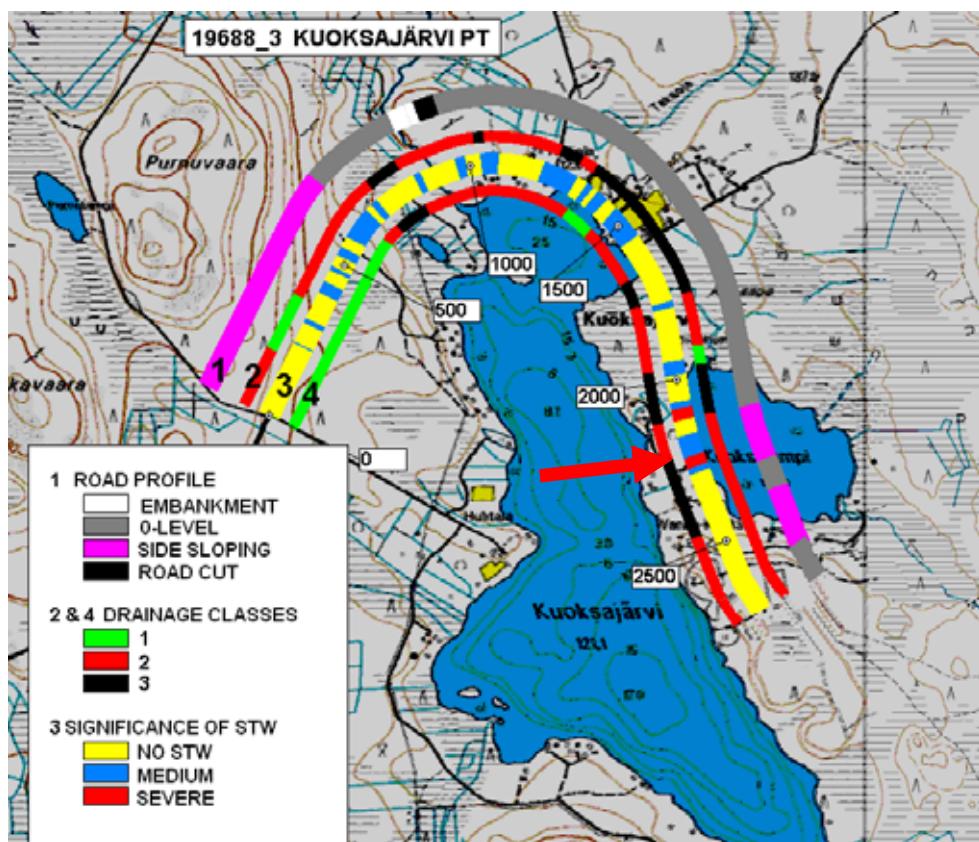


Figure 42. Spring thaw weakening (STW), drainage classes and road profile on road 19688 section 3 in Kuoksaajarvi in Rovaniemi. The red arrow points to the place for the photo in figure 43



Figure 43. Poor drainage on a section with severe spring thaw weakening problems

4.4. DRAINAGE AND LOAD BEARING CAPACITY ON GRAVEL ROADS

As a part of rehabilitation design, bearing capacity measurements were carried out in fall 2005 on every road section apart from section 2 from of road 952 using a Falling Weight Deflectometer (FWD) device. Since there were only 5...70 measurement points in each road section the results do not always represent the bearing capacity distribution of the whole road. However, the results still provide a good data base with which to compare the relationship between bearing capacity and drainage. The actual FWD results were calculated in the form of Surface Curvature Indexes (SCI) and Base Curvature Indexes (BCI). The Surface Curvature Index describes the stiffness of the upper part of the pavement structure whilst the Base Curvature Index describes how the road can spread the load over a weak subgrade.

Figure 44 presents the average BCI and SCI values in different drainage classes from the test roads. Quite surprisingly there did not appear to be any major differences in SCI values in different drainage classes. This indicates that the stiffness of the upper part of the road is not markedly affected by drainage condition at least in early fall (September) when the data was collected. The biggest difference can be seen in the BCI values. Based on experiences from past Roadscanners projects, the risk for mode 2 permanent deformations begins when BCI value is higher than 40 μm and these problems become very obvious when BCI value is higher than 60 μm . In this case the average BCI value in drainage class 3 was 89 μm which indicates major risk for permanent deformation in the road structure / subgrade interface.

Statistical analysis also showed that there was no correlation between bearing capacity and spring thaw weakening. The explanation is that there are different types of spring thaw problem sections, some of them can be related to the presence of bedrock and others to peat areas.

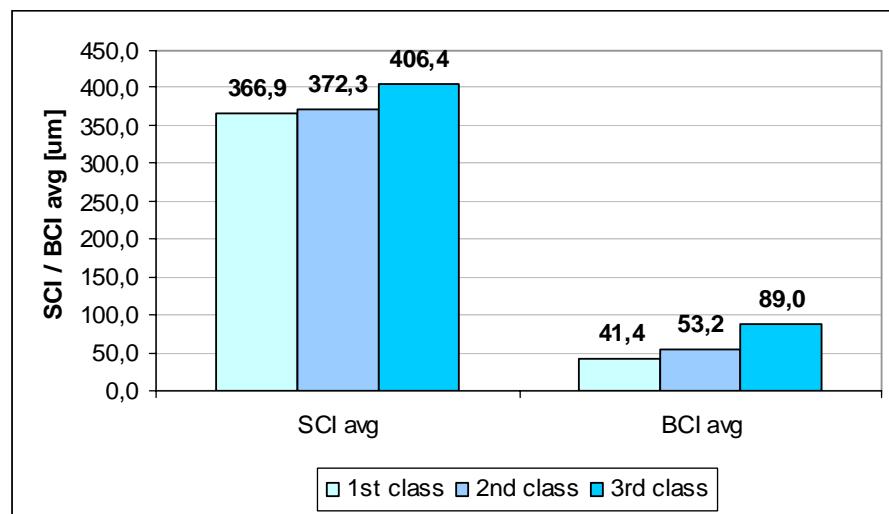


Figure 44. SCI and BCI values in each drainage class on tested gravel roads

4.5. DRAINAGE AND ROAD ROUGHNESS ON GRAVEL ROADS

Since, as previous results from paved roads showed, the roughness of paved roads correlated quite well with decreasing drainage condition it was assumed that this trend could also be seen on gravel roads. However as figure 45 shows the roughness was only slightly higher on road sections with poor drainage; the ratio between IRI values of drainage classes 3 and 1 is only moderate 1.10. One reason for that is that gravel road measurements were done in winter and at that time compacted snow evened by a grader smoothes the rough spots and only places with differential frost heave can be found. So a conclusion can be drawn that poor drainage is not the major reason for roughness issues on gravel roads, at least not in every road section.

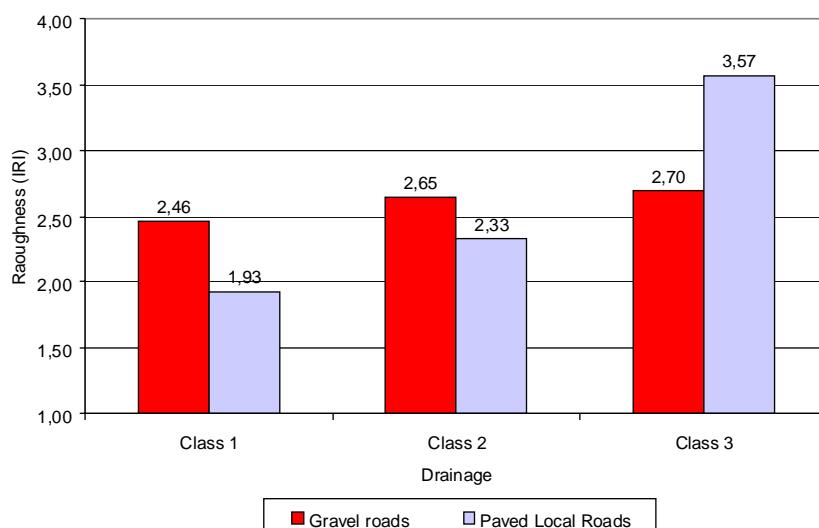


Figure 45. Roughness (IRI) value in different drainage classes on gravel roads measured during the winter compared with average IRI values from paved local roads.

4.6. DRAINAGE IN DIFFERENT ROAD PROFILES

On gravel roads in the Rovaniemi area, according to figure 46, the best profiles for gravel roads, from the perspective of drainage condition, are embankments and road cuts. On embankments, the average drainage class is 1.54 whereas on 0-level it is 2.00. That means that on 0-level there is equal amount of drainage classes 1 and 3. The surprisingly good ranking of road cut can be explained by road structure. The structures of the road have been built more carefully since the profile in itself does not provide any of it. Also, because of maintenance history, in case of problems road cut sections are the first ones to be repaired. Therefore deterioration has not had as much time to develop as in other road profiles.

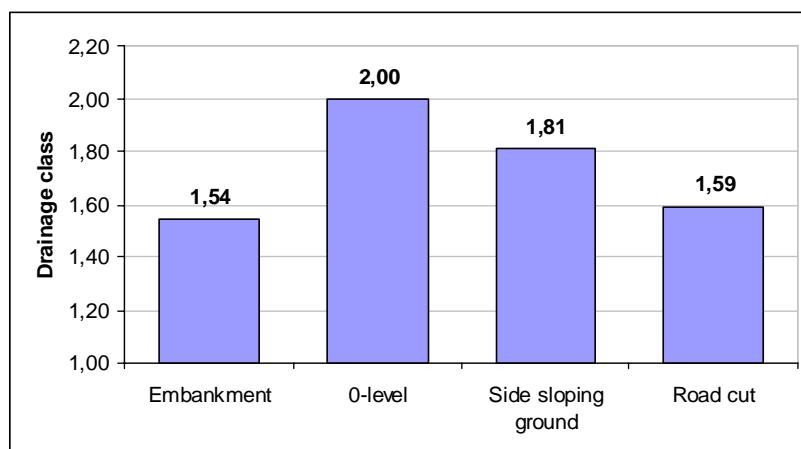


Figure 46. Average drainage class on different road profiles.

Figure 47 shows the distribution of each road profile on gravel roads. Figures 46 and 47 show that the two worst road profile types are unfortunately also the two most common ones. The proportion of embankment is only 4.2% while 0-level's share is 36.0 %. The most common road profile is side sloping ground, 49.7 %.

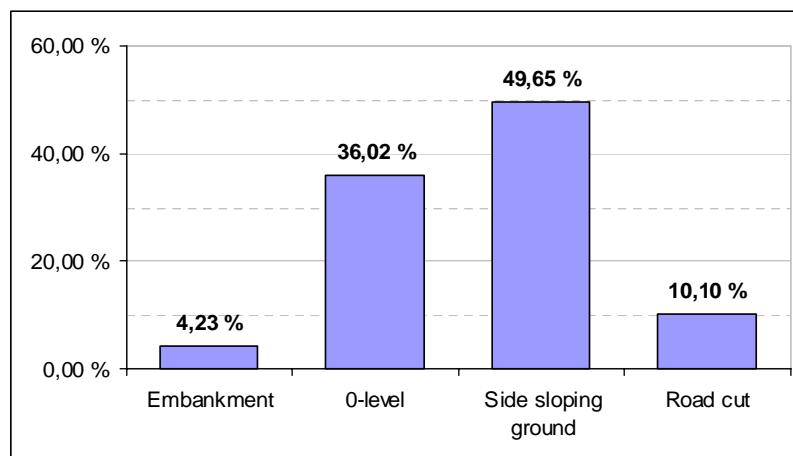


Figure 47. Percentage of each road profile on gravel roads in the Rovaniemi maintenance area.

When it comes to drainage on different road profiles and spring thaw weakening, the chart (figure 48) is quite similar to drainage class distribution. On 0-level, a total of 8.9 % of the roads suffer from either type 1 or 2 spring thaw weakening. Type 2 spring thaw weakening occurs on less than 2 % of each road profile. In road cuts it does not occur at all. Quite surprisingly, embankment is not the best profile from the viewpoint of spring thaw weakening. This can be

explained in that in certain roads very poor material has been used when building the embankments.

From the road profile data and figures 46, 47 and 48 it can be summarised that the average drainage condition is worst on road sections with foundations on ground level (0-level) or on roads located on sloping ground and these two profiles comprise roughly 85 % of the road network. Furthermore spring thaw weakening is also most common on these profiles.

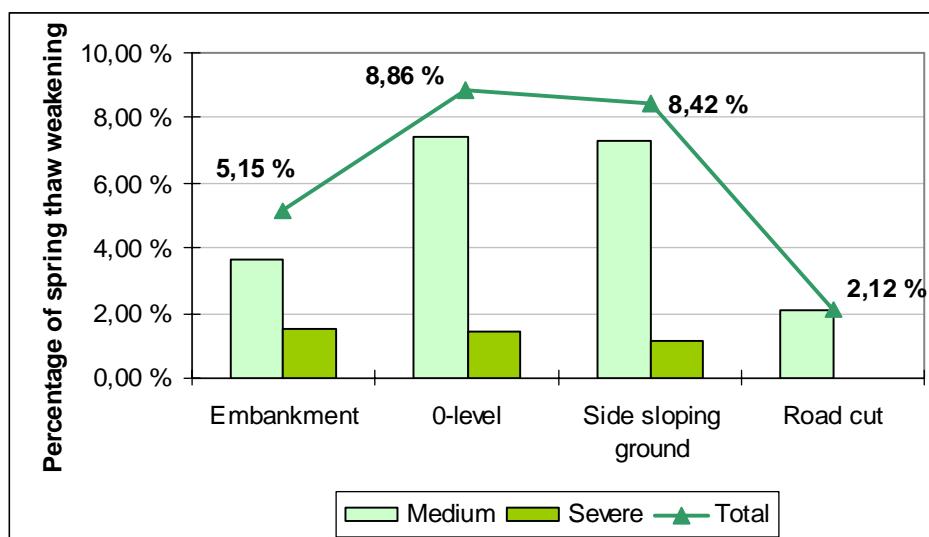


Figure 48. The proportion of medium and severe spring thaw weakening on different road profiles. The line represents the total amount of any spring thaw weakening.

5. DRAINAGE AND PAVEMENT LIFETIME IN THE ROVANIEMI AREA – LIFE CYCLE COST CALCULATIONS

The results of the previous ROADEX drainage reports, also confirmed by the results of this survey, have clearly indicated that a reduced quality of the road drainage system also means shorter pavement lifetimes - and thus higher road owner costs for the road network. However there were still some questions about the concrete benefits that road owners will receive when the road network drainage is improved and maintained at a higher standard. The easiest way to demonstrate it is to calculate how much improvement affects the annual paving costs.

For these calculations the paved road network, as in the previous analysis, was also divided into main roads, regional roads and local roads and average 10 % pavement lifetime factor were calculated for these road groups as presented in chapter 3.4. For the calculations it was also required to obtain information concerning the average widths of the road in each road class and average lifetime of the pavement in each class. This information was provided to the researchers by Lapland Road Region staff that in turn had obtained the data from the Finnish PMS data base. Paving costs in these analysis calculations were 5 €/m² in all road classes and the discount rate was 4 %. Table 2 presents the input parameters used in these calculations.

Table 2.. Input parameters used in life cycle cost calculations

	Main roads (m)	Regional roads (m)	Local roads (m)	Total (m)
Length (m)	382 361	146 719	115 930	645 010
Width (m)	7.2	6.2	5,7	
Paving cost €/m	36	31	27.5	
Average lifetime (years)	10	13	11	
Drainage lifetime factor	1.16	1.19	1.24	
Increased lifetime (years)	11.6	15.5	13.6	

After the input parameters were defined the life cycle cost calculations were done based on the question what would be the economical benefits for road owners if drainage class were raised to class 1 in all road sections. Table 3 presents the results of these calculations showing that savings percent in each road class varied between 10.8 % on regional roads to 14.5 % on local roads. When this was calculated into euros, the results show a total theoretical sum of 335.000 € in annual savings, which is quite a remarkable sum which could be invested into improvements of the drainage system – and still be profitable.

Table 3.. Results of Life cycle cost calculations for Rovaniemi area

	Main roads	Regional roads	Local roads	Total
Annual paving costs (€)	1 917 000	517 000	415 000	2 849 000
Costs if drainage improved (€)	1 698 000	461 000	355 000	2 514 000
Savings (€)	219 000	56 000	60 000	335 000
Savings (%)	11.4	10.8	14.5	11.8

6. EFFECT OF IMPROVED DRAINAGE ON GRAVEL ROADS – COST BENEFIT CALCULATIONS

Lifecycle cost calculations for gravel roads were quite difficult to make because there were no similar parameters, as rutting on paved roads, which could be directly related to the pavement lifetime. However some indirect calculations could be made. For instance if improving the drainage from class 3 to class 1 on local paved roads in Rovaniemi saves rough 15 % of the annual paving cost, it can be evaluated that with gravel roads, that have much thinner and worse quality structures than paved roads, the savings with annual maintenance costs due to structural problems will be 20 % or more. As chapter 4.4 shows the subgrade stiffness is much worse in areas with poor drainage and this enhances mode 2 rutting on the road – and this triggers the need for adding gravel to the road surface.

In Scandinavia, the greatest benefit of drainage improvement is a reduction in the amount of spring thaw weakening problems. In the Rovaniemi maintenance contract area, approximately 850 000 € will be invested during the years 2008, 2010 and 2011 to repair spring thaw weakening sites. Keeping the drainage in adequate condition the lifetime of these section can be increased by at least a factor of 2, which means that the annual cost for the repaired section will be reduced by roughly 5500 €/km down to 3800 – 4000 €/km (see Saarenketo and Aho 2005). In the Rovaniemi maintenance contract this would translate into about 30.000 € in annual savings only taking into account the improved lifetime of the repaired road sections. Finra have been using annually 10 M€ for strengthening spring thaw weakening sites and 3 M€ for emergence repair. With the better drainage management these figures could be markedly reduced.

7. NEW DRAINAGE MANAGEMENT POLICIES IN THE ROVANIEMI MAINTENANCE CONTRACT 2007 - 2012

7.1. GENERAL – DRAINAGE AND PROCUREMENT

Over the last 10 years Road Administrations in the NP area have had major organisational changes and today road maintenance is carried out everywhere by contractors selected after open competitions. Tight competition will mean that the maintenance contractors will only be doing those maintenance measures that are clearly specified in the procurement documents.

But as the results of this work show there is also a need to change the drainage maintenance policies. Thus far drainage has normally been improved at certain year intervals, like after 8-12 years. This means that on paved roads the drainage has been improved mainly together with the paving project – basically once it has become too late for the old pavement but also often too late for the new pavement as well. This work has been done by the maintenance contractor or has been paid separately or has been a part of the paving contract. After these measures the drainage maintenance has been generally focused on keeping the culverts open and cutting the grass from the road slopes. Maintenance of outlet ditches has, all too often, been ignored. The problem with this system is that it does not focus on the critical points and the actions programmed by road regions are done, for the most part, too late.

Another trend in road procurement policies is the move towards performance based contracts where Road Administrations will define the service level or quality standard of roads. This policy could also be much more effectively used in drainage maintenance and new drainage standards could and should be used in maintenance contracts because immediate actions are required when drainage condition starts to deteriorate even though it is not yet affecting pavement lifetime.

These ideas are being tested in a pilot project using the Rovaniemi maintenance contract 2007-2012 and the procurement documentation, process. The initial experiences from this system are described hereafter.

7.2. SPECIAL DRAINAGE MAINTENANCE CLASS

As this report has already shown there is a big potential for major savings with the paving costs if the drainage system of the road network is improved to good condition and maintained as such. However, experience has shown that the drainage condition of the critical road sections affecting pavement lifetime can substantially worsen in a little as 1-3 years after it has been improved. That is why these critical sections need to have a new classification "special drainage class" and they need to have continuous monitoring over the contract period. Then if and when

needed, maintenance actions to improve drainage should be made immediately after deficiencies have been detected. The same principles can be applied also on gravel roads.

In the Rovaniemi maintenance contract it was decided, in co-operation with the ROADEX project, to test on a part of the paved road network the concept of special maintenance classes and set special standards for their maintenance. For the tests, a total of 9.65 km of road was selected from roads 78, 926 and 934 (see table 4) where the drainage was clearly causing either increased rutting and/or pavement cracking and shoulder deformation and that were also in the rehabilitation programme for 2006. Selection was based on the drainage analysis results and in these sections it was obvious that the normal 8-12 years maintenance interval was not enough to ensure good pavement performance. Only the critical side of the road was selected for the special maintenance class.

After selection, the drainage of these sections was improved to class 1 in summer 2006 during the paving project. The condition of these roads was recorded again in order to be able to demonstrate the required drainage standard of these classes and to document their condition at the beginning of the contract in 2007. Figures 49 and 50 present some examples of the road sections selected for the special maintenance class. All the survey data including drainage analysis and still photo data from the roads was then delivered to the contractors when they were preparing bids for the contracts.

Table 4. List of paved road sections selected for the special drainage maintenance class in the Rovaniemi area.

ROAD	SECTION	DIRECTION	START	END	LENGTH (m)
934	3	Right ditch	1700	1950	250
		Right ditch	2450	2950	500
		Right ditch	3800	4200	400
		Right ditch	5800	7000	1200
		road section (m)		2350	
934	4	Right ditch	200	450	250
		Right ditch	750	1250	500
		Right ditch	4800	5550	750
		Right ditch	5750	6000	250
		road section (m)		1750	
926	17	Left ditch	4300	4750	450
		Left ditch	4950	5350	400
		Right ditch	5700	6100	400
		Left ditch	5500	6100	600
		road section (m)		1850	
926	19	Right ditch	0	800	800
		Right ditch	1500	1700	200
		road section (m)		1000	
78	219	Left ditch	6250	6450	200
		Left ditch	6650	6950	300
		Right ditch	7000	7350	350
		Left ditch	7000	7350	350
		Left ditch	7650	8150	500
		road section (m)		1700	
78	222	Left ditch	4300	4600	300
		Right ditch	6150	6850	700
		road section (m)		1000	
		All together (m)		9650	

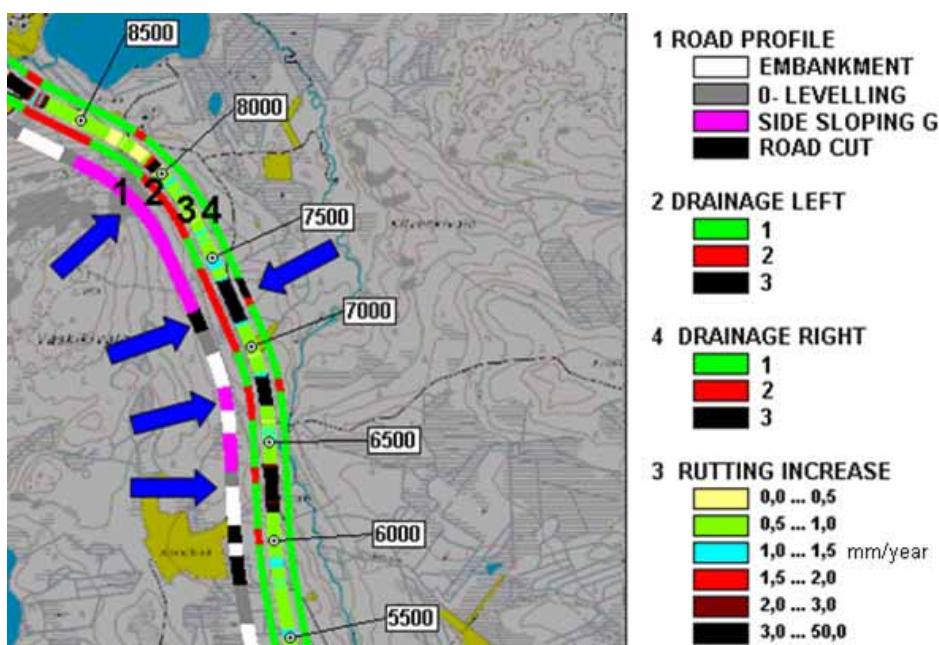


Figure 49. Example of the selection criteria for the special maintenance class, road 78, section 219. In this case road sections with higher annual rutting value than 3 mm/year and that had at least class 2 drainage (blue arrows) were selected for the special drainage class.



Figure 50. Example of a road section selected for the special maintenance class, road 78, section 222, 4505 m.

7.3. MAINTENANCE GUIDELINES FOR PAVED ROADS IN THE ROVANIEMI PILOT PROJECT

On paved roads in the Rovaniemi maintenance contract the performance based drainage standard was required only on the special drainage class sections (see chapter 7.2) and in other sections drainage improvement were still made based on a separate plan made by the road region.

According to the procurement documents, in these special maintenance class sections the drainage standard always has to be class 1 during the entirety contract period. Maintenance work in these sections is a part of the general maintenance work, which means that no extra money will be paid.

To ensure that the drainage remains in good shape the contractor has to monitor the drainage in these sections every year during the end of May or early June before vegetation prevents reliable classification. Then the contractor has to report to the road owner the monitoring results and, if needed, take maintenance improvement actions. These measures have to be taken at the latest by the end of September during the same year in which the road owner checks the drainage condition of the road.

If the drainage class verified by road owner during the autumn is exceeded on more than 5 % of the section length then the following penalties will be levied:

Required class	verified class	Penalty (€/m)	
1	2	6	€/m,(minimum 1000 €/section)
1	3	12	€/m,(minimum 1 000 €/section)

7.4. MAINTENANCE GUIDELINES FOR GRAVEL ROADS

On gravel roads the Rovaniemi pilot project covers all those gravel roads that were surveyed for spring thaw weakening rehabilitation design (see Figure 36). In these roads there were no special drainage classes but the road profile defined the required drainage class. On roads located side sloping ground the drainage class must always be class 1, on other road sections the lowest class allowed was 2. Drainage class 3 is not allowed at all starting the summer 2008. During the contract time all class 3 drainage sections must be improved during the same summer when their condition is verified.

On gravel roads the contractor also has to monitor road drainage class every year by the end of May or early June. If deficiencies are detected these sections have to be improved at least to the minimum class allowed by the end of September during the same year, when the road owner checks the drainage condition of the road. If the verified drainage class is exceeded on more than 5 % of the section length, the following penalties will be incurred:

Required class	Verified class	Penalty (€/m)
1	2	4 €/m, (minimum 500 €/section)
1	3	8 €/m, (minimum 1 000 €/section)
2	3	6 €/m, (minimum 800 €/section)

7.5. FEEDBACK FROM CONTRACTORS

During the Rovaniemi maintenance area contract competition Lapland Road Region conducted an interview among the bidding contractors to evaluate their opinions of the new drainage guidelines as a part of Finra new policies "towards performance based maintenance contract". The feedback was collected by Eero Kenttälä from Lapland Region and the following text is a summary of the comments.

In general some contractors thought this was the right direction towards performance based contracts but there were also contractors that did not like the new system at all and they clearly indicated that they would prefer old "unit based" drainage improvement contracts that were easy to calculate and that did not have "wild cards" that would cause major risks in the calculations.

According to contractors performance based drainage maintenance might cost slightly more for the contractors because in this maintenance work there was a need to apply certain "security factors" which, in practise, mean a little bit more work. On the other hand there were also statements that unit based drainage improvement measures are sometimes just "cosmetics" for the road rather than making measures to remove the problem. The idea of a restricted special maintenance class for the most critical places on paved road network was accepted and thought to be good, especially if at the same time the rest of the drainage will be improved as unit based work.

In the contract calculations the problems were in the evaluation of how often the ditches will become clogged and have to be cleared and it was suggested that public records should be kept about the maintenance actions in these areas. Otherwise only the current contractor would have an idea about the scale and scope of the problem in the area. It was also stated that the transportation costs of ditch cleaning machinery units might play a big role in the total costs. The biggest problem however was thought to be the clearing of the outlet ditches where finding the local landowners and getting their permissions might take a lot of time. Especially in that part of work contractors would like to have the road region share the risk.

To questions regarding the road survey data and bidding documents the contractors commented that it was too difficult to go through and analyse all the survey data within the short contract bid calculation time. They also felt that they would need more training to be able to properly analyse this new material.

In October, two weeks after the contract had started a telephone interview was conducted with the local project leader of the contractor that had won the contract. At this time the contractor

agreed that the new system was basically good but that too much risk was carried on their shoulders because nobody had a clear idea of how much work was needed. The big question, and risks, were what is the real need for fixing the culverts and to what extent do outlet ditches have to be cleared and how easily will landowner permissions be acquired in this work. In their bid calculations the contractor had used average drainage maintenance costs.

The contractor's plan is, in the first years, to focus, in general, on ditch cleaning and then later focus on drainage maintenance of the critical areas. The contractor also thought that the drainage management of the paved roads would be easier to carry out compared with the gravel roads.

7.6. FEEDBACK FROM ROAD OWNERS

In October 2007, after contract had started, the views and opinions of the personnel responsible for maintenance contract procurement in Lapland Road Region were mapped using a short written interview form. The summary of these results are presented in the following paragraphs.

In general, this performance based drainage maintenance was thought to be a "right step in the right direction". The Road Region now defines the target value and trigger values for drainage class and the contractor is responsible for a well working drainage system. This reduces the drainage improvement programming work for Road Regions. In the change phase it takes 2-3 years for a contractor to raise the drainage to the optimum standard and after that the main duty is to keep it at that level.

An opinion regarding the results of drainage analysis was also asked and, according to the answers, the analysis results were partly surprising, partly expected. Especially on gravel roads the results were as expected.

The main concern towards the contractor was if they had understood the task correctly and evaluated all the measures needed. In the future, the definition for certain critical drainage class values in the field might cause some discussion. In the Road Region the local Road Master is a key person to follow up the work of the contractor. Guarantee times and sanctions were thought to be in at a correct level and they will ensure the good work of the contractor.

The greatest benefits for this new system on paved roads will be that the paving intervals will be markedly increased because the critical sections triggering the paving need for the road will now have much better care. On gravel roads the amount of spring thaw weakening problems will be most likely substantially reduced.

The main risk in moving towards performance based drainage maintenance is the costs for this work during first two three years. Some concerns were also expressed whether the contractor will select the right machinery for this work and not break the pavement.

8. SUMMARY AND RECOMMENDATIONS

In pavement management systems, the lifetime of the road is normally ruled by the lifetime of the 10 % worst rutting, IRI or pavement distress in road sections which can trigger the need for a new paving project. One characteristic that is common to all of these sections in the Northern Periphery area is that their drainage is mainly in very poor condition. By improving the drainage it is possible to substantially increase the lifetime of paved roads. The same policy can also be applied to gravel roads.

This report tries to describe and summarise the process and the actions that are needed in order to better manage the drainage of paved and gravel roads in the Northern Periphery area. It provides information about the survey technology used to map and classify drainage condition, how to analyse the data and, when considering pavement lifetime, how to locate critical places in the road network. Finally this report presents a case where this information is being used in the maintenance contract procurement process.

Poor drainage has a clear effect in increasing rutting values. On local roads the rutting values were 2.3 times higher in poor quality class 3 sections compared with class 1 sections. Surprisingly this effect was also quite big on main roads which tell that this policy should not only be applied on low volume roads but on the entire road network. A great part of the rutting on main roads can be related to frost heave and thaw settlement during spring thaw weakening, for instance on main road 4 in the Rovaniemi area, where road structures are normally 1,2 m thick, frost heave on silty subgrade soils is 190 mm if the drainage is poor but will be reduced to 110 mm when the same soil is well drained.

In addition to rutting, poor drainage also caused increased roughness values in the road network. This effect seemed to be especially strong on roads that were located on morainic formations with frost susceptible glacial till subgrade. An increased amount of different pavement distress problems, especially shoulder deformation, longitudinal cracking and shoulder cracking could be found in road sections with poor drainage.

When comparing rutting in different road profiles, main roads and regional roads had higher rut values only in road cuts. But on local low volume roads the rutting was higher on other road profiles than embankments.

The cost benefits calculations demonstrated a great potential for savings in the annual pavements costs of the Rovaniemi area: more than 330.000 € each year. This amount of money could be used first to improve and maintain the drainage of the Rovaniemi road network in good condition and the investments would still be profitable. Making a general assumption, that the drainage class distribution of the paved road network in the whole of Finland is the same, it can be roughly estimated that 30 – 40 M€ in savings for the entire Finnish paved road network if more focus were placed on maintaining a good drainage system. This is even greater than the annual paving budget of many road regions.

The results can be directly applied to other NP areas. Figure 51 shows the comparison of rut depth averages and ratios between the Rovaniemi area and the Skellefteå area in Sweden where a similar pilot project was carried out in summer 2006. The Skellefteå roads were mainly in the same category as connecting roads in Rovaniemi and the figure shows that the rut depth ratios in each drainage class are on the same level as in Rovaniemi, even though the absolute rutting level was smaller in Skellefteå. These ratios are also on the same level as those calculated in the Troms area in the Roadex II project (Berntsen and Saarenketo 2005).

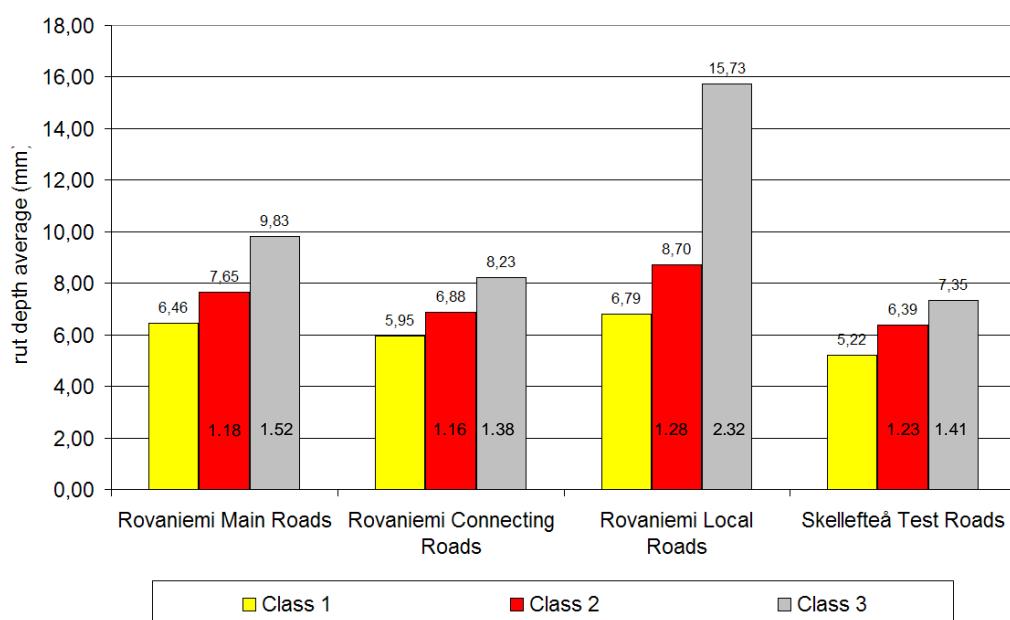


Figure 51. Comparisons of average rut depths in each road class in Rovaniemi are with corresponding figures collected from Skellefteå area in Sweden. Skellefteå test roads were on the same standard as connecting (regional) roads in Finland.

The results of this report also showed that poor drainage can be related to special problems on gravel roads. In the Rovaniemi maintenance area those sections with the poorest drainage conditions also had the highest amount of spring thaw weakening problems. For instance frost heave calculations showed that on gravel roads on frost susceptible soils, in the Rovaniemi area, with 300 mm thick structures frost heave would be reduced from roughly 360 mm down to 200 mm if the drainage were improved. Poor drainage is not just causing problems in frost areas. In warmer climate zones, poor drainage of gravel roads also decreases the stiffness in the lower part of the road structures and on the top part of the subgrade and thus makes them susceptible to permanent deformation and mode 2 rutting problems.

Even though it is generally known that poor drainage causes many kinds of problems on roads and reduces their asset value, the issue of better and more precise drainage maintenance has mainly been ignored. One reason is that there has not been any descriptions of how to classify the drainage and how to locate the problems spots. One example, used successfully in this pilot project, is presented in figure 52. Following this procedure it is possible to locate problem sections and define special maintenance standards for them. These standards should be made in such a way that drainage in these sections will always be kept in good condition even though it would require some measures on these sites every year.

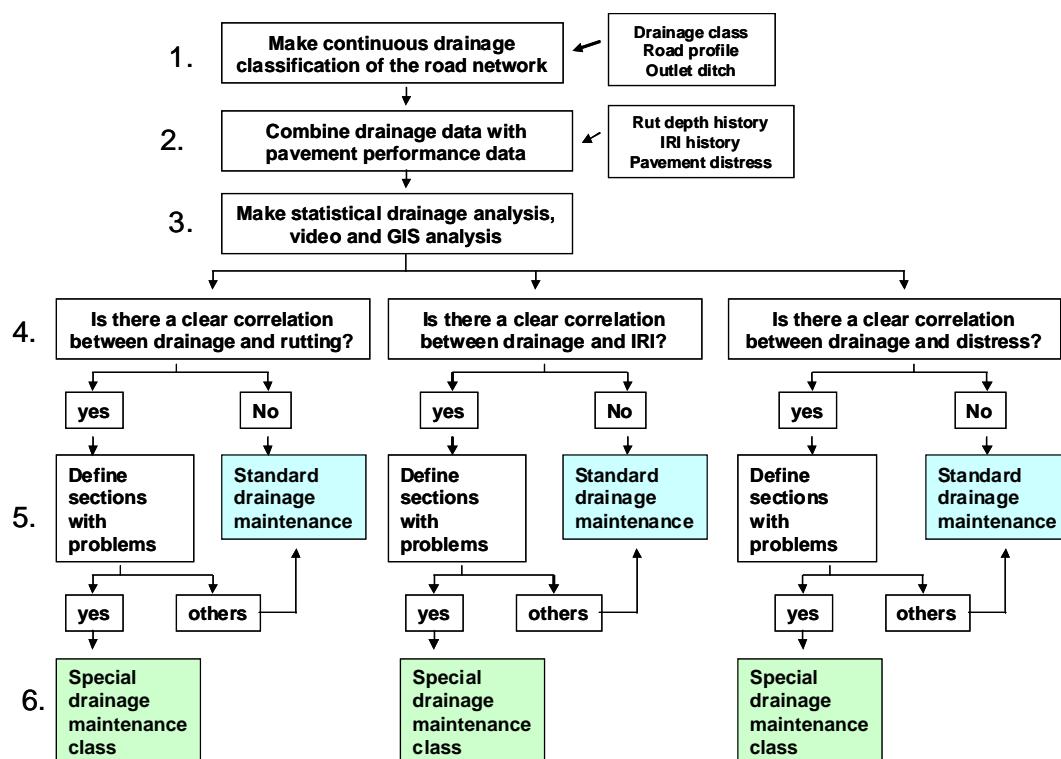


Figure 52. Process for defining special drainage classes for maintenance contracts on paved roads

Even though there have not yet been enough experiences concerning drainage standards in maintenance contracts some preliminary suggestions can still be made. Those sections within the special drainage maintenance class should always be kept in class 1 and when class 2 problems are detected they should be fixed in the same year. On other road sections, class 3 drainage should only be allowed on embankment sections and only a small amount of drainage class 2 should be allowed in road cuts and on upper ditches of roads located on sloping ground. In general, on paved roads, the amount of class 2 drainage should never be higher than 20 % and class 3 drainage not higher than 1 % in each road section.

On gravel roads the first goal should be that there should not be class 3 drainage on more than 10 % and the amount of class 2 drainage should not be higher than 50 %. In the next phase these figures should be improved so that class 3 drainage should not be allowed at all and the maximum allowed amount of class 2 drainage should be 20 %.

A special problem in the implementation of better drainage policies in road regions can be related to road region organisations and how routine maintenance and paving and rehabilitations projects are handled in them. In most cases road regions have different divisions for routine maintenance and for paving and rehabilitation project and these works are also carried out in the field by different contractors. With that background a common question is why should maintenance division and contractors have hard times with the drainage when the paving division and contractors will get the benefits. Also it is claimed that the drainage survey and analysis cost too much in the maintenance procurement process. But this process should be viewed from the point of the whole road regions and it should be asked why cannot we invest to a single survey that cost 40 – 50.000 € when the results make possible for annual savings will be 300.000 € for the region.

In the future the paving contracts will also be moving towards long term performance based requirements. In this game a poor maintenance contractor can ruin the good work of a paving contractor by ignoring good drainage maintenance. If this dilemma is not solved it will become a major issue in the future when and if sanctions are imposed upon paving contractors. That is why good and clear rules should be made regarding the standards and responsibilities in drainage maintenance. Finally, the maintenance contractor, that is responsible for the work should not only be punished for bad work but they should also be rewarded when they are doing good work which will be to the economic benefit of everyone. Good drainage maintenance is also a big step towards environmentally sustainable road condition management because it saves in the use of non-renewable resources like bitumen.

Finally, road regions should not rely solely on the maintenance contractors to take care of drainage problems. Regions should also spare some money for the more expensive and longer lasting improvements of the drainage problems spots. These structures are so expensive that the payback time is longer than the maintenance period, so contractors will not make them if they are not subsidised by road regions. Figure 53 presents some good examples from Sweden about slope protections that will have a long term effect on drainage improvement.



Figure 53. Examples for slope protection used in the drainage improvements in the Northern Region in Sweden .

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