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DRAINAGE MAINTENANCE FOLLOW UP – EXPERIENCES FROM THE ROVANIEMI AND KITTILÄ PROJECTS, FINLAND

ABSTRACT

Research results from the ROADEX project have shown that the good management of drainage can substantially increase the life time of paved roads and thus reduce roads management costs. ROADEX also developed a drainage analysis method that helps to identify critical drainage sections that need improvement. Once these sections have been identified and improved they can be classified as special drainage sections for the drainage maintenance contractor to keep in good condition.

Drainage analysis has been used for a number of years in Finnish Lapland. The ROADEX drainage demonstration project in the Rovaniemi and Kittilä maintenance areas comprised a monitoring survey that aimed to answer three questions: 1) How well had the contractors succeeded in their task of maintaining the special drainage sections in faultless condition? 2) If drainage deficiencies were continuing what were the reasons for them? 3) Had the improved maintenance really increased the pavement life time in the roads concerned?

The survey was carried out on selected road sections in the Rovaniemi and Kittilä maintenance areas during springs 2010 and 2011. The follow up sections were supervised visually and also surveyed with a laser scanner. Special surveys were additionally carried out on road 934 close to Rovaniemi using ground penetrating radar and a high precision laser scanner.

The results from the Rovaniemi special drainage class sections, using strict criteria, showed that, after 3 years, the drainage was in good condition in 41 % of the special drainage maintenance class sections. Minor drainage deficiencies were detected in 57 % of the total length of the follow up sections, but Class “poor” could only be found in 2 % (154 m) of the follow up sections. In the Kittilä maintenance area only 35 % of the total length of the follow up sections was found to have “good” drainage class. 40 % of the sections had adequate drainage condition and 25 % were classified as poor. The reason for this was that a substantial proportion of the roads were located on peat land areas where drainage was not able to be improved with the given resources. The only suitable solution for these problematic sections might be the lifting of the road profile.

The identified drainage deficiencies have not yet however affected the condition of the roads. The study results show that roughness and rutting values have risen in 5 – 25 % of the total length of the monitored sections of the Rovaniemi maintenance area. In the Kittilä area anomalous roughness and rutting values were detected on 20 – 40 % of the follow up sections. These proportions will get higher in future years if the deficiencies in the drainage are not repaired.

The frost heave surveys using the laser scanner technique on road 934 gave some surprising results especially on the role that private road accesses play in the main road defect process. The results showed that frozen, clogged or missing private road access culverts are causing frost heaves and damages to the main road and this can be seen on the road a long way before and after a private access. Frost heave problems were found in 54 % of the total number of private road accesses on section 3 of road 934, and on section 4 the amount was 36 %. The problem is that private road access culverts are usually poorly installed and their maintenance is not included in normal maintenance contracts management tasks in Finland. Another problem was that ditch bottom levels were too high compared to the bottom level of pavement structures.

These ROADEX drainage maintenance follow up results show that repairing the drainage has been successful in 75 – 79 % of the special drainage maintenance class sections in the Rovaniemi maintenance area and in Kittilä area 20 – 40 % of the sections. This is a good result, when it is remembered that these follow up sections were the most critical sections for the condition of the roads. The analyses and follow up techniques should be developed in the future.

KEYWORDS

Drainage, rutting, roughness, laser scanner, frost heave, sheet ice, ditch slope

PREFACE

This task "*Drainage maintenance follow up – Experiences from Rovaniemi and Kittilä projects*" was carried out in the ROADEX IV Work Package 3, "Local Demonstrations". The goals were to follow up the drainage maintenance procedures in Rovaniemi and Kittilä maintenance contracts and assess their influence on the condition of the roads surveyed.

The field measurements were carried out during 2010 - 2011 in Rovaniemi and Kittilä maintenance areas. Seppo Tuisku, Juuso Pääkkö, Jani Irvankoski and Anne Peltoniemi-Taivalkoski carried out the measurements during these years. The measurement data was handled by Seppo Tuisku and Anne Peltoniemi-Taivalkoski. This report was jointly written by Anne Peltoniemi-Taivalkoski and Timo Saarenketo. Timo Saarenketo steered the demonstration project as lead manager of the D1 "Drainage Maintenance Guidelines" group. The software specialists were Timo Saarenpää, Jani Irvankoski and Pekka Maijala. Ron Munro checked the language.

Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout. Authors would like to thank ROADEX IV steering Committee for its encouragement and valuable guidance in this work.

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CONTENTS

1. INTRODUCTION

The ROADEX II, ROADEX III and ROADEX IV projects have carried out a range of studies on the effect of poor road drainage on the pavement lifetime since 2005. These have shown that poor drainage can expose road structures to fast deformation and frost action. Calculations have shown that if the sections with poor drainage could be repaired, and the drainage kept in good condition, the lifetime of the road could be extended to 1.5 - 2 times longer. The main conclusion of these studies has been that if the repair and management of drainage is possible to be carried out economically, significant savings in the management of paved road systems can result (Berntsen and Saarenketo 2005, Saarenketo 2007, 2008, 2009).

This study was part of the “Local Drainage Demonstration Projects” of the ROADEX IV project and was done in co-operation with Roadscanners Oy and ELY-center of Lapland. The main goal in the work was to study the effect of drainage maintenance procedures on road condition on special drainage class maintenance sections on selected roads in Rovaniemi and Kittilä maintenance contract areas. The practical goal was to find out if the contractors had been successful in improving the drainage condition and after that keeping it in good condition, and what were the reasons for any identifiable drainage deficiencies. An addition aim was to find out if the deterioration rate had really decreased as a result of better drainage maintenance. Finally the ROADEX drainage analysis process was evaluated to confirm if it could indeed detect problem drainage sections in the long term.

ROADEX drainage analyses have already been done In Finnish Lapland in Rovaniemi, Kittilä, Kemi, Kemijärvi-Posio, Ranua and Sodankylä maintenance areas. As results of these analyses the most critical sections for drainage and road condition have been defined and scheduled for repair. The drainage maintenance contractor will then be responsible for keeping the sections in good condition for the duration of the contract.

The Rovaniemi maintenance area in Finland was first selected as a ROADEX pilot area as the procurement documents for the new maintenance contract 2007 – 2012 had been prepared based on the results of the ROADEX III project (Saarenketo, 2007) and because there was good historical information available from the from the first drainage condition analyses carried out in 2005. The Kittilä drainage maintenance contract started later and the first drainage condition analyses were made in 2007.

Drainage condition analyses were carried out on roads 78, 926 and 934 in the Rovaniemi maintenance contract area. In the Kittilä maintenance area, the monitored special drainage maintenance class sections were on highway 21 and on roads 80 and 93. The first visual monitoring survey was done in early spring, when the snow was starting to melt. The aim of this survey was to check the locations of frozen culverts and the places where sheet ice occurred. The second visual survey was made after the snow had totally thawed. This used the standard ROADEX drainage analysis technique. Videos were also recorded to check and correct any errors in the office. Laser scanner surveys were done later on in early summer before the growth of vegetation impeded the measurements. The data collected in these surveys was used to assess the effect of access roads on the condition of the main road, to measure the depths of the side ditches, and to determine if soil was flowing on the ditch slopes. Ground penetrating radar measurements were done on road 934 in the Rovaniemi maintenance contract area. This road was also surveyed using Geovap Quantum 3D high precision laser scanning to measure any frost heave.

This report summaries the findings of the drainage condition monitoring data in Rovaniemi and Kittilä maintenance contract areas in years 2010 – 2011. More detailed results are presented in the reports “*Erikoiskuivatuskohteiden kuntoseuranta Rovaniemen ja Kittilän hoitoalueilla – Väliraportti 2010 testeistä*” (Saarenketo, 2010), “*Erikoiskuivatuskohteiden kuntoseuranta Rovaniemen hoitoalueella. Loppuraportti 2010 – 2011 testeistä*” (Peltoniemi-Taivalkoski and Saarenketo, 2012) and ”*Erikoiskuivatuskohteiden kuntoseuranta Kittilän hoitoalueella. Loppuraportti 2010 – 2011 testeistä*” (Peltoniemi-Taivalkoski and Saarenketo, 2012).

2. DRAINAGE MONITORING IN ROVANIEMI AND KITTILÄ CONTRACT AREAS

Three roads were selected for drainage analyses in the Rovaniemi maintenance area: rd 78 (Pudasjärvi – Rovaniemi), rd 926 (Kemi – Rovaniemi) and rd 934 (Saarenkylä – Meltaus). All the special drainage maintenance class sections were monitored and the total length of the sections surveyed was 9,650 m. The proportion of special maintenance class sections on each road sections is shown in Table 2.1. The special drainage maintenance class sections were sited on six different sections (Figure 2.1).

Table 2.1. Proportion of special drainage maintenance class on the surveyed roads and road sections in the Rovaniemi maintenance area.

Road	Section	Special maintenance class (%)
934	3	16.0
934	4	10.2
78	219	9.5
78	222	6.0
926	17	13.8
926	19	7.9

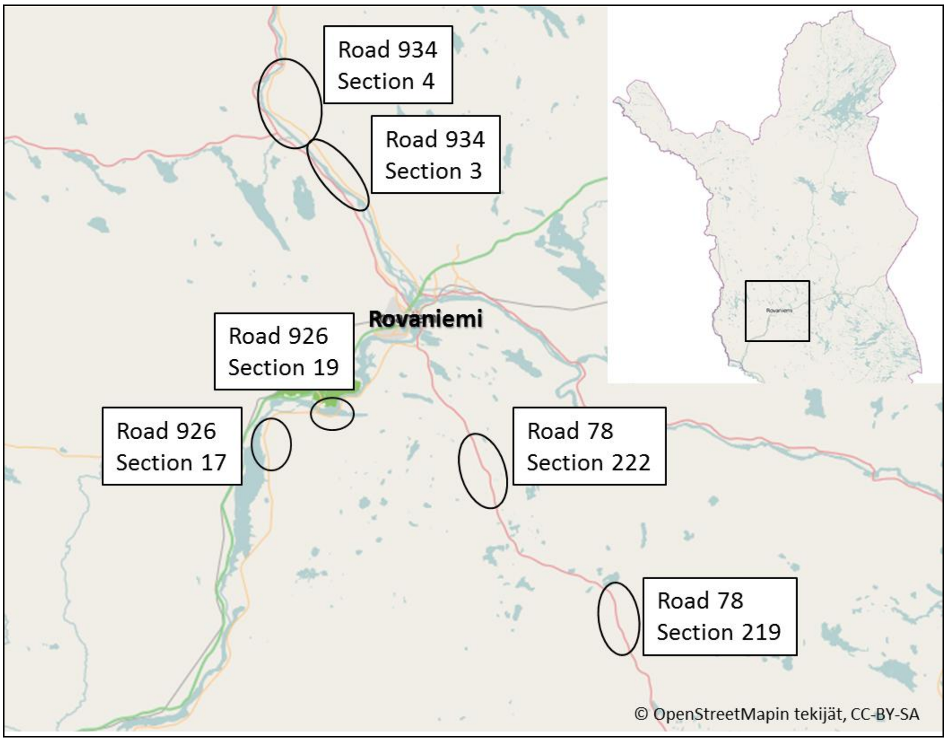

Figure 2.1. The surveyed roads and road sections in the Rovaniemi maintenance area.

The total length of road sections analysed in the Kittilä maintenance area was 29,766 m. Not all of the special drainage maintenance class sections were monitored and analysed. Twelve sections in total were selected from highway 21 (Tornio – Kilpisjärvi), from road 80 (Palojoensuu - border of Norway) and from road 93 (Kittilä – Sodankylä). The proportion of the special follow up sections is shown in Table 2.2. On highway 21, the road sections with special drainage maintenance class sections were located over 100 km of the road. The general environment on road sections 216 and 220 differ greatly from the other sections. Section 216 is located mainly on peat and section 220 is located on side sloping ground on two fells. Section 216 was included in the study as a reference section and it did not have any follow up sections. Figure 2.2 shows the location of the drainage follow up sections in the Kittilä maintenance area.

Table 2.2. Proportion of special follow up sections on the measured road and road sections in the Kittilä maintenance area.

Road	Section	Special follow up sections (%)
80	10	14.7
80	11	40.1
80	12	54.0
93	3	7.7
21	151	7.0
21	152	2.2
21	153	4.6
21	205	28.1
21	207	8.9
21	208	21.5
21	209	5.2
21	220	31.3

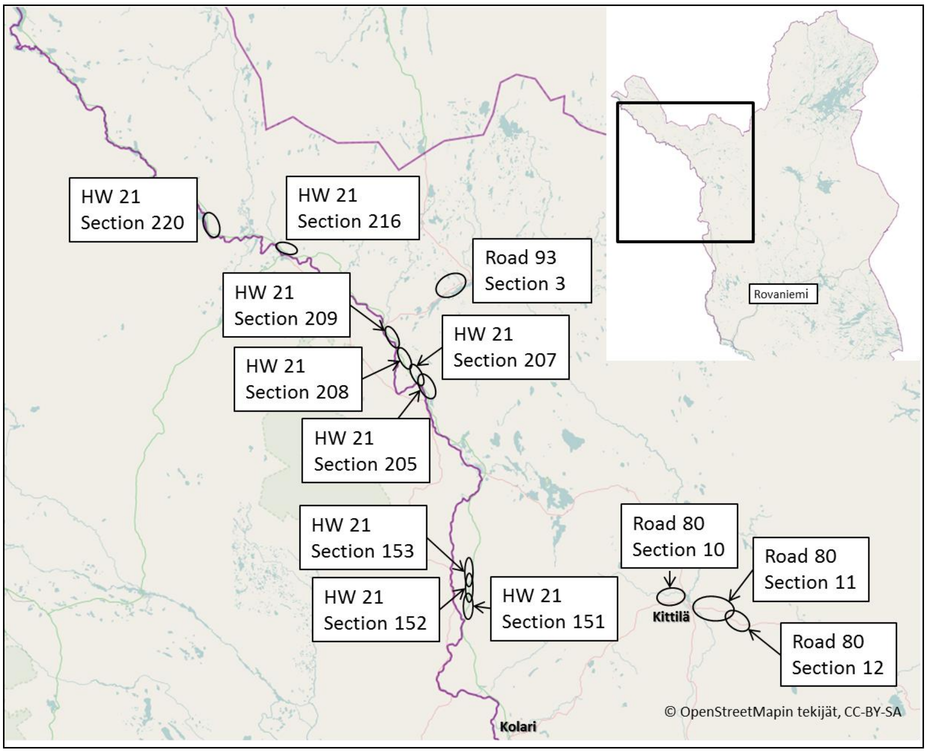

Figure 2.2. The surveyed roads and road sections at Kittilä maintenance area in Finnish Lapland, Northern Finland.

The difference between the Rovaniemi and Kittilä maintenance areas was that the drainage had been repaired in every special drainage maintenance class section in the Rovaniemi maintenance contract before the contractors won the contracts. On the other hand the special drainage maintenance class sections in Kittilä maintenance area were repaired during the contract. The drainage analysis made in 2011 was the first comparable survey after the drainage had been improved.

In some cases, for example in road 80 sections 11 and 12, it was not possible to improve the drainage condition because the road was located on flat peat land. Also, the surveys on road 93 identified palsa mires with thawing permafrost that were causing settlements and in this case improving the drainage would have enhanced the thawing of the palsas.

3. SURVEY AND ANALYSIS TECHNIQUES

The following survey techniques were used at different times in the Rovaniemi and Kittilä maintenance contract areas during the project.

In the spring when the snow had started to melt the first thing was to check the road sections that were to be followed up. The aim was to identify any problems that had been caused by sheet ice and record any frozen culverts. All of the problems observed were documented by a digital camera.

After this first control survey, and when the snow had melted, a visual drainage analysis was made on the surveyed sections. If the follow up sections were on both sides of the road, both sides were analysed separately. One video camera was used to record the condition of the side ditches and the outlet ditches, and the other video camera recorded the road. A "Road Doctor CamLink" video-logging system was installed on the car roof and the videos were recorded on to a laptop. The drainage classification was done by recording the analysis through the keyboard of the laptop. Also during the drainage analysis audio comments were recorded to help interpret and correct any erroneous keyboard entries later. An INCA 2 GPS device was used for GPS positioning. All of the collected data was linked with GPS coordinates to Road Doctor projects in the office.

Drainage conditions were classified into three different classes according to the ROADEX proposal (Saarenketo 2007): good (Class 1), adequate (Class 2) and poor (Class 3). In Class 1, the drainage is defined as faultless and water has a clear passage in the ditches (Figure 3.1). In Class 2, the vegetation prevents water flow from the pavement to the ditch and it also creates dams in the ditches. The soil slipping from the road slopes raises the bottom of the ditch (Figure 3.2). In Class 3, the road shoulders may have high verges or the dense vegetation can cause ponding on the road. Vegetation and unstable soil restrains water flow in ditches (Figure 3.3). All the problem cases lead to the development of deformation and damages in the road profile.

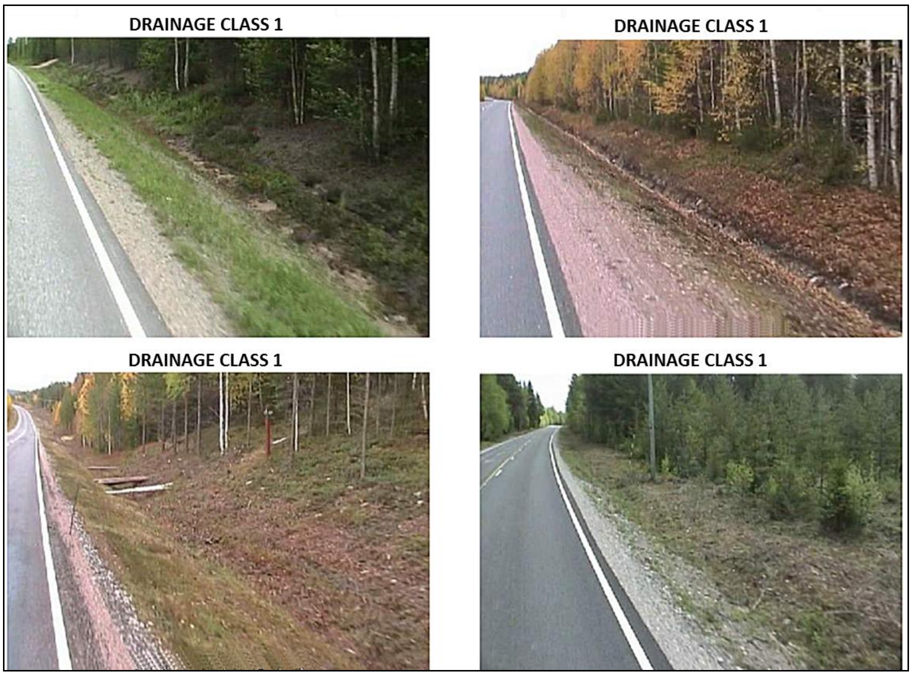

Figure 3.1. Examples of ditches with drainage Class 1.

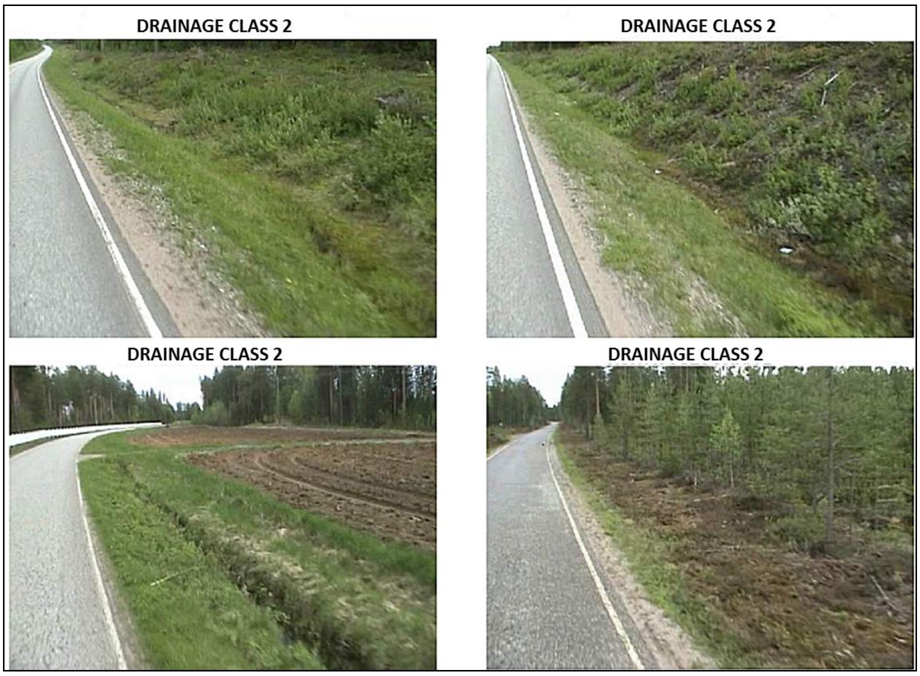

Figure 3.2. Examples of ditches with drainage Class 2.

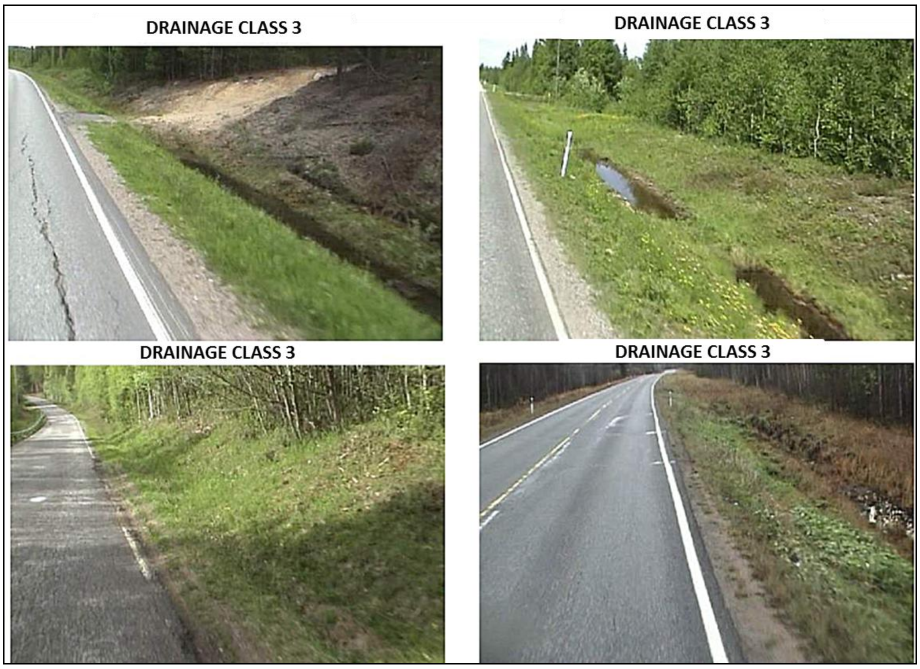

Figure 3.3. Examples of ditches with drainage Class 3.

The surveyed sections were measured with a laser scanner at the beginning of June before vegetation obscured the ditches, (Figure 3.4). Laser scanner techniques are described in report "*New survey techniques in drainage evaluation – Laser scanner and thermal camera*", (Matintupa, Saarenketo 2011). The data collected with laser scanner was linked to the respective Road Doctor project with GPS coordinates.

A special survey was carried out on road 934 in Rovaniemi using a Quantum 3D laser scanner from Czech GEOVAP Ltd . The absolute height of the road was measured two times: first in late April when the frost heave was at its maximum level, and second in June when the frost was almost gone. The accuracy of the system allows the measurement of frost heaves to an accuracy of 2- 4 cm from the whole road surface (Figure 3.5).

In addition to the laser scanner surveys, ground penetrating radar (GPR) measurements were also done in order to be able to compare the ditch bottom depth level with the level of the bottom of the road structure (Figure 3.4). According to guidelines, the ditch bottom depth should be always 20-30 cm deeper than the bottom of the road structure. Matintupa and Saarenketo (2011) have described the GPR techniques in more detail.

The profilometer data used in the analysis of this study was provided by ELY-center of Lapland. The latest survey data available for each road and section was used in the analysis. In most cases the latest profilometer data was from summer 2011, but in some cases from summer 2010. The method is described in report the "Palvelutasomittaus (PTM) tien rakenteen parantamisen suunnitelussa" (Onninen, 2001).

Figure 3.4. The survey van equipped with laser scanner at the back (high above the roof) and a 400 MHz ground coupled antenna at the front of the van. The orange box on the front of the roof is the CamLink video-logging system.

Figure 3.5. The Quantum 3D laser scanner survey vehicle of GEOVAP Ltd measuring road 934 in April 2011.

4. RESULTS

4.1. GENERAL

The results of the drainage monitoring surveys are presented in this report in the order they were carried out: first, the drainage follow up monitoring survey recording the problems that can be detected in early spring when the snow starts to melt, and second, the drainage deficiencies in late spring early summer. In addition a short description of each road being surveyed is made. Many special new techniques were also used in the surveys of road 934 in the Rovaniemi area to support the drainage monitoring, and key results of these surveys are also presented in the report.

4.2. DRAINAGE PROBLEMS IN EARLY SPRING

Drainage monitoring in early spring immediately after the snow has started to melt has proven to be an excellent time to survey as it is possible to see many types of drainage problems that cause pavement damages that cannot be verified if the site visit is later. The first, and maybe the most important observation in the monitoring surveys, was the number of frozen and clogged private access road culverts that were causing flooding of the side ditches. These frozen culverts block the water flow in the ditches causing the water to flow over the private road on to the main road (Figures 42_1 and 42_2). Later it was found out that this flooding water was infiltrating into the cold and frozen road structures where ice lenses were created causing differential frost heave.

Another drainage issue that was found to cause problems to the condition of the main road was sheet ice (Figure 42_3) from shallow ground water slowly flowing to a ditch and freezing. If this sheet ice was not removed from the ditch it caused a higher water table in the ditch that infiltrated into the road structures during spring, with further consequential road failures.

A third drainage problem found during early spring was side ditches that flooded due to frozen main road culverts or clogged outlet ditches. These flooding ditches caused shoulder deformation and differential frost heave (Figures 42_4, 42_5)

A final problem category that was found in many places was bus stop and rest areas where snow was stored on the ditch. This stored and compacted snow blocked the water flow in the ditch causing it to infiltrate to the adjacent main road structures (Figure 42_6).

Figure 42_1. An example of a clogged private access road culvert from road 934, section 3, right ditch. Photographs are taken in spring 2010 (left) and in spring 2011 (right). The private road access culvert (chainage 1700 m) was frozen in both years and water was flooding into the ditch and flowing to the road.

Figure 42_2. An example from road 78, section 219, left ditch, from spring 2011. At chainage 8030m the private road access blocks the water flow and creates a pond in the ditch causing water to infiltrate into the road structure.

Figure 42_3. Sheet ice on road 926, at the beginning of section 19. The road is on side sloping ground and water is flowing from the slope creating sheet ice. Shoulder deformation, alligator cracking and transfer cracking were observed on this road.

Figure 42_4. An example from road 80, section 11, from chainage 3980 m forward. The side ditch is full of water and there are frost heaves on the road.

Figure 42_5. An example from road 80, section 12, from spring 2011. The left ditch is flooding (chainage 4590 m forward), because the main road culvert (chainage 4960 m) is frozen and stopping the flow of water from the left ditch to the outlet ditch.

Figure 42_6. An example from highway 21, section 151, chainage 2000m. Melting snow behind the rest area keeps the ditch wet and prevents the flow of water. This has caused damages to the rest area and to the main road.

4.3. DRAINAGE CONDITION CLASSIFICATION IN LATE SPRING

4.3.1. General, analysis technique

The drainage analyses of the special drainage maintenance class sections made in late spring used a more critical scale for its drainage classification. The reason for this was to try to identify any early drainage problems and analyse the differences between sections. The new classification used a tighter scale for drainage class. The general instructions on how to estimate drainage condition were however still followed.

During the monitoring survey it was noticed that if the drainage was classified as "adequate" or "poor", the condition of the ditch may not have affected the road condition. In order to overcome this, and because visual analysis is objective, it was decided to compare roughness and rutting values to drainage problems in the ditches. This was done by identifying the locations of anomalous roughness and rutting values, which were clearly higher than the average level, and checking at that point the condition of the ditch. If problems were observed in that section in the ditch, the problem was marked. But if there were no visual problem in the side ditch, the reason for causing the growth of roughness or rutting values was marked "unknown". The location of high IRI values caused by a main road culvert that was not clogged was not noted. Altogether nine different categories were used in the revised classification.

One problem that arose in the profilometer data analysis was that all the data was collected from the right lane in Direction 1, and many of the special drainage maintenance class sections were located on the left side of the roads. So in these cases the possible effect of poor drainage on road condition would have been seen only if the profilometer data had been measured also from the left lane in Direction 2. Appendix 1 shows an example from highway 21, section 205 how this inventory was done.

4.3.2. Rovaniemi

Figure 432_1 shows the drainage analysis results of the condition of the special drainage maintenance class sections in Rovaniemi maintenance contract area. The Figure shows that in the Rovaniemi maintenance area the special drainage maintenance class sections were mainly (56.8 %) in adequate condition (Class 2) in 2011 and the relative proportion of the ditches that were in good condition (Class 1) was 41 %. Poor condition ditches (Class 3) were observed on less than 2 % of the roads surveyed, which was only about 150 m in length. When individual roads were compared, the biggest share of the drainage Class 3 could be found on road section 222 of road 78, where the percentage of poor condition was 7.2 %. The best condition was road 934, from section 3 on, where 61.5 % of the follow up sections were classified to be in good condition. Outlet ditches in the special drainage maintenance class sections were for the most part in good condition. In some single cases vegetation growing in the outlet ditches was slowing down the flow of water and making them flood.

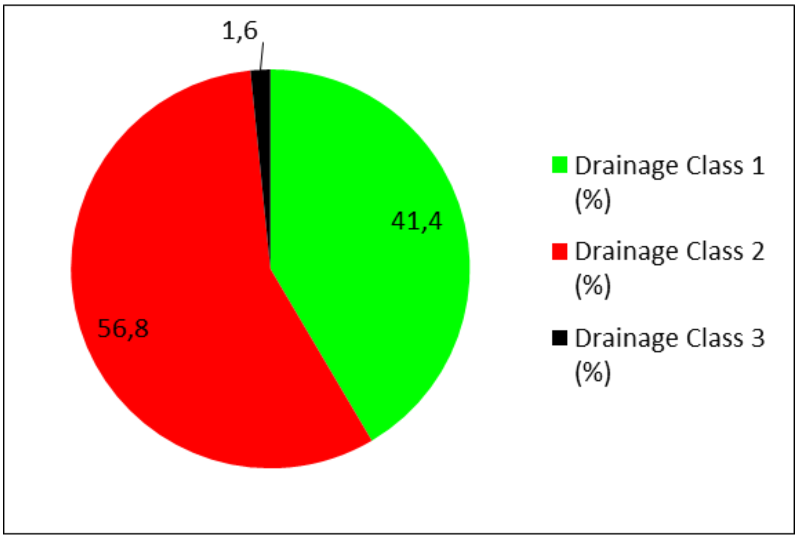

Figure 432_1. Distribution of the drainage classes in the special drainage maintenance class sections in the Rovaniemi maintenance area in 2011.

When comparing the rutting and roughness values to the condition of the side ditches, the results showed that 84 – 95 % of the special drainage maintenance class sections were in good condition in the Rovaniemi maintenance contract area (Figure 432_2). That means that neither rutting nor roughness values had risen. Most of the special drainage maintenance class sections on road 78 were on the left side of the road and 95 % of the total length of the special drainage maintenance class sections was in good condition. On the road 926 over three quarters of the special drainage maintenance class sections were in good condition. Three of four special drainage maintenance class sections were on the left ditch on section 17 of road 926. On road 934 almost all the ditches were repaired during 2010-2011 and over 80 % of the special drainage maintenance class sections were in good condition.

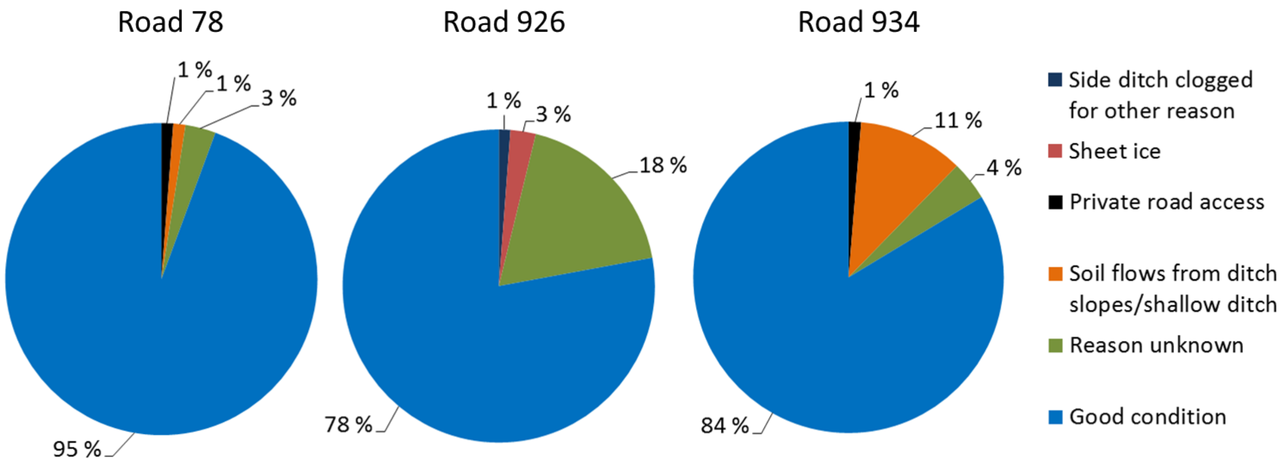

Figure 432_2. Reasons for the higher rutting or roughness values on roads 78, 926 and 934 in the special drainage maintenance class sections in Rovaniemi.

Road 78

All of the special drainage maintenance class sections on road 78 were repaired. One of the sections was initially forgotten, but this was fixed later. Vegetation and soil flows from ditch slopes were slowing down water flow in the ditches and the condition of the drainage was brought down to Class 2. The proportion of drainage Class 2 was 65 % on section 219, and 64 % on section 222. The drainage condition was dropped down to Class 3 in cases where the bottom of the ditch was clogged up with vegetation and was causing ponding. Class 3 drainage could be found on less than 4 % in section 219, but on section 222 the amount of drainage Class 3 was almost twice that, at over 7 %.

When the rutting and roughness values higher than average were compared to the problems in drainage on road 78, it was noticed that not all of the problems observed in the drainage could be seen in a rise in rutting or roughness values. This may result from the fact that these values were measured on the right lane and the special drainage maintenance class sections were in most of the cases on the left side of road 78. The same problem was found in ROADEX drainage tests in Scotland and Norway. Another reason could be that road structures in road 78 were quite thick. Figure 432_3 provides an example of the effect of a missing private access road culvert can have on road failures. In this case the problem can be seen also on the profilometer data measured on the other lane.

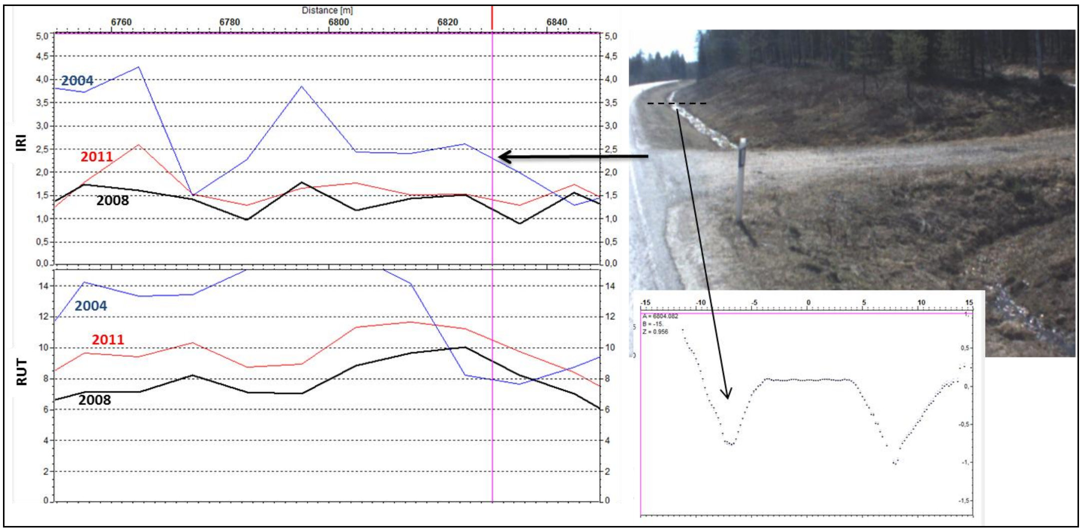

Figure 432_3. Example from road 78, section 219. The culvert is missing under the private road access (chainage 6830 m) and water is ponding in the left ditch. Moss in the left ditch is also

preventing the water flow. The rutting values (second frame on the left) show that at this point the values from 2011 are just slightly higher than the average values. This may result from the fact that the values have been measured from the right lane. The profilometer results from 2004 show that the values have been high at this same point earlier. The roughness values are still low. The cross section from chainage 6805 m (on the lower right) shows that the bottom level of the left ditch is only about 70 cm deeper than the road profile.

Road 926

Almost 40 % of the length of the special drainage maintenance class sections in road 926 was in good condition. However even though most of the ditches were in good condition, they were full of water. This indicates that the longitudinal gradient in the ditches was insufficient (Figure 432_4) or that the outlet ditch was clogged by vegetation. On section 19 most of the special drainage maintenance class sections (96 %) were classified as drainage Class 2 because soil was flowing from the ditch slopes, causing the ditches to be too shallow.

Special problems were caused by the tree trunks that were piled on the side ditches on both sections of the road 926 in spring 2011. When the anomalous rutting and roughness values were compared with the drainage problems seen in ditches, it was noticed that there was slight growth in IRI and rutting values at the same point as the woodpiles. Even though these piles were not in the same places for a long time, but because they were clogging up the ditches in early spring, when the structure of the road was still frozen, it is possible that water had risen up and absorbed into road structure. Sheet ice could be also detected at the beginning of section 19, but at that point the shallow right ditch could have caused the slightly higher rutting values. A clear visual reason could not be found for 20 % of high rutting and roughness values, and in these causes the reason might be that the ditches were too shallow. It is possible that in this road section the thickness of road structures is also too thin and heavy traffic is the main reason causing the high growth of rutting and roughness values.

Figure 432_4. Ditch in adequate condition. The ditch has water as the longitudinal gradient is not sufficient in the left ditch. An example from road 926, section 17, chainage 5300 m.

Road 934

The special drainage maintenance class sections in the Rovaniemi maintenance area were in the best condition on road 934 even the observed problems were the clearest in that road. The proportion of drainage Class 1 was the highest on section 3, over 60 %. The majority of the problems on this road was caused by soil flowing from the ditch slopes (Figures 432_5 and 432_6), and clogged private road access culverts. The ditch slopes had slipped down after the contractor had repaired the ditches.

The results from road 934 showed that over 10 % of the follow up sections, where the rutting and roughness values were clearly higher than average, had observed soil flows or the bottom of the ditch was too shallow.

Private road access road culverts were causing problems in many places. An example is shown in Figure 432_7.

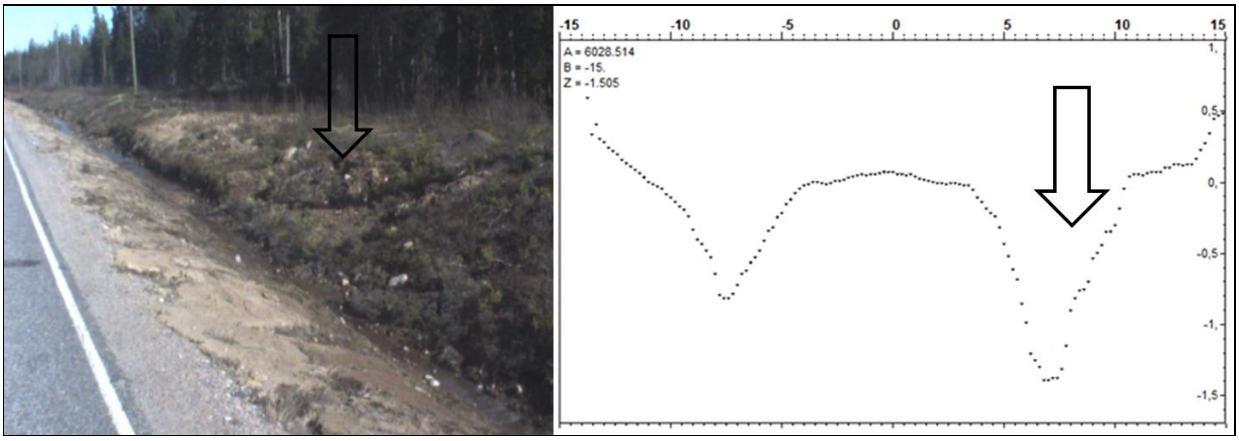

Figure 432_5. Road 934, section 3, 6020 m. Soil flows on the outer slope of the right ditch and is blocking the flow of water downhill. The cross section on the right shows how narrow the bottom of the ditch is.

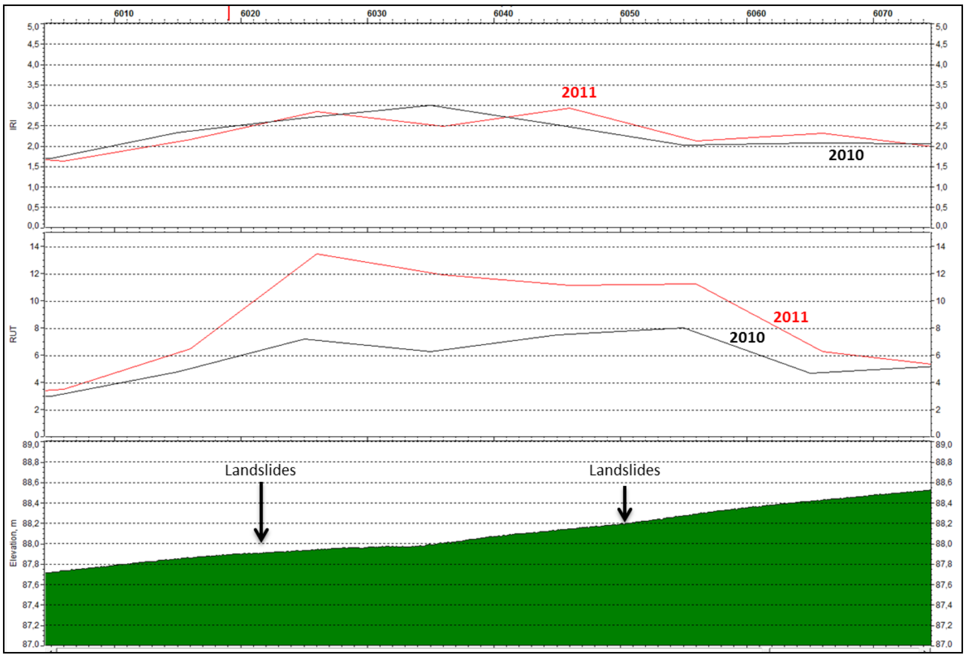

Figure 432_6. Rutting values (in the middle) in 2011 have increased even more than 4 mm/year just above the section where soil flow has filled the ditch, and are 14 mm at the highest. Roughness values (first frame) are rising at this point too. The elevation graph (lowest frame) shows the direction of the water flow in the ditch.

Figure 432_7. Example from road 934, section 3. The private road access culvert (chainage 6290 m) has been poorly installed (and clogged) and is blocking the water flow. The rutting values (second frame on the right) are high at the private road access, and rise even higher further on. Water above the clogged culvert is saturating the soil in the ditch slopes and the high water table is causing the growth of rutting and roughness values. The IRI values are shown in the upper right.

Gravel roads in Rovaniemi maintenance area

A selection of gravel roads were analysed in Rovaniemi maintenance area in spring 2010. The drainage in these analysed roads was mainly in good condition. The results also showed that improving the drainage had reduced frost heaves and further spring thaw weakening problems in these roads. A few serious problems could still however be noticed and one example was from road 19686, where a ditch in silty moraine area had clogged and caused water to soak the road and cause further spring thaw problems (figure 432_8).

Figure 432_8. Clogged side ditch causing road problems and frost heaves on the local road 19686.

Poorly installed or clogged culverts were the biggest reason for the problems in the gravel roads monitored. Figure 432_9 shows examples where flooding water from a clogged access road culvert is saturating the material on the inside ditch slope which then flows and fills the ditch bottom. Melting ice lenses also create a big hole in the road. The Figure also shows an example of poorly installed main road culvert.

Figure 432_9. A clogged private road access culvert has caused the water level in the ditch to rise and soil flow from the inner ditch slope (left). The stick in the road shows the location of a big hole in the road due to melting ice lens (left photograph). The right photograph shows an example of a poorly installed main road culvert. Both examples are from road 19688.

4.3.3. Kittilä

The terrain in the Kittilä maintenance area varies from dry and sandy soils to very wet peat bog areas. Figure 433_1 presents a statistical summary of the drainage analyses of the special drainage maintenance sections in the Kittilä maintenance contract area. The proportion of good drainage Class 1 was only 1/3, and only on highway 21 were there sections where the drainage was entirely in good condition.

The main reason for the poorer results than in the Rovaniemi area can be found on road 80, sections 11 and 12, where the amount of drainage Class 2 and 3 was high as the sections were located in peat areas. Another problem road was road 93, where there were difficulties in repairing the ditches because of permafrost and because of the high amount of flat peat bog areas.

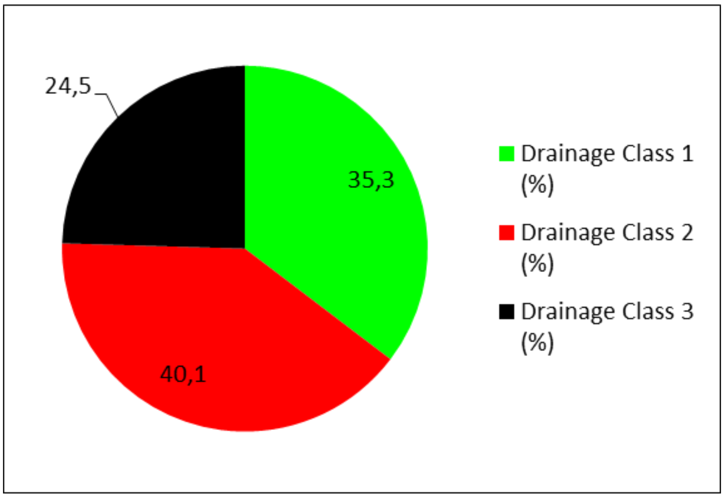

Figure 433_1. Distribution of drainage classes in special drainage maintenance class sections in Kittilä maintenance area in 2011.

When the anomalous roughness and rutting values were compared with the condition of the side ditches, the results showed that on highway 21 over 80 % of the follow up sections were in good condition, but this reduced to about 70 % on road 80, and just 60 % on road 93 were in good condition. The statistical analysis and problem diagnostics from the Kittilä maintenance area special sections are shown in Figure 433_2.

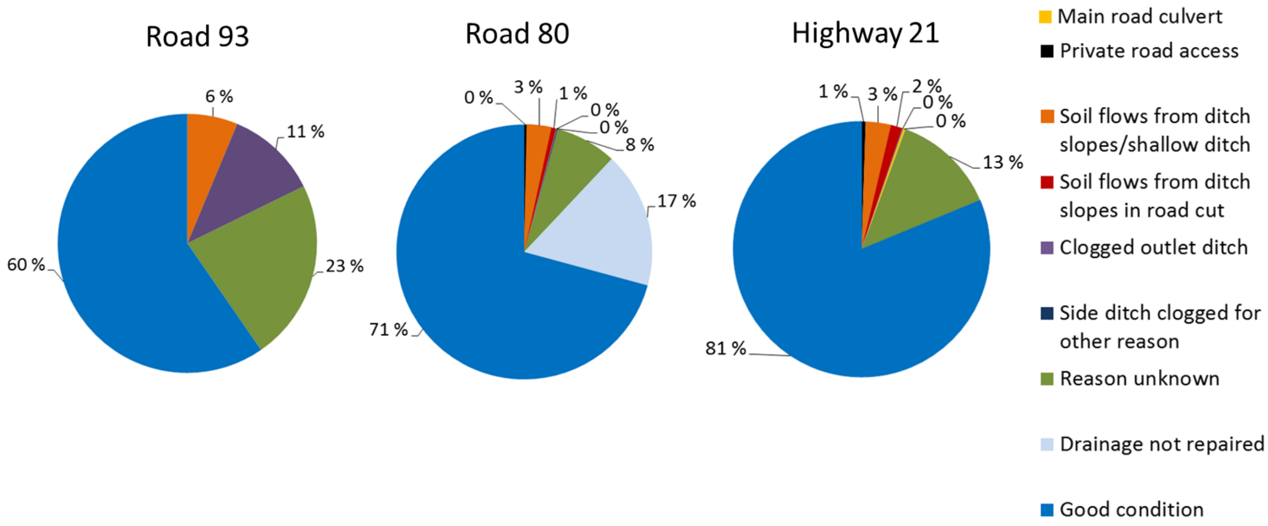

Figure 433_2. Reasons for the anomalous rutting or roughness values on roads 93 and 82 and highway 21 in the special drainage maintenance class sections in 2011, in Kittilä.

In general, as with Rovaniemi maintenance area, the outlet ditches in the special follow up sections in the Kittilä maintenance area were in good condition in most cases.

Road 80

The biggest problem on road 80 was that it is not possible to repair the ditches on the follow up sections on road sections 11 and 12 because they were located on wet bog and clearing the ditches would be too expensive (Figure 433_3). On section 10, most of the ditches on the follow up sections had been repaired, but still the proportion of adequate or drainage Class 2 was almost 80 %. Vegetation and soil flows from ditch slopes were blocking water flow in the ditches and poorly working private road accesses were the reasons for poor results in section 10.

Figure 433_3. Example from road 80, section 11, chainage 2020 m. The cross section (top right) from the right ditch shows that the bottom level of the ditch is only about 50 cm from the road profile and clogged with vegetation, which is preventing water flow. The elevation frame (bottom middle) shows how flat the topography is in the area. The rutting values from 2011 (second graph in the middle) have grown evenly by about 1 mm from the results of 2010. The maximum rutting values are about 10 mm at this point. The IRI values (top middle) are about 2.0 mm at the highest.

Road 93

The main problem on road 93 section 3 was that the road was also partly located on an area of peat bog. The location of a lake close by the road also prevented the repair of the ditches at the first two follow up sections. Deepening the ditches at this point could make the lake water flood into the ditches. Some ditches at the follow up sections were repaired, but vegetation and soil slippages continued to hinder the flow of water and cause problems to the road (Figure 433_4).

In most cases the underlying reasons behind the problems on road 93 could not be determined from the videos or laser scanner data, but it was thought that melting of palsas could be one of the reasons. Clogged outlet ditches, soil flows and shallow ditches were present at the places of anomalous roughness and rutting values (Figure 433_4).

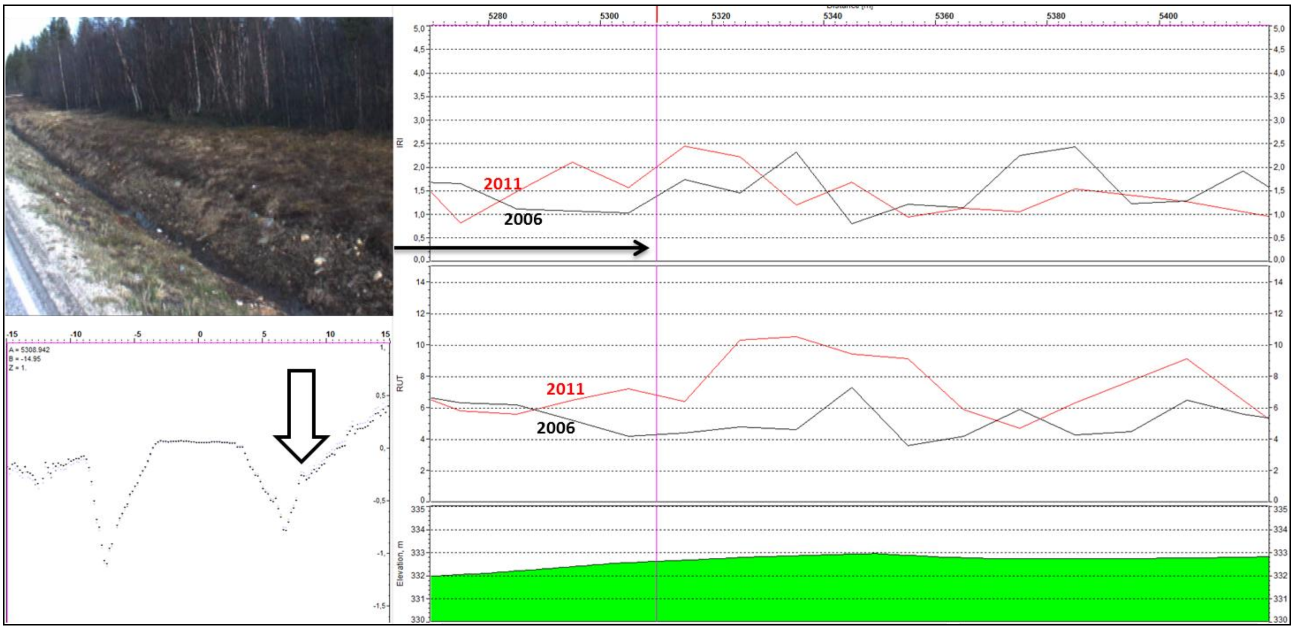

Figure 433_4. Example from road 93, section 3, chainage 5300 m where soil flow from the outer slope has blocked the ditch and the water flow. This is causing further water flow into the road structures. Rutting values (second frame on the right) above the blockage have grown by about 6 mm from 2006 to 2011 and are now 11 mm at highest. Roughness values (first graph on the right) show just small changes at this point. Soil flows can also be seen in the cross section of the ditch (lower left). The road surface elevation profile (lower right) shows that water should be able to flow freely from right to left at this point.

Highway 21

The drainage in highway 21 was in the best condition and six sections out of nine special drainage maintenance class sections had drainage Class 1 at least 50 % of their length. Only one section in the follow up sections had a drainage Class 3 in the survey. The problems on highway 21 included soil flows, clogged private road accesses (Figure 433_5) and vegetation slowing down the water flow in the ditches. In some cases vegetation had clogged up the outlet ditches and caused water to lie in the ditches.

A range of problems occurred on highway 21 at places with anomalous roughness and rutting values. In most of these the reasons for the growth of roughness or rutting could not be determined just from the videos. Soil flows from the ditch slopes and shallow ditches were common on this road, as well as soil flows from ditch slopes at road cuts. There were only a few private road accesses, clogged outlet ditches and culverts under the main road, but they could cause local problems and damages to the road.

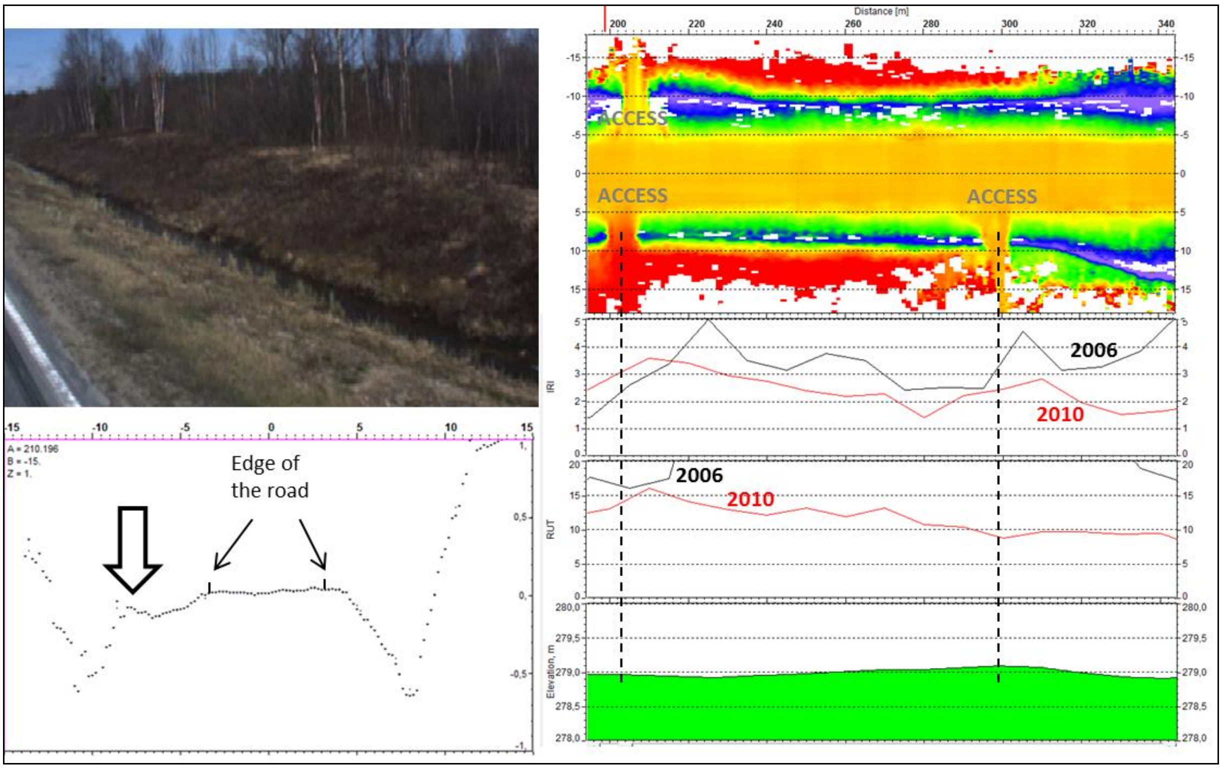

Figure 433_5. Example from drainage problems on highway 21, section 205. The water in the ditch on the right has backed up between the private road accesses, as can be seen from the video picture taken from chainage 210 m. Most likely the private road access culverts are clogged. The elevation frame (fourth on the right) also shows that the road elevation shelves gently down to the private road access at chainage 200m. Rutting values (third frame on the right) were higher than 20 mm in 2006 but had decreased by 2010. This is due to the road being repaved between surveys, but the highest value still reaches 16 mm. The cross section (lower left, chainage 210 m) shows that the depth of the right ditch is only about 60 cm. Excavated materials from cleaning out the left ditch bottom have been deposited on the inner slope of the ditch (arrow) and this slope is now slipping and filling the ditch.

4.4. RESULTS OF ROAD 934 SPECIAL SURVEYS

4.4.1. General

As mentioned earlier in chapter 3, road 943 was selected for special monitoring measurements, mainly as it was close to Rovaniemi and easy for daily access. A summary of the key findings of these special tests are presented in the following.

4.4.2. Problems with private road accesses

Point cloud frost heave videos made it easy to detect the places where frost heaves occurred and immediately it was noticed that frost heave locations were regularly situated close to private road accesses. The number of such accesses giving rise to frost heave problems was really high. Statistics showed that frost heaves were found at around 54 % of private road accesses on section 3 (Figure 442_1). On section 4 the proportion was slightly smaller at 36 % but this section was located mainly on sandy ground. The data shows that clogged private road access culverts block the water flow downstream and this causes ponding in the ditches. Frost heaves are created over a short period in spring when the snow starts to melt. At that time the road structures are still frozen, and when water is permitted to infiltrate into the cold road structures this causes differential frost heaves.

Figures 442_2 – 442_4 present some examples from problems close to private road accesses on the road 934. All the examples are from the special drainage maintenance class sections.

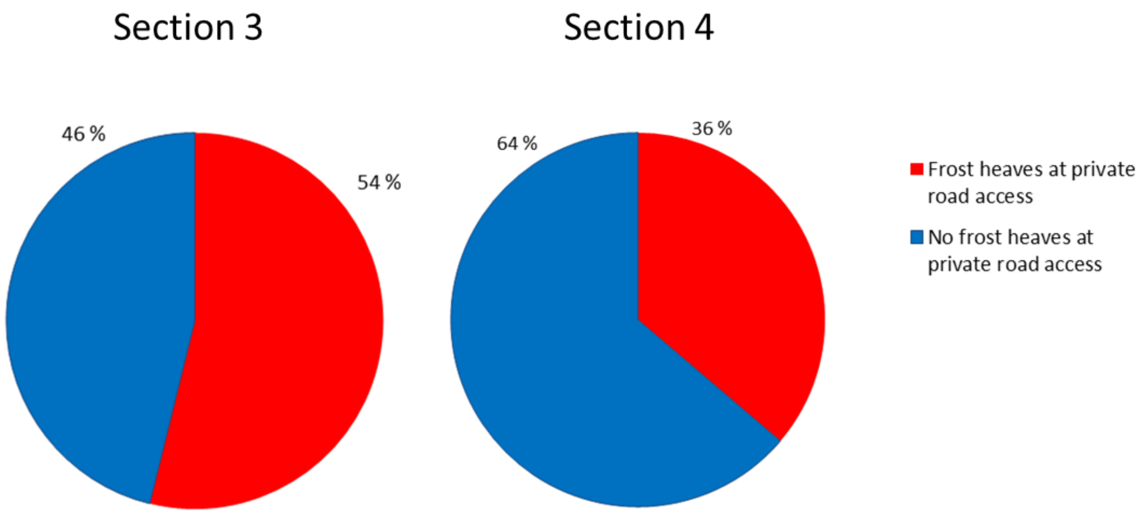

Figure 442_1. Amount of frost heaves associated with private road accesses on road 934, sections 3 and 4.

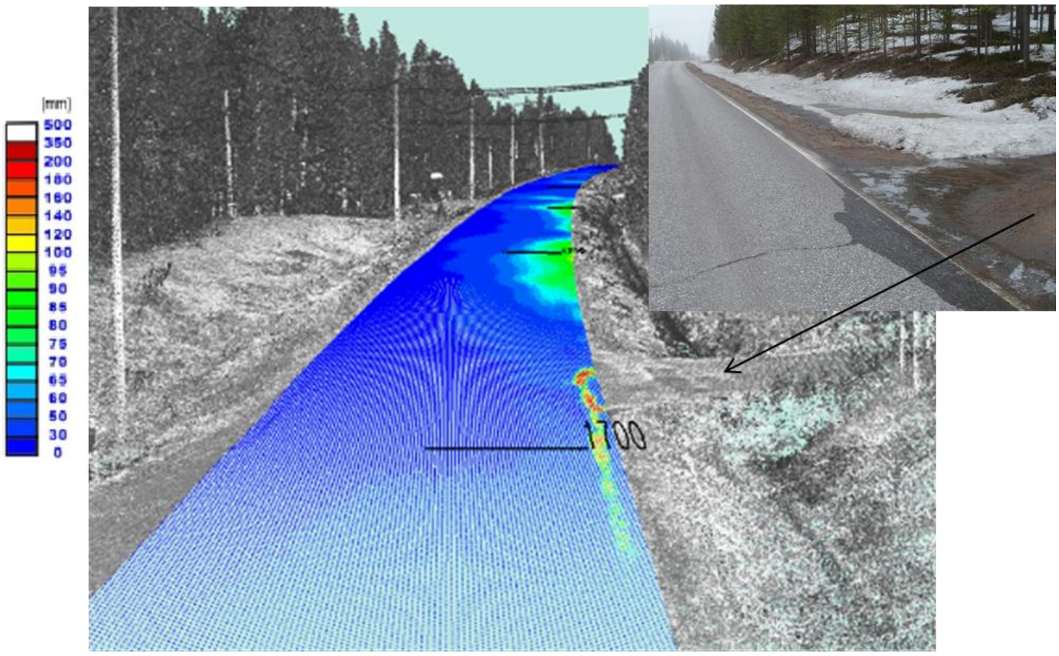

Figure 442.2. Example from road 934, section 3. Frost heaves above beside a private road access (chainage 1700 m), where the culvert was clogged in early spring (see also Figure 42_1 in chapter 4.2).

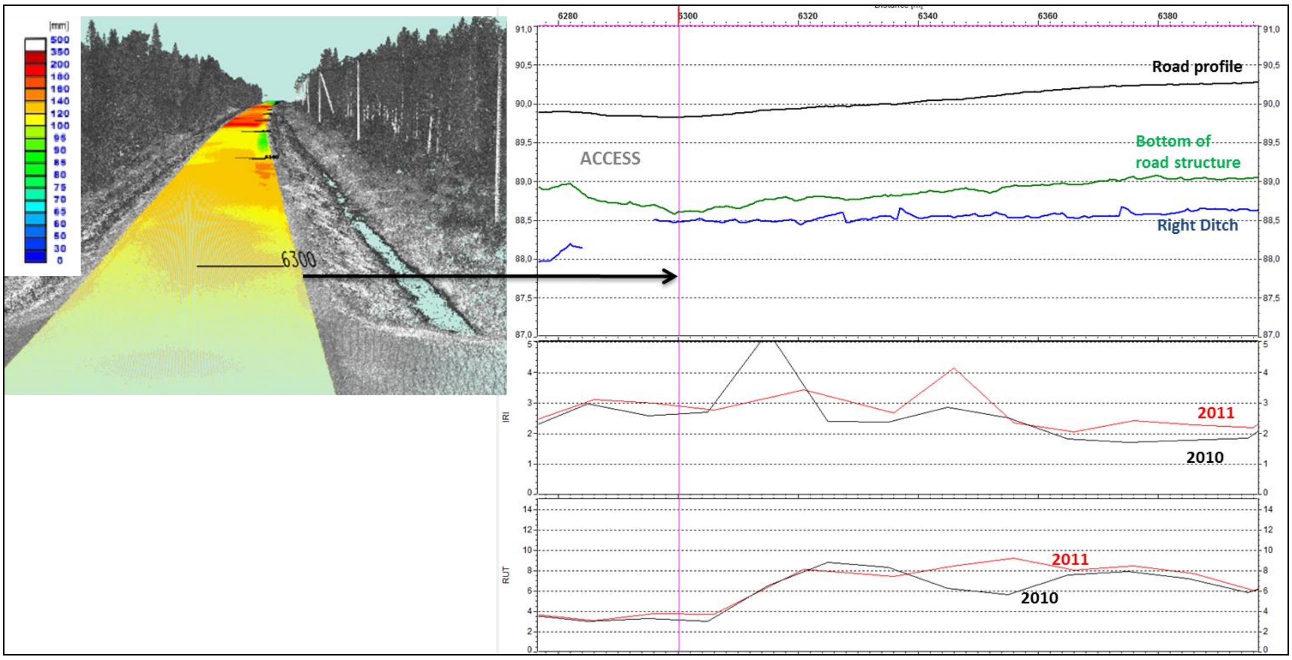

Figure 442_3. Example of drainage problems at chainage 6300 m, road 934, section 3. The private road access is preventing the flow of water downhill and has cause material sedimentation above the culvert which can be seen from the horizontal bottom level of the right ditch (the blue line on the top frame). The longitudinal gradient in the 78 m long section before the private road access is only 2.2 mm/m, when minimum specified value is 4 mm/m. The roughness and rutting values (second and the third graphs on the right) have started to grow at this point. The values from 2010 and 2011 are given in both frames. Figure 432_7 shows still photographs from the same point.

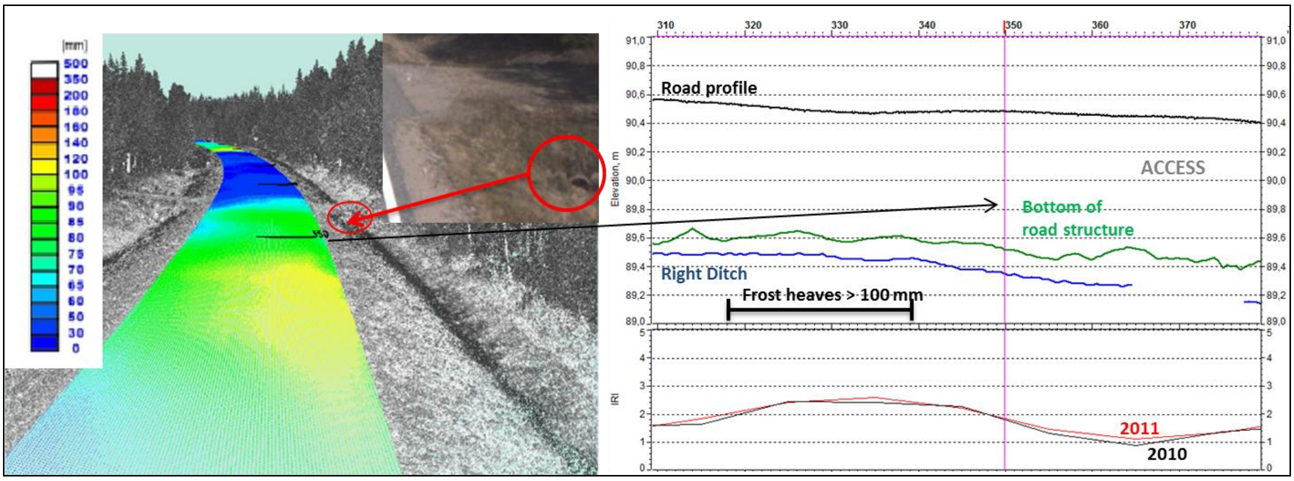

Figure 442_4. Example from road 934, section 4. The frost heaves above the private road access (chainage 370 m) can be related to the private road access. The inset photo shows, how the private road access culvert is clogged by vegetation and soil. The elevation data (upper right) shows the elevation of the road profile, elevation of the right ditch and the bottom of the road structure. The roughness values (second graph on the right) have risen higher than the average values. Frost heaves occur at the highest point, over 100 mm (yellow).

4.4.3. Problems with side ditch levels

One of the benefits of combined analysis of point cloud data and ground penetrating radar is that the level of side ditches can be compared to the road structure thickness. In some places where frost heaves occurred, it was found out from GPR data that the bottom level of the ditch was too shallow compared with the bottom of the road structure. The report "*New survey techniques in drainage evaluation – Laser scanner and thermal camera*" (Matintupa and Saarenketo 2011) carried out a statistical analysis of ditch and road structure depths. The results showed that when the thickness of the road structure was between 0.6 – 1.0 m, the ditch bottom level had the most significant effect on the road performance.

In this work the ditch bottom level was compared to the bottom level of road structures of road 934 at sections 3 and 4 (Table 443_1). The ditch bottom level should be at least 30 cm deeper than the bottom level of road structure. The results showed that almost half of the ditches on both sections were deep enough. Over 30 % of the right ditch on road section 3 had the bottom level higher than the bottom level of the road structure. In other ditches the figure was less. However the proportion of these ditches may be slightly too high as at bus stops and rest areas the depth of ditch may have been calculated too low in some cases, because the laser scanner could not reach the real bottom level of the ditch.

Table 443_1. The depth of the ditches compared to the bottom level of the road structure on the road 934, section 3 and 4.

	Section 3		**Section 4**	
	Right Ditch (%)	**Left Ditch (%)**	**Right Ditch (%)**	**Left Ditch (%)**
Ditch bottom level is > 0,3m deeper than bottom level of road structure	46,9	45,9	46,9	58,7
Ditch bottom level is 0-0,3 m deeper than bottom level of road structure	21,1	29,9	30,6	23,7
Ditch bottom level is > 0 m higher than bottom level of road structure	32,1	24,2	22,6	17,7

The connection between frost heaves and soil blocking water flow in the ditches was also observed. When the water flow slows down in the ditch, it starts to rise and flood. Even if the bottom level of ditch is deep enough compared with the bottom of road structure, water can easily rise so much that it can start to infiltrate into the road structure. This causes frost heaves and the growth of rutting and roughness values on the adjacent road.

4.4.4. Problems on the road 934, outside the special follow up sections

It is not easy to visually discern areas with deformation problems or frost problems in the field. These deviations are however easier to visualize with the rainbow maps made from laser scanner data. A rainbow map shows road surface topography and its deviations and damage. Each colour in rainbow colour palette scale represents a 30 mm change in surface level. An optimal road surface with two sided cross fall should resemble a perfect V-shape and in sections with straight cross fall it should present as straight lines. Figures 444_1 – 444_2 represent rainbow data from road 934 showing the road surface topography measured during the time of maximum frost heave in early spring 2011. The rainbow images show clearly the places where clogged private road accesses, soil flows and flooded ditches have caused damages to the road.

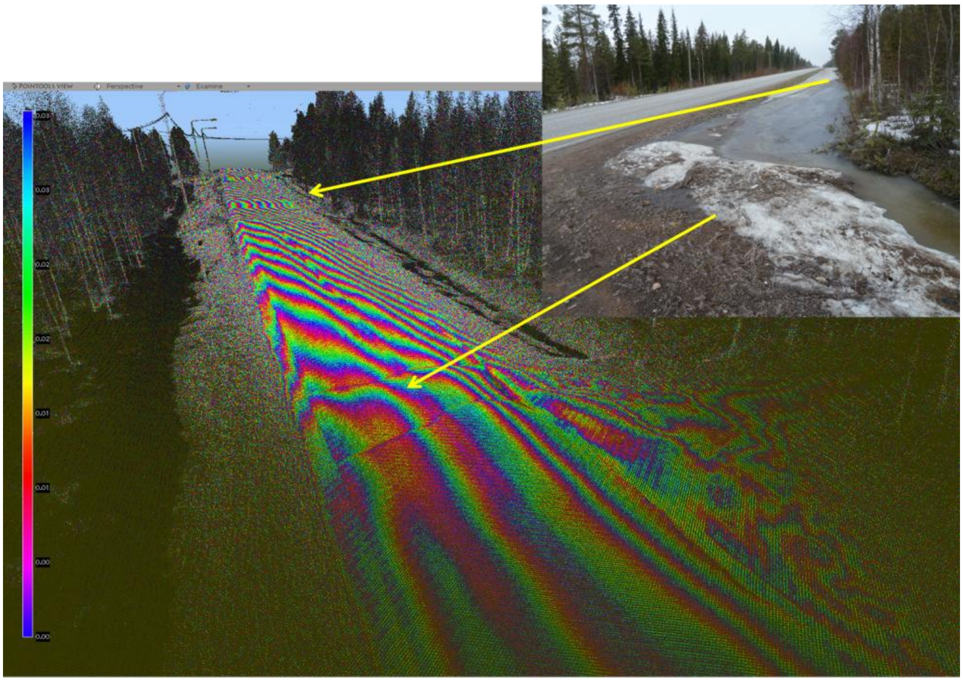

Figure 444_1. Example from road 934, section 2. The private road access is frozen and the culvert clogged with the result that water has flooded above it in the right ditch. The rainbow image shows the places where the problems appear on the road: 1) around the private road access and 2) at the end of the flooded "lake" .

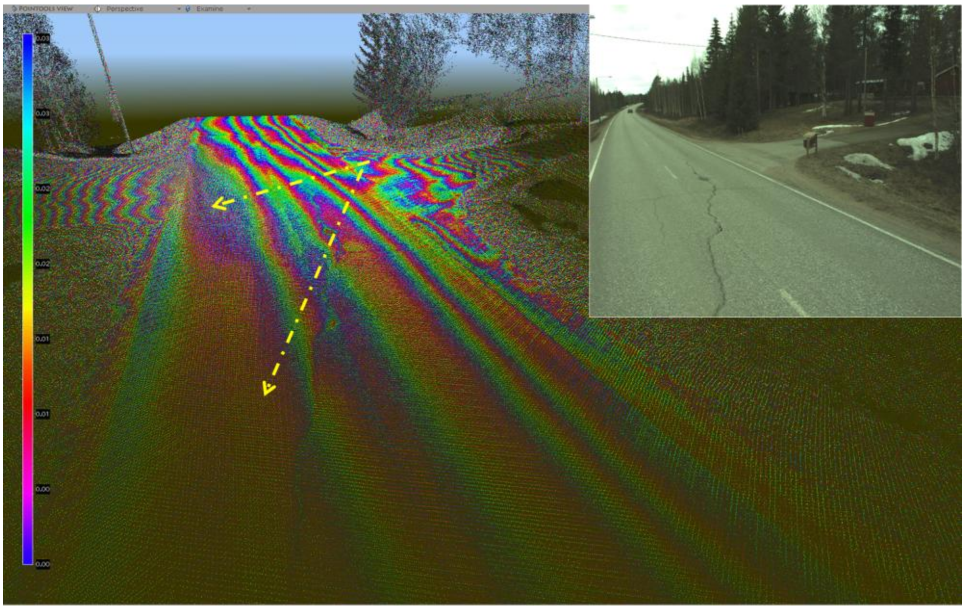

Figure 444_2. Another example from road 934, section 2. The private road access culvert has clogged up during winter and water is flooding above it. Water is flowing into the road structure and differential frost heave is causing cracking in the pavement.

5. CONCLUSIONS AND RECOMMENDATIONS

The drainage maintenance follow up in the Rovaniemi and Kittilä maintenance areas showed that, when analysed with very strict criterion, the drainage in the special drainage maintenance class sections in Rovaniemi maintenance area was in good condition in 41 % of the total length, and 35 % in Kittilä maintenance area. Minor deficiencies were observed in most of the special drainage maintenance class sections in both maintenance areas. Only 2 % of the follow up sections in Rovaniemi area were in poor condition, but in the Kittilä area the proportion with drainage Class 3 was as much as 25 %. The reason for this is that the ditch cleaning on the flat peat bog areas on road 80 in Kittilä could not be done with the given resources, and the alternative choices to improve the drainage were not used.

In most of the cases the main reason for the poor drainage lengths was soil flowing from the ditch slopes and clogging up the flow of water. In the Rovaniemi maintenance area insufficient longitudinal gradient in the repaired ditches reduced the drainage class, and the total results. In Kittilä maintenance area the effects of private road access lower the drainage class, primarily due to poorly installed or clogged culverts. In addition unstable ditch slopes in road cuts and clogged outlet ditches were also reasons for weaker drainage results.

Based on this study, three main drainage problem types causing road damages could be found (Figure 5_1). The first type involves bus stops and rest areas where during winter the cleared snow from the road, bus stops and rest areas, is stored off the road and above the ditches (Figure 5_1A). In spring, when the snow begins to melt, these snowbanks prevent the water flow in the ditch causing the water level to rise. This enables water to infiltrate into the cold road structure and this causes frost heaves and high rutting and roughness values to the road. The second type concerns clogged or missing private road access culverts (Figure 5_1B). These slow down the water flow or stop it totally. When the water level rises enough it infiltrates into the road and causes road damages as described above. Additionally the high water level resulting from a clogged culvert also causes the ditch slopes to become saturated with water and the soil on the ditch slopes to flow into the ditch. This raises the bottom level of the ditch, or blocks it altogether (Figure 5_1C). Soil flows also restrict the water flow in ditches.

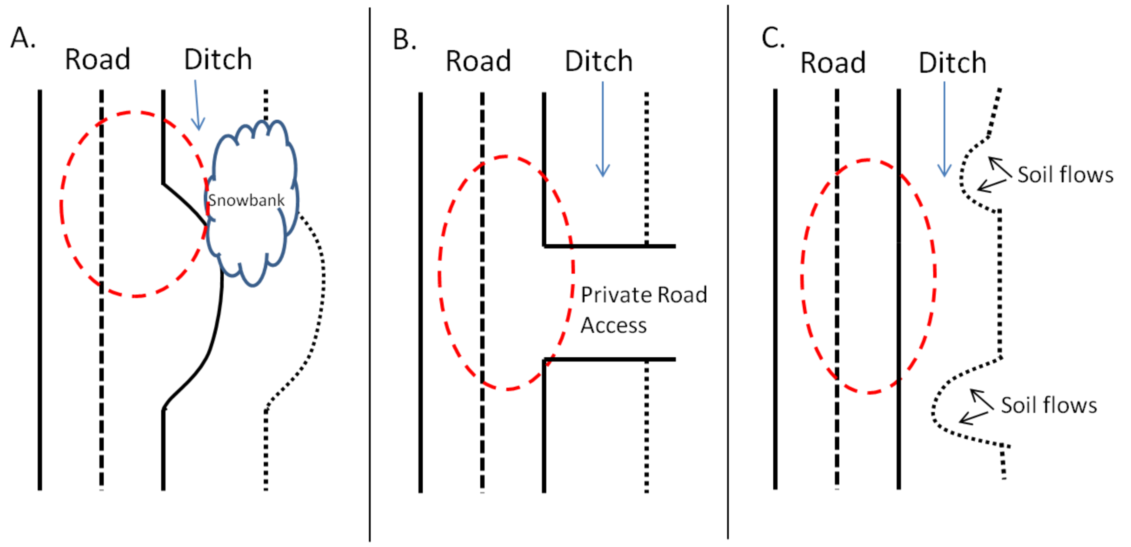

Figure 5_1. Three common problems causing damages to roads. Water flow is marked with a blue arrow and the area that is most likely going to be damaged is circled with a red, dashed line. A: Snowbank behind bus stop or rest area preventing the water flow. B: Clogged or missing private road access culvert . This hinders the water flow and causes problems to road at private road access. C: Soil flows from ditch slopes preventing water flow.

The observed deficiencies in drainage have not yet affected the rutting and roughness of a road in all special drainage maintenance sections. At the time of the surveys 5 – 25 % of the special drainage maintenance class sections in Rovaniemi maintenance area had increased roughness and rutting values, and in the Kittilä area the corresponding percentage was 20 – 40 %. Soil flowing from ditch slopes and shallow ditches were the most common problems observed in the places with high IRI or rutting values.

A major defect in this analysis however was that the profilometer data was collected only from one lane of the road, which in most cases was the right lane. In the cases where the follow up section was on the left side of the road, it was possible that the problems on the left lane caused by poor drainage will not be seen in the results that are measured from the right lane.

The special surveys carried out on road 934 gave surprising results on the connection of frost heaves with private road accesses. The results clearly showed that frozen culverts, or culverts clogged for some or other reason, were causing remarkable frost heaves and other damages to the road. These damages can be seen a significant distance before and after private road accesses. More than 50 % of private road accesses on section 3 were causing problems, and on section 4 the proportion was almost 40 % (Figure 442_1).

Combining the laser scanner and ground penetrating radar data gave good results on how shallow ditches and soil flows from ditch slopes caused frost heaves to roads. Soil flows restrict the flow of water in the ditches causing ponds to form, and the rising water can easily infiltrate into the road structures.

The correlation between anomalous rutting and roughness values and frost heaves were compared on road 934 section 3 and 4. In this comparison all the rutting and roughness values higher than average were marked and then checked if there were clear, weak or no frost heaves at each point. The comparison was made over the full section lengths. The results differed in the two sections (Figure 5_2). On section 3 over 65 % of the anomalous rutting and roughness values had a clear correlation with adjacent frost heaves, whereas on section 4, 65% of the rutting or roughness values did not correlate with frost heaves at all. In these sections the reason for the visible rutting was poor road materials and the rutting Mode was mainly Mode 1. The results that frost heaves are not the only reason for the growth of rutting and roughness values. Other circumstances, such as road structure quality and the amount of heavy traffic, can have an impact on rutting and roughness too.

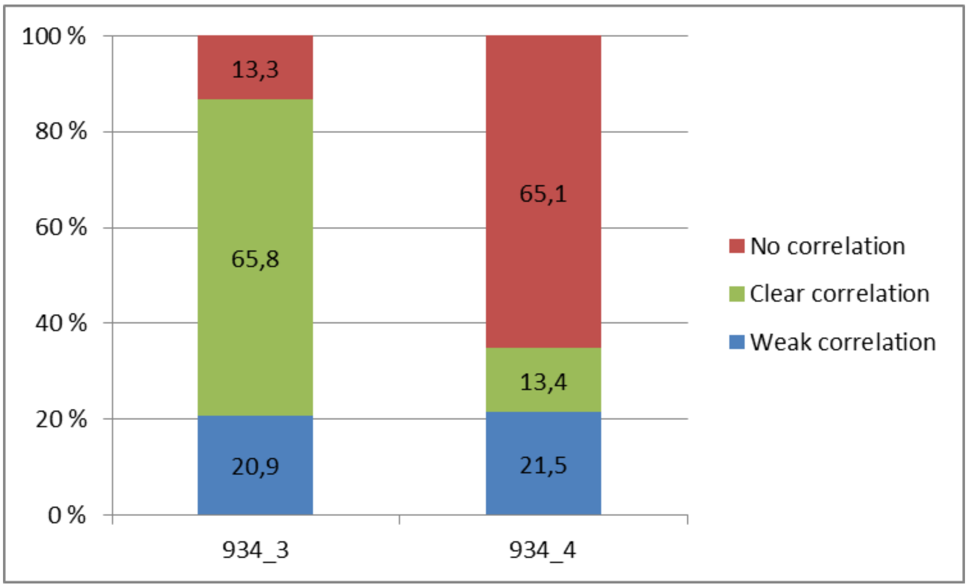

Figure 5.2. Correlation between frost heaves and anomalous rutting and roughness on road 934, sections 3 and 4.

The outlet ditches surveyed were mainly in good condition. The main problem observed with them was vegetation growing in the ditches and preventing the flow of water.

Keeping the drainage in good condition on the gravel roads surveyed was having a surprisingly good effect in preventing spring thaw weakening problems. Opening culverts and outlet ditches in spring time are operations that should have a higher priority. The surveys found a number of poorly installed main road culverts.

In summary it can be stated that the drainage analysis method developed in the ROADEX project, has been proven to give reliable results in the Rovaniemi and Kittilä maintenance areas. Most of the selected sections for follow up monitoring were located at the most critical sections from a pavement life time perspective. Figure 5_3 shows an example from road 934 on how improving the drainage has ensured that the rutting values have been retained at a low level. The results from 2004 are the rutting values measured before the drainage was improved, and the pavement repaired. When the rutting values from 2010 and 2011 are compared to those of 2004, it can be seen that that outside the special drainage management class sections the 2010/11 values are higher at some points than before the drainage and pavement was repaired. This clearly shows that the improvement of the drainage has had a good influence on the condition of the road, and where the improvement was not carried out the values have tended to grow.

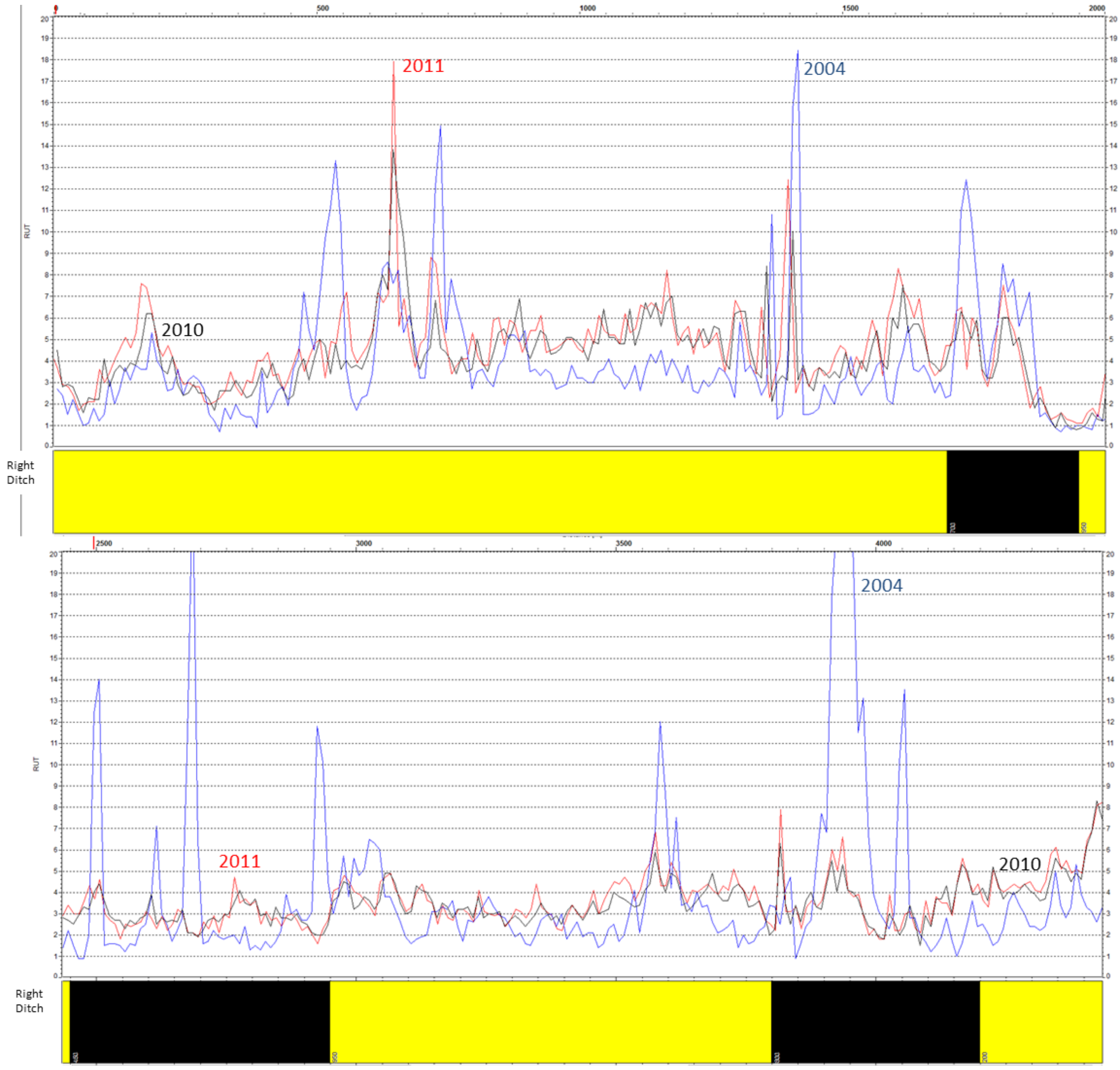

Figure 5_3. Example from road 934 showing how the improved drainage has helped the rutting values rutting values stay at a low level in the special drainage maintenance class sections. These sections are marked with black in the second and fourth frames. The first frame shows rutting values between 0 – 2000 m and the third frame the rutting values between 2450 – 4400 m.

The repair of the drainage in the Kittilä maintenance area was carried out relatively recently and as a consequence the precise conclusions on how the contractor has managed in this work, and how the repaired drainage has affected the condition of the respective roads, will require to be done in the future. In the Rovaniemi maintenance area however the roads had been paved and the ditches repaired by the time the contractors got the contracts. Unfortunately, during the contract, not all of the observed shortcomings were repaired. If this is accepted, and if the deficiencies in the drainage are not repaired, the omissions will be seen in the growth of damaged roads. Soil flows on ditch slopes and clogged private road culverts are seen to cause most of the problems. The trouble is that the opening of clogged private road culverts is not part of the normal management tasks within Finnish road maintenance contract. To address this failing, consideration should be given to changing the policy so that these operations can be included in the standard management tasks during winter time. Other option is that the management of drainage is included in the long term pavement contract in future.

Drainage condition analysis is a very subjective tool and is not the best, or easiest, way to define sanctions for a drainage maintenance contractor should he fail. New techniques, such as the laser scanner, should therefore be developed further. With the laser scanner the bottom level of ditches can be measured, and unstable ditch slopes preventing water flow can be identified. The use of laser scanner rainbow maps make it easier to visualize the changes in pavement surface topography and the deviations and damages that can be caused by poorly performing ditches, missing or clogged main road culverts, private road access culverts or frost problems.

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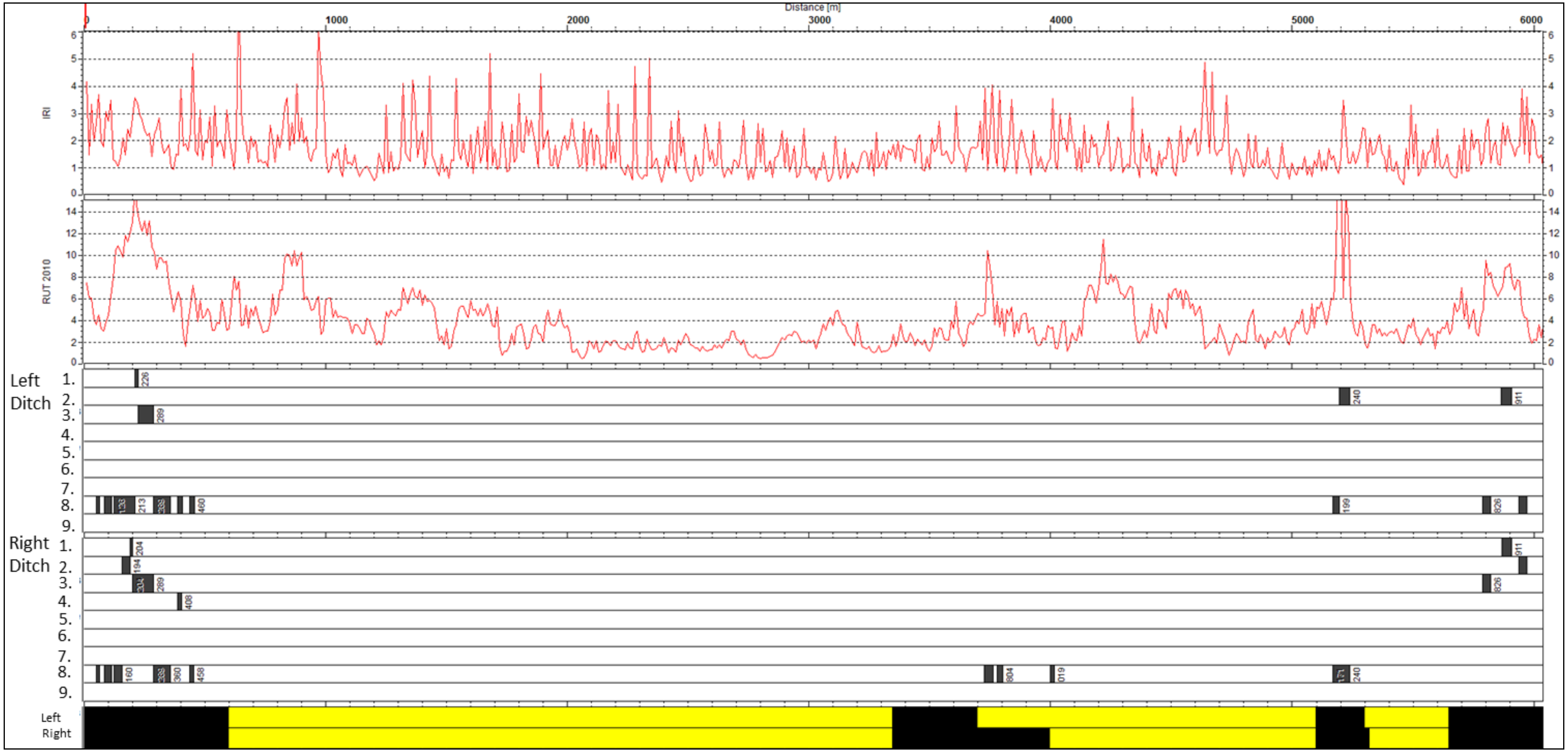
APPENDIX



Appendix 1. Comparing the anomalous roughness (first frame) and rutting values (second graph) to the problems observed in the drainage video. The problems in each ditch are marked separately. The categories the problems were divided into are: 1. private road access, 2. soil flows from ditch slopes or shallow ditch, 3. soil flows from ditch slopes in road cut, 4. clogged outlet ditch, 5. side ditch clogged for other reason, 6. sheet ice, 7. main road culvert, 8. reason unknown and 9. drainage not repaired. The lowest graph shows the special follow up sections on both ditches. This example is from highway 21, section 205.

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