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NEW SURVEY TECHNIQUES IN DRAINAGE EVALUATION - LASER SCANNER AND THERMAL CAMERA

A ROADDEX IV report for Task D1 "Drainage maintenance guidelines"

ABSTRACT

The ROADEX project has carried out a number of drainage analysis demonstration projects in the Partner areas using the ROADEX drainage analysis technique. This technique, based on visual evaluation, has been found to have the deficiency that all of the required critical drainage condition parameters cannot be observed from the moving vehicle. In order to overcome this shortcoming the new survey techniques of digital thermal camera and laser scanner were additionally trialed in drainage analysis surveys in late spring 2010 by Roadscanners Oy. These surveys were carried out on selected roads in Umeå Södra maintenance area in Sweden in conjunction with routine drainage analysis being carried out in the area.

The laser scanner and thermal camera techniques proved to be very useful in the surveys. Thermal camera imaging had previously shown its potential in earlier drainage analysis tests in Finland, and the improved camera under test proved to be even better and more accurate. The results obtained during the tests showed that thermal camera imaging could prove to be a very effective tool for detecting access road culverts and their condition (i.e. well working or clogged). Culverts that were impossible to see in digital videos were found to be relatively easy to find in thermal camera images. One major deficiency found with the thermal camera was that reliable data collection could not be assured during daytime as direct sunlight affected the results. For this reason it is recommended that thermal camera surveys should be performed after sunset. This is likely to make data collection more expensive as the other data has to be collected in day time.

The laser scanner and GPR were used to determine the level of ditch bottom vs the depth of road structure bottom. An aim of the test was to identify the effect of the difference of road structure bottom level and ditch bottom depth level on the performance of the road. Road design guidelines in Nordic countries require that the ditch bottom should be 20-30 cm deeper than the road structure bottom. The road structure depths were measured by GPR and the ditch bottom level by laser scanner. Results obtained during the tests showed that if the ditch is 20-30 cm deeper than the bottom of the road structure, the drainage works better and rut values and IRI values are substantially lower – and pavement life time longer. Statistical analysis of the results also indicated that the condition of the ditches had the greatest significance when the thickness of the road structure was 0.6-1.0m. Laser scanner measurements proved to be sensitive to local environmental conditions such as the presence of roadside vegetation, rain, fog and dust. For this reason it is recommended that laser scanner surveys should be conducted in spring at time when the vegetation has not yet begun to grow.

Both the laser scanner and thermal camera were found to be very useful devices in the tests for drainage evaluation but both methods suffered from being sensitive to environmental conditions. Other potential applications for thermal camera and laser scanner may be possible in the future. For example, it may be possible for to use laser scanner data during ditching and ditch improvement work to monitor the depth and inclination of the ditch.

It is recommended that laser scanner measurements should be included in drainage analysis in the future as they provide numerical facts rather than subjective evaluations.

KEYWORDS

Drainage analysis, thermal camera, laser scanner

PREFACE

This task “*New survey techniques in drainage evaluation – laser scanner and thermal camera*” was carried out as part of the ROADEX IV Work Package 3, “Local demonstrations”. The field measurements were organised by Tomi Herronen. The survey data was handled by Anna Maijala, Elmo Haavikko, Eetu Pussinen and Sami Tuisku. Matti Saarenketo carried out the statistical analysis of the effect of ditch depth compared to road structure and road condition. The traditional drainage analysis was made by Tomi Herronen, Seppo Tuisku and Annele Matintupa. The analysis of laser scanner and thermal camera data was performed by Annele Matintupa, who also wrote the report jointly with Timo Saarenketo. The software specialists were Pekka Maijala and Jani Irvankoski. All of the above-mentioned are employed by Roadscanners Oy, Finland. Ron Munro of Munroconsult Ltd checked the language. Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout. The authors would like to thank the ROADEX IV Steering Committee for its encouragement and valuable guidance in this work.

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1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organisations across northern Europe that aims to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finland Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX IV from 2009 to 2013.



Figure 1. The Northern Periphery Area and ROADEX IV Partners.

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

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

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

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

1.2 THE DEMONSTRATION PROJECTS

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

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

- D1 - "Drainage Maintenance Guidelines"
- D2 - "Road friendly vehicles and Tyre Pressure Control"
- D3 - "Forest Road policies"
- D4 - "Rutting, from theory to practice"
- D5 - "Roads on Peat"
- D6 - "Health and Vibration"

This demonstration project was part of the D1 "Drainage Maintenance Guidelines" group. The goal of the project was to test if the new survey techniques of laser scanner and thermal camera could provide extra value in the drainage evaluation process. Thermal camera imaging had previously shown its potential in drainage analysis, but more reference studies were needed. Laser scanning and GPR were used to evaluate if ditch and road structure depths could be determined in the drainage analysis surveys. This project tested if road structure depths and ditch bottom depths could be combined to a single value. General practice in the Nordic countries has been that the bottom of the ditch should be 20cm deeper than the road structure bottom. Road structure depths were evaluated with the GPR method.

2. ROADS SURVEYED

In late spring and summer 2010 Roadscanners Oy carried out a series of thermal camera and laser scanner surveys on selected roads in connection with the Umeå Södra drainage analysis in Northern Sweden (Figure 2).



Figure 2. The location of the roads surveyed. The Umeå Södra area is marked in red.

The roads selected for the demonstration were chosen from the roads to be surveyed in the Umeå Södra drainage analysis project. These roads represent a range of different types of roads. The surveyed roads and their lengths are listed in table 1.

Table 2: The surveyed roads in this project.

Road	Length [km]	Gravel road	Thermal camera	Laser scanner
353	25,9	-	x	x
514	17,6	-	x	
515	6,8	2810-5989	x	x
520	10,1	6363-10033	only 0-6318	x
522	23,3	-	x	
523	13,9	-	x	x
568	10,5	-	x	
total	108,1			

3. SURVEY TECHNIQUES

3.1 LASER SCANNER

In recent years the greatest advancements in all of the NDT techniques used in road surveys have been made using the laser scanner technique. Such has been success of laser scanning that it is inevitable that the technique will become a standard tool for a variety of tasks in road condition management.

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

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

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

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

The accuracy of a laser scanner survey can however be reduced by different factors that affect visibility, such as dust, rain, fog or snow. High vegetation can also prevent the system from obtaining data on the actual ground surface.

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



Figure 3. The survey van equipped with a laser scanner at the rear of the van.

3.2 THERMAL CAMERA

Thermal cameras have been used in traffic infrastructure surveys for several decades but recently their quality has increased so much that greater interest in this technology has started to grow. Currently, new high precision thermal cameras can measure small changes in surface temperatures, even down to changes as small as 0.05°C . The camera measures infrared radiation with a wavelength of 8 - 12 μm . Because the results of thermal camera measurements are very sensitive to solar radiation, it is recommended that data is collected after sunset.

The use of the thermal camera in drainage evaluation surveys is a fairly new application. In this demonstration project the data was collected using a digital thermal camera made by Flir Systems Inc. The thermal camera data collection software used in the surveys was Road Doctor™ CamLink by Roadscanners Oy. Surveys were carried out in both directions and, in addition to thermal data, digital videos were also recorded. The frame rate was 60 frames per second. All the data was linked to GPS coordinates using Road Doctor™ CamLink -software. The survey van used is shown in Figure 4.

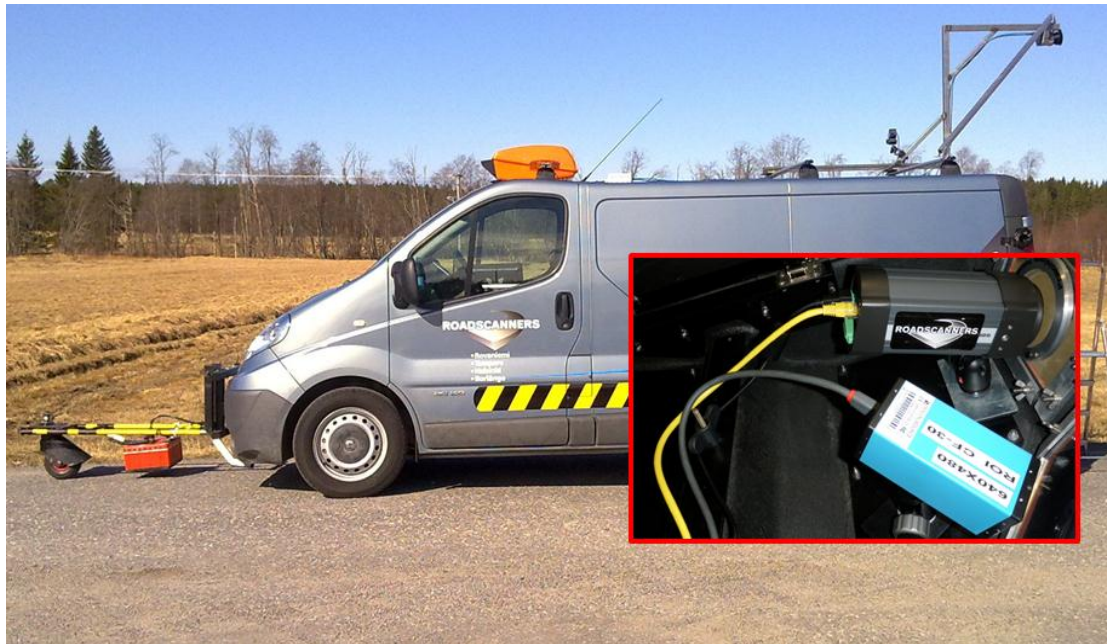


Figure 4. The survey van equipped with a thermal camera at the back of the van on the roof. The van is also equipped with a laser scanner (mounted high above the roof) and a 400MHz ground coupled GPR antenna in front of the van. The thermal camera is shown in the insert in close-up together with the digital video camera.

When interpreting thermal camera results it should be kept in mind there are also other significant factors that effect the measured infrared emission of the soil and road surface, such as cloudiness, buildings, road cuts, vegetation and atmosphere. The weather and climate (example.g. the temperature and air humidity) can also have an effect on thermal camera measurements. The most significant factors affecting thermal camera measurements are shown in Figure 5 below.

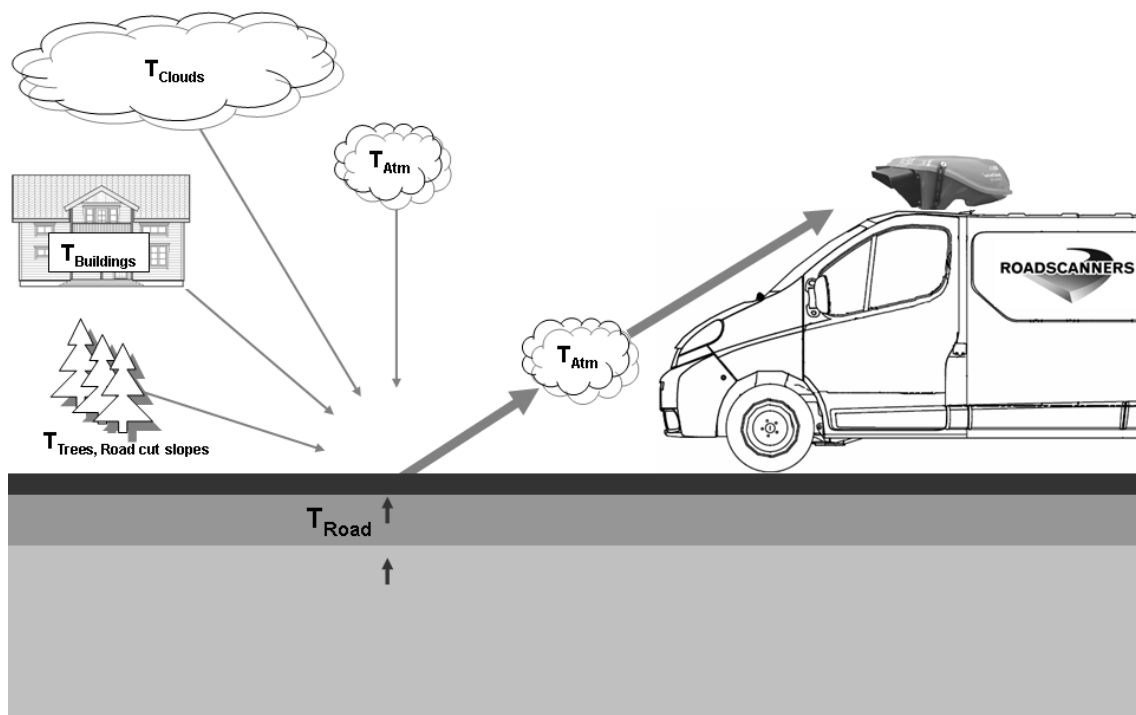


Figure 5. Factors that can affect thermal camera measurements.

3.3 GPR TECHNIQUE

Ground Penetrating Radar (GPR) is a non-destructive ground survey method that can be used in researching roads, railways, bridges, airports, environmental objects, etc. Its main advantage is the continuous profile it provides of the road structures and subgrade soils and, as a consequence, the technique is becoming an increasingly important tool especially in the structural evaluation of low volume roads. A further, important advantage in road surveys is that it does not interfere with other traffic using the road.

The method is based on transmitting short pulses of electromagnetic energy into materials using either an air coupled or ground coupled antenna. When an electromagnetic wave hits a boundary between substances with different dielectric constants, part of the wave reflects back to the surface and the antenna of the receiver picks it up. The rest of the wave either carries on into the underlying substance or is scattered in multiple directions. The position and type of changes in the dielectric properties of the materials can be revealed by the amplitude and frequency of the reflected pulses.

There are many different electromagnetic wavelengths and antenna frequencies that can be used in GPR surveys depending on which layers are being surveyed. In pavement surveys, or surveys of the top part of the pavement structure, it is recommended that a high frequency (short wavelength) antenna is used as it provides higher resolution data with which the user can differentiate thin layers. The penetration depth for high (1.0 – 2.5 GHz) frequency antennas is approximately 0.5-1.2 m and for lower frequency antennas (400-500 MHz) it is around 1.5 – 4.0 m. The resolution of data obtained with low frequency antennas can only be used to distinguish thick layers so the data is not necessarily as useful as high frequency pavement data. As a whole the accuracy of GPR method in thickness surveys is +/- 10 %. If however if there are reference drill cores available the accuracy can be improved to +/- 5 %.

In this project, the GPR surveys were carried out using a 400MHz ground coupled (GC) antenna and a SIR-20 GPR main unit manufactured by GSSI. The GPR system was attached to the survey van (Figure 5) on a front mounted rack. The time window used in the GC data collection was 80 ns. The sampling interval for the antenna was set at 10 scans / metre. The GPR survey was carried out at a speed of 20-30 km/h.

4.TEST RESULTS

4.1 LASER SCANNER

4.1.1 General

The laser scanner surveys were mainly carried out in spring 2011, but some test measurements were also performed later in the summer. The spring measurements were done in the beginning of the May and the summer measurements at the end of June. The purpose of collecting data in two different seasons was to find if there were any effects of seasonal conditions and variations on the results. The effectiveness of scanner in seeing through the vegetation in the bottom of the ditch was also determined. The primary points of the comparison were the depths of the ditches.

Figure 6 presents the depth of left ditch bottom of Road 353 from 2860m to 3425m. This part of the road had no vegetation in the bottom of the ditch in the spring surveys, but there was vegetation during the summer surveys. The results show some noticeable differences between the respective datasets. During the summer surveys the ditch bottom level was seen to be higher than in spring. In this section, the bottom of the left ditch is on average about 36.5cm higher in the summer scanning than in the spring scanning. In the right ditch the difference is about 29cm.

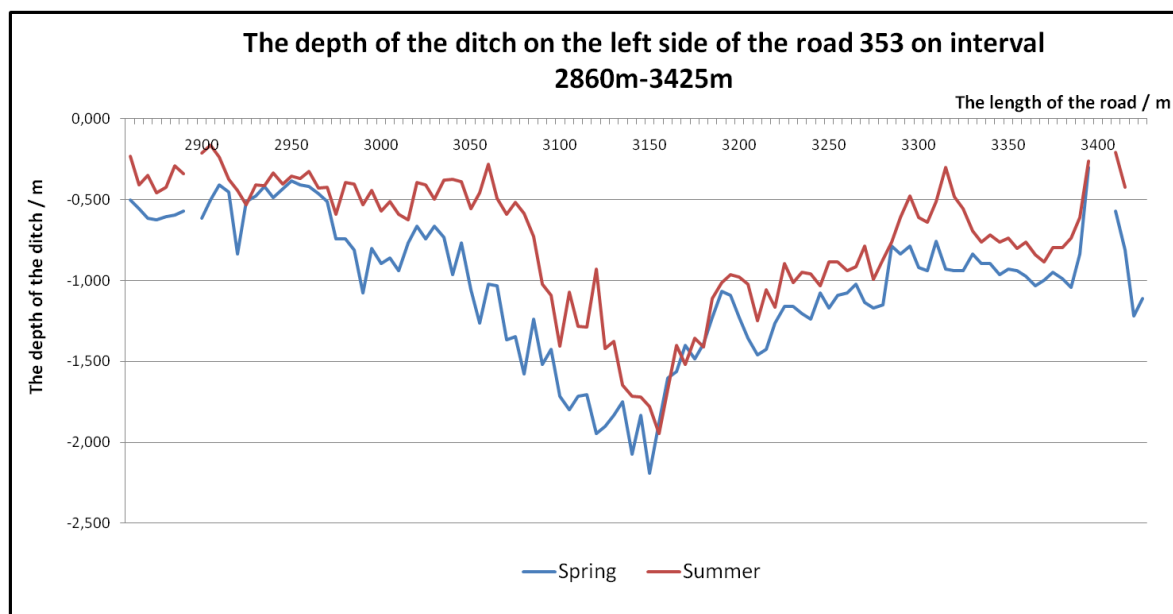


Figure 6. The depth of ditch bottom of Road 353 from 2860m to 3425m. The blue line represents the spring measurement results and the red line the summer measurement results.

The difference in the measured ditch bottom level can be mainly explained by vegetation, but part of the difference can also be due to frost heave effects, which can be present in Spring measurements. Snow filled ditches usually insulate the ditch bottom from frost heave with the result that the ditch bottom level generally remains at the same level in the Spring. The road surface on the other hand can be higher because of frost heave. On Road 353 the ditch bottom level was seen to be roughly 30-40cm higher in summer due to the presence of vegetation in the ditch. Given these results it is recommended that laser scanning measurements should be conducted in the Spring at a time when the vegetation has not yet begun to grow.

Laser scanner measurements can also be sensitive to other factors which reduce visibility, like dust, fog or rain. During the spring measurement period the weather was foggy during the night and, as such, the laser scanner data had some errors (Figure 7) compared to data of acceptable quality (Figure 8). In these circumstances the true cross section of the road cannot be determined.



Figure 7. An example of laser scanner data affected by fog. The cross-section of the road cannot be seen and only a few points are visible. The surface level colour map produced with laser scanner data is also incomplete.

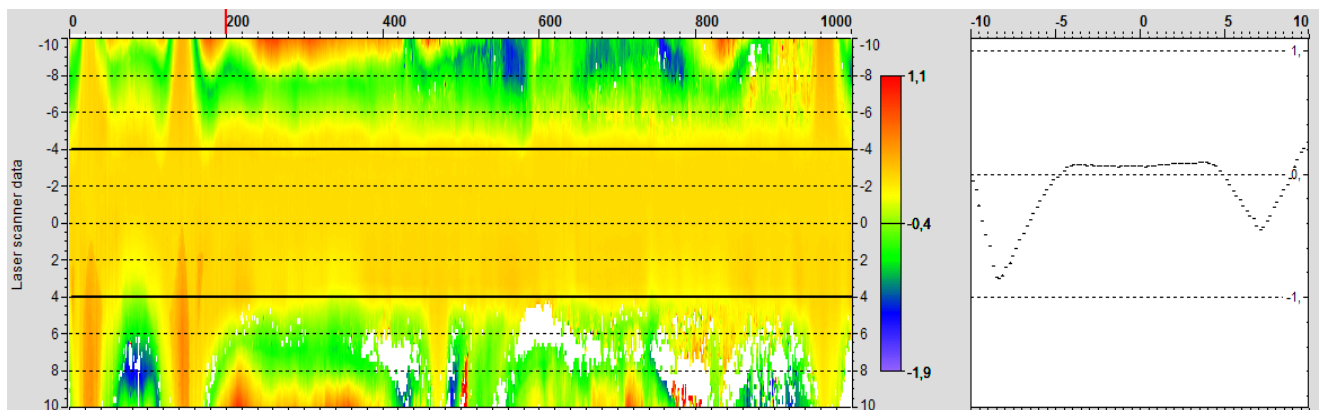


Figure 8. An example of laser scanner data with sufficient quality. There are no interruptions and the shape of cross-section is easily seen.

4.1.2 Road Shape Surveys

In order to survey and evaluate the road shape, both road cross-sections and surface level colour maps were produced and analysed using the laser scanner data. Figure 9 shows a high grass verge on the right edge of the road that can also be seen in the laser scanner data. In some cases the grass verge is difficult to see from the digital video but can be clearly seen in the laser scanner data.

Laser scanner data can also be viewed as a surface level colour map, where different colours can be used to represent the height difference of the road surface level. An example of this is shown in Figure 10. The approximate or designed road edges can be projected onto the map with black lines which makes it easier to evaluate where the road has problems, e.g. with widening due to Mode 2 rutting. Laser scanner data can also show where the inner and outer slopes have kept their shape. If the slopes are flowing into the ditches this can be clearly seen from the data.

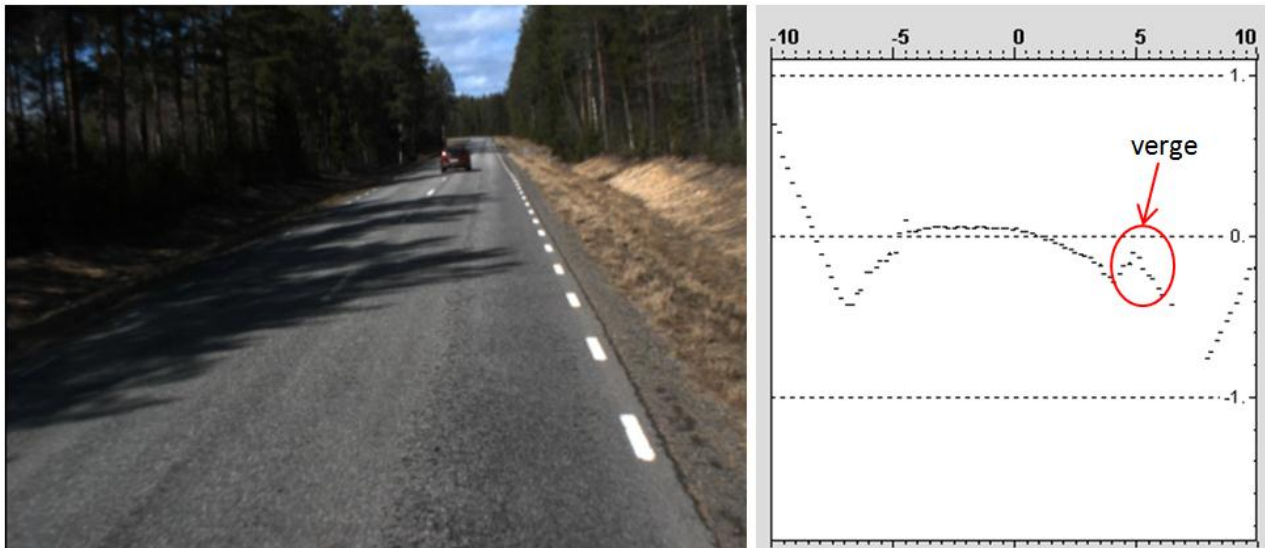


Figure 9. The cross section of Road 353 at point 2285. The verge is marked in red.

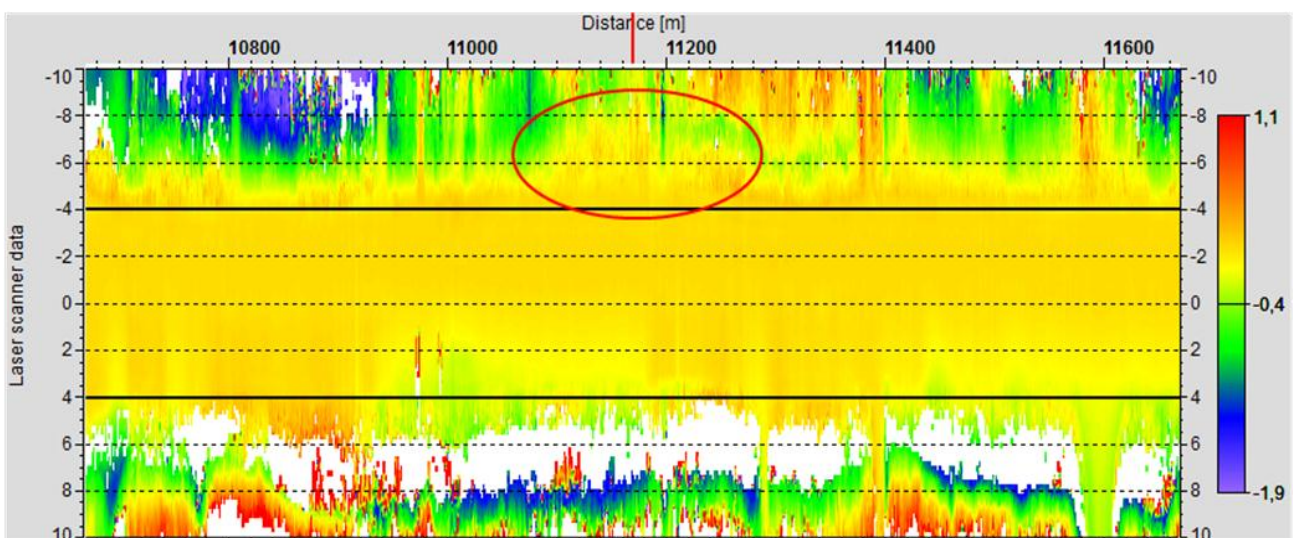


Figure 10. Laser scanner data from Road 353, from 10650m to 11650m. The colour of the road surface level is orange or yellow, the black lines represents the road edges. The red oval shows a section where the left inner slope is flowing into the ditch.

4.1.3 Ditch Bottom Depths

Nordic countries road design guidelines recommend that the bottom of the roadside ditch should be 20-30 cm deeper than the bottom level of the road structure. This is to ensure that water will flow from road structures to ditches and not vice versa (Figure 11). In order to ensure if this “rule” was being adhered to the level of the ditch bottom and level of road structure bottom were surveyed with laser scanner and GPR techniques. This data was then also compared to rutting, roughness and drainage data.

The Umeå test roads surveys showed that only 20-50% of ditches were deep enough. The percentages of each of the analysed roads are listed in Figure 12. Figure 13 presents the distribution of drainage classes of Roads 353, 515, 520 and 523. On Road 353 (both sides) and Road 523 (left side) the ditches are, for the most part, in good condition. Most of Road 523 (right side) and Road 515 (left side) were rated as Class 3, poor drainage.

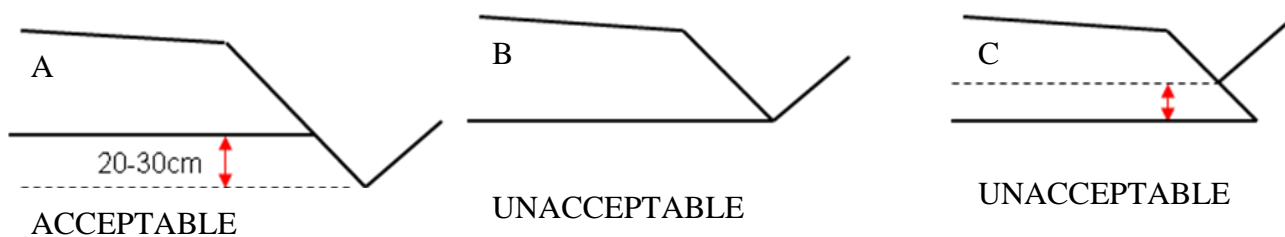


Figure 11. Diagrams showing possible relationships between ditch bottom and road structures. Case A is acceptable; the ditch bottom is deeper than the road structure. Case B is unacceptable, because the ditch bottom and the bottom of road structures are at the same level. Case C is unacceptable, because the bottom of the ditch is at a higher level than the bottom of the road structure.

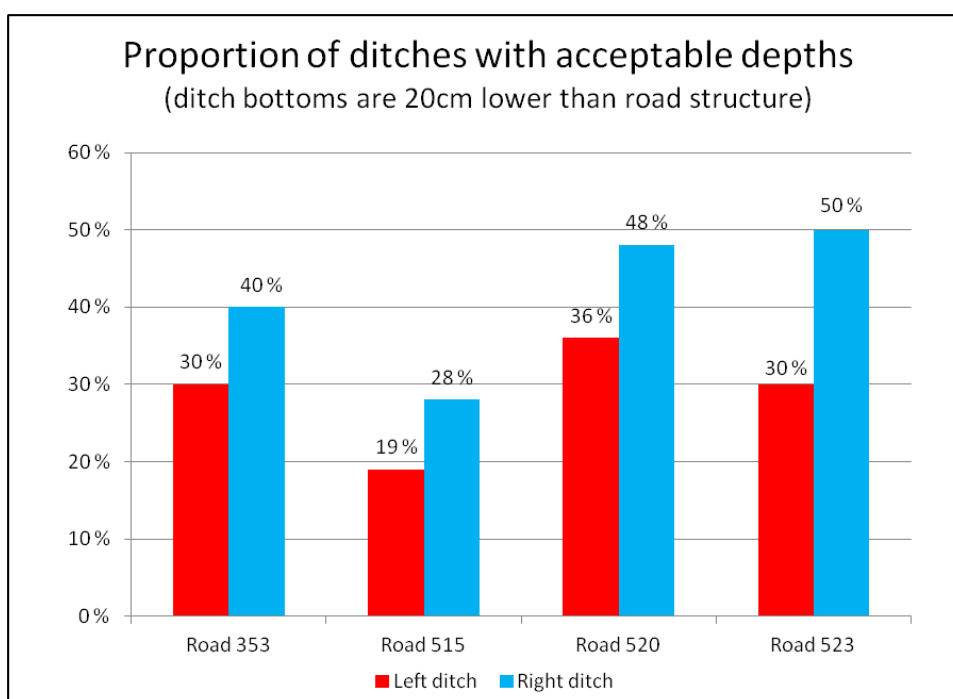


Figure 12. Diagram showing the percentage of ditches surveyed that were deep enough (i.e. over 20cm deeper than the road structure).

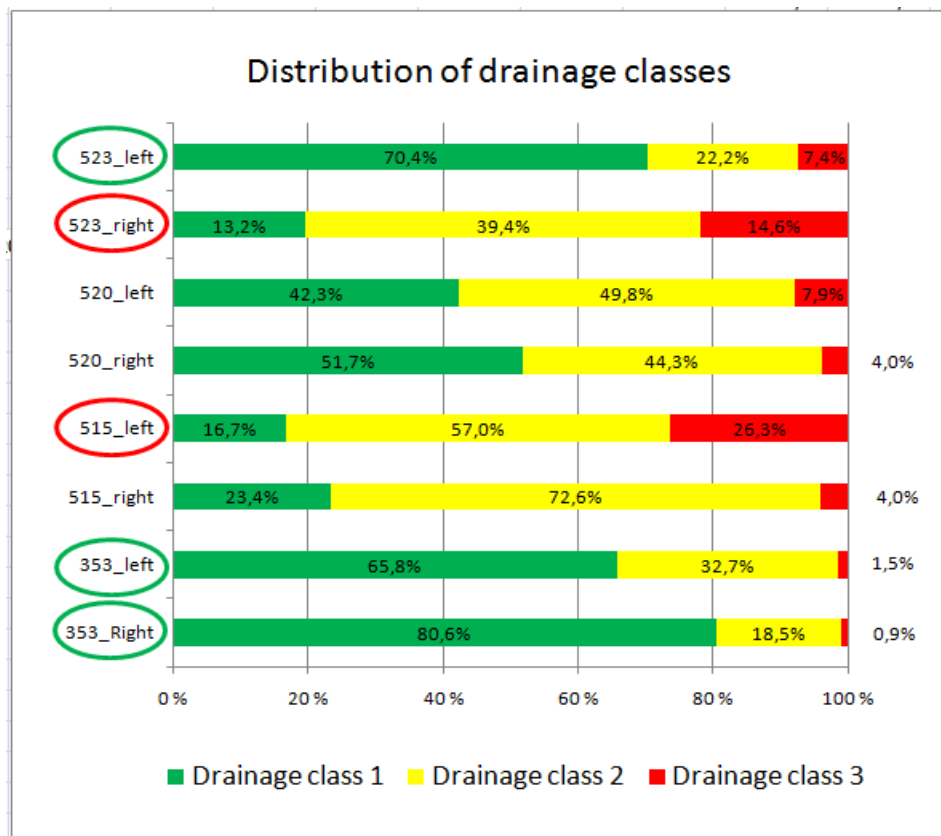


Figure 13. The distribution of drainage classes on the surveyed roads.

4.1.3 Statistical Analysis with Rutting and Roughness Values

A statistical analysis of the ditch and road structure depths compared to road condition (rutting and roughness values) was made for Roads 353, 520 and 523. In the calculations the road structure thickness was divided into three groups; where the road structure was thinner than 0.6m, where the road structure was between 0.6-1.0m, and where the road structure was thicker than 1.0m. Road sections with Class 1 drainage were left out of the examinations and only Classes 2 and 3 were analysed. The results from Road 353 are reviewed in the following paragraphs.

The statistical analysis of the survey data (Figures 14) showed that for thin roads (i.e. roads with a structure of less than 60cm) the depth of the bottom of the ditch had no effect on the road roughness or rutting values. This is likely to be due to the fact that thin roads only survive over good and drainable soils. If they had been constructed on poor soils or water permeable subgrades they would have collapsed a long time ago. This is why we do not see a good correlation between the ditch bottom level vs. road rutting and roughness

The results of the analysis clearly show that the ditch bottom depth level had the most significant effect on road performance when the thickness of the road structure is between 0.6 and 1.0m (Figures 15). This is the usual case with low volume roads in Nordic countries. The analysis also showed that both roughness and rutting values were higher if the ditch bottom level was higher than -0.3m. The median of the IRI-values, for example, is 15% higher when the bottom of the ditch is more than 0.3m higher than the bottom level of the road structure. Similarly the rut value median

for the same case is 35% larger, and the worst 10% values (the conditions that measure pavement lifetime) are roughly 3-4 times larger than the median values.

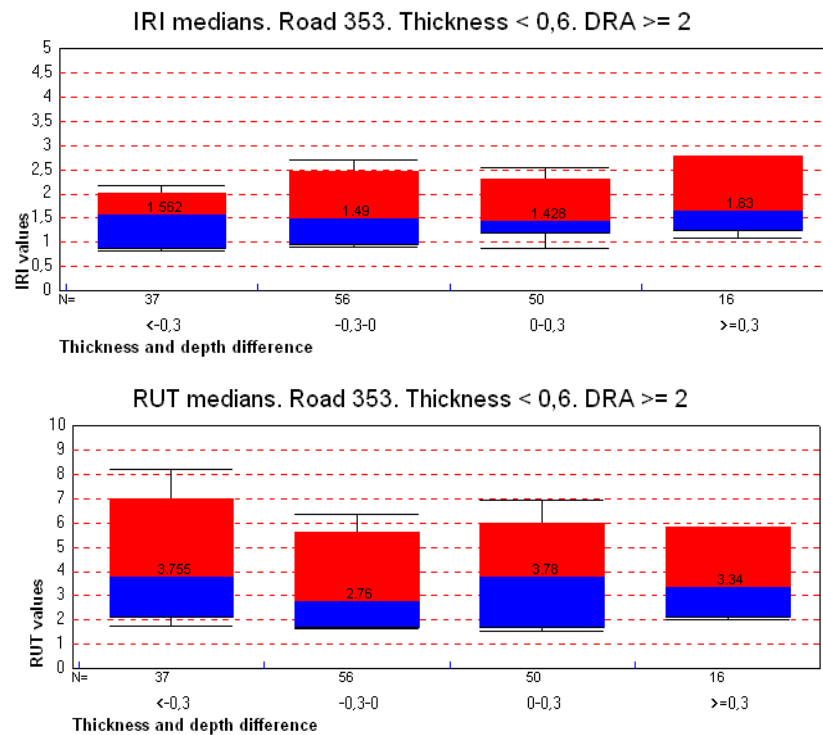


Figure 14. Road 353; distribution charts of rut depths and roughness values as function of the difference between the road structure depth level and ditch bottom level. The road structure thickness of the road in this chart is less than 0.6m. The horizontal axis classifies the different ditch bottom depth vs road structure bottom depth. The rightmost bar (≥ 0.3) represents those cases where the ditch bottom level is clearly above the bottom level of the road structure. The value inside the columns shows the median value of the class.

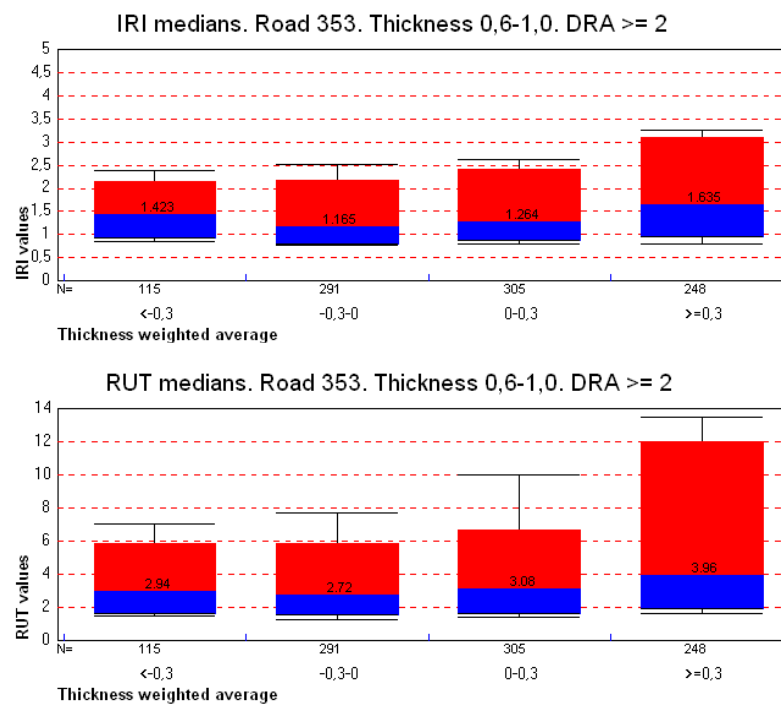


Figure 15. Road 353; distribution charts of rut depths and roughness values as function of the difference between road structure depth level and ditch bottom level. The road structure thickness

in this chart is 0.6 – 1.0 m. The horizontal axis classifies the different ditch bottom depth vs road structure bottom depth level. The rightmost bar (≥ 0.3) represents those cases where the ditch bottom level is clearly above the bottom level of the road structure. The value inside the columns showss the median value of the class.

Where the road structure is thicker than 1.0m, the ditch bottom level seems only to have a meaningful effect on the highest rut depth values as Figures 16 show. Here the median values of rutting and roughness increase slightly when the elevation of bottom of the ditch rises.

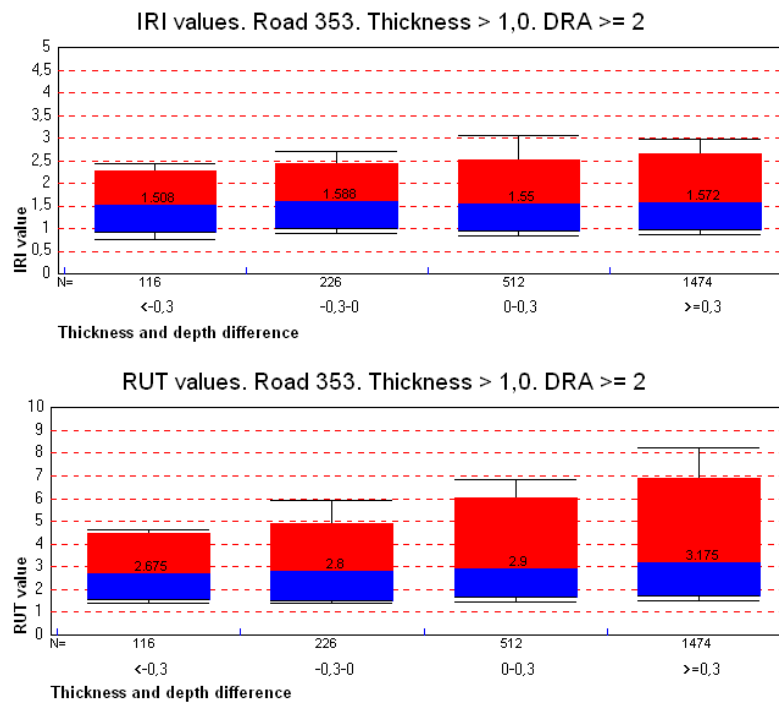


Figure 16. Road 353; distribution charts of rut depths and roughness values as function of the difference between road structure depth level and ditch bottom level. The road structure thickness in this chart is thicker than 1.0 m. The horizontal axis classifies the different ditch bottom depth vs road structure bottom depth level. The rightmost bar (≥ 0.3) represents those cases where the ditch bottom level is clearly above the bottom level of the road structure. The value inside the columns shows the median value of the class.

Based on the above analyses results it can be stated that maintaining a drainage system in good condition is especially important in sections where the thickness of the road structure is between 0.6 and 1.0m. When the drainage is in good condition, the road can be kept in good condition as seen by lower roughness and rutting values.

4.2 THERMAL CAMERA

Test results in the ROADDEX project have showed that the condition of access road culverts have a significant effect on the functionality of a road drainage system and to road performance as a whole. It is extremely important therefore that access road culverts are open and in good shape.

Unfortunately in most cases it is difficult to observe an access road culvert and its condition (i.e. if it is well working or clogged) from from a digital video, but it is relatively easy to observe one by means of thermal camera images. Usually the culvert stands out from thermal camera image as a

point warmer than the surroundings. Examples of access road culverts from both digital video, still images and thermal camera images are shown in Figures 17, 18 and 19.

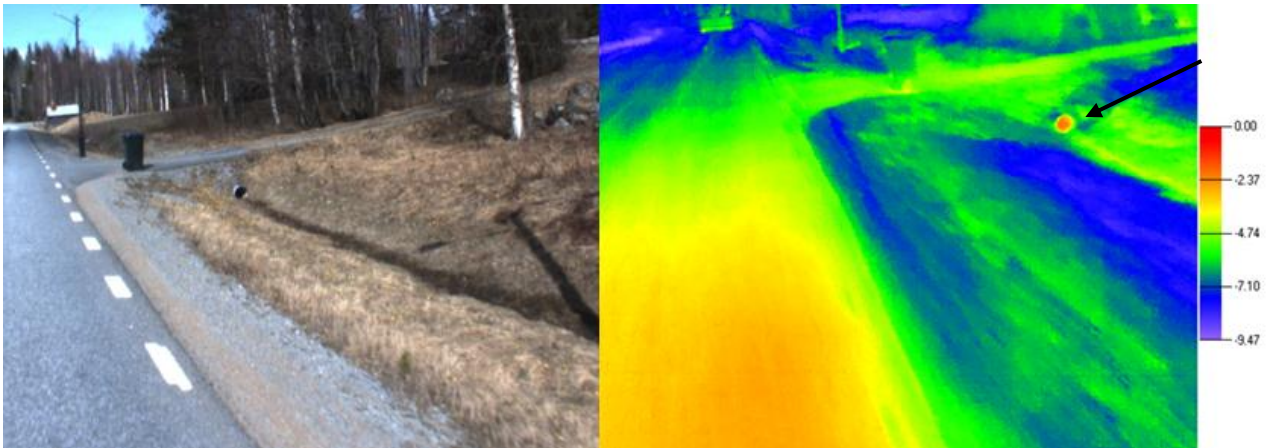


Figure 17. Road 353, chainage 22184m, right ditch; the access road culvert is in good condition (sufficient size and open, not clogged). The access road culvert can be seen in both digital video and thermal camera image. The location of the access road culvert is indicated with a black arrow.

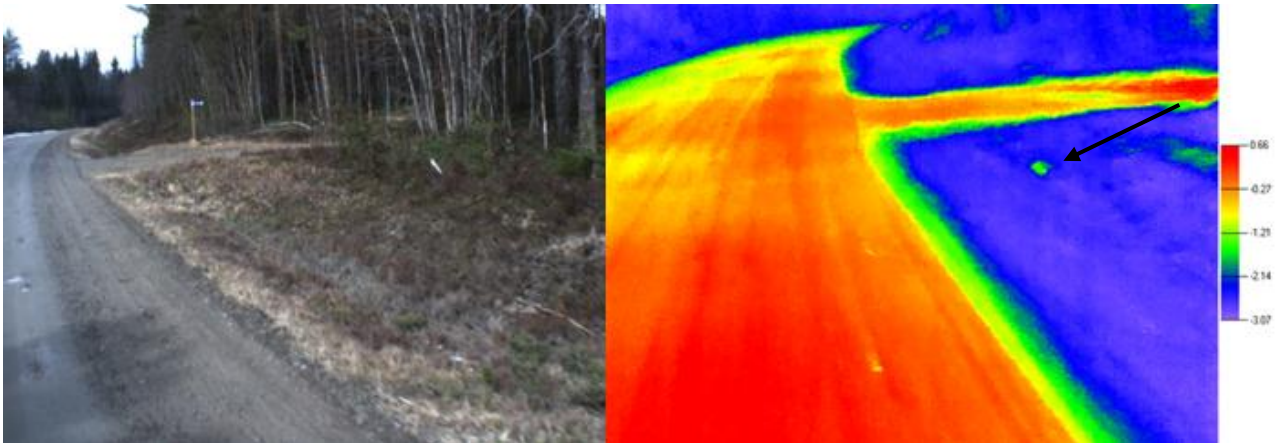


Figure 18. Road 515, chainage 5832m, right ditch; the access road culvert is almost clogged. The access road culvert can be seen in the thermal camera image, but not in the digital video. The location of the access road culvert is indicated with a black arrow.

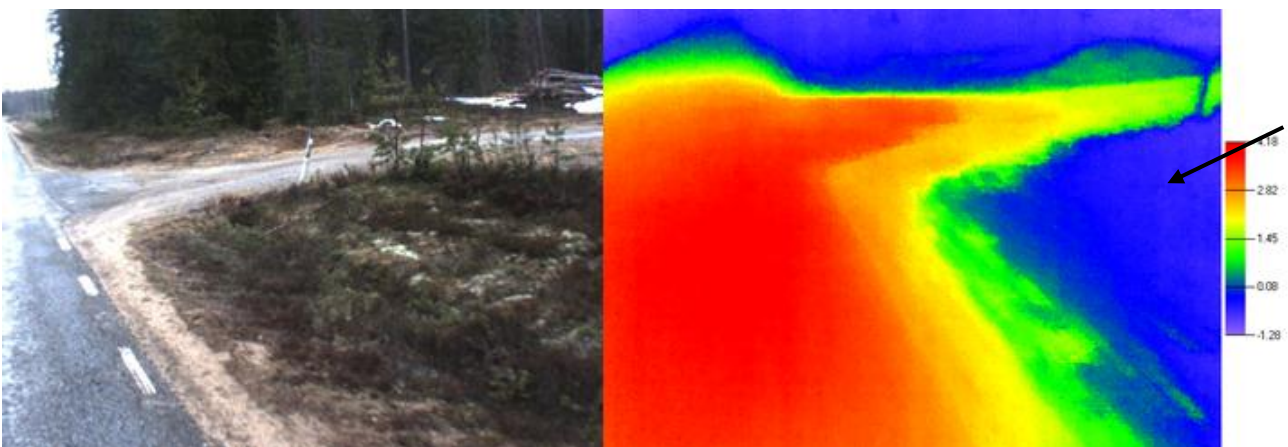


Figure 19. Road 514, chainage 2730m, right ditch; an access road without a culvert. The access road culvert cannot be seen either in the thermal camera image or in the digital video. The place where an access road culvert should be installed is indicated with a black arrow.

Digital video can almost always show sections where water is standing in the bottom of the ditch. Thermal camera images can confirm these observations with the water standing out as either colder or warmer than its surroundings. The temperature indicated in the thermal image is not however the actual temperature of the water, as the surface of the water can also function as a mirror and reflect infrared waves from surroundings (Figure 5). Examples of digital video still images and thermal camera images of water standing in the bottom of a ditch are shown in Figures 20 and 21.

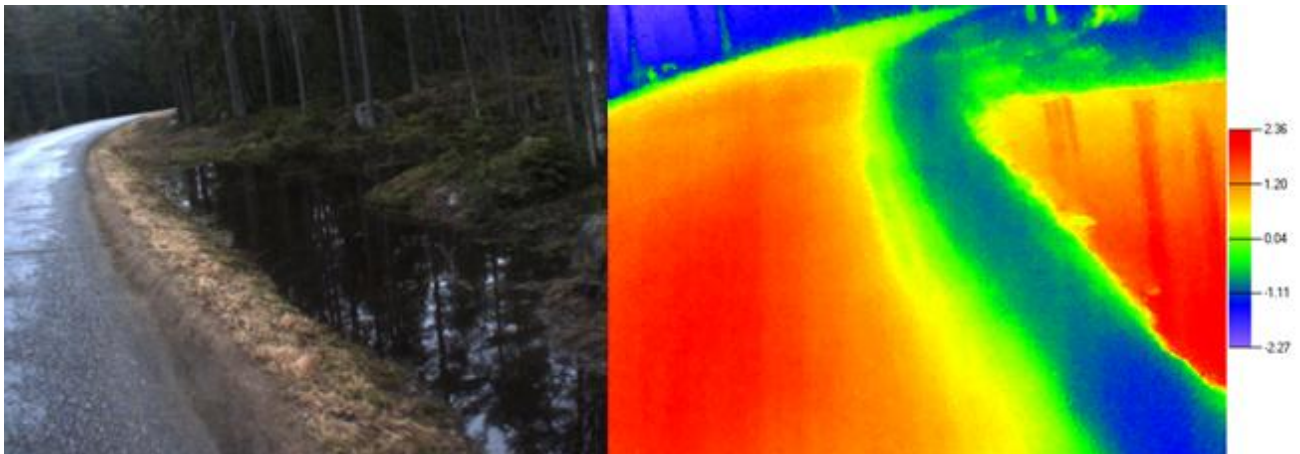


Figure 20. Road 514, chainage 6765m, right ditch; a large quantity of water is trapped in the ditch. The water surface acts partly as a mirror and reflects thermal waves from surroundings (see the tree trunks on the water surface in the thermal camera image).

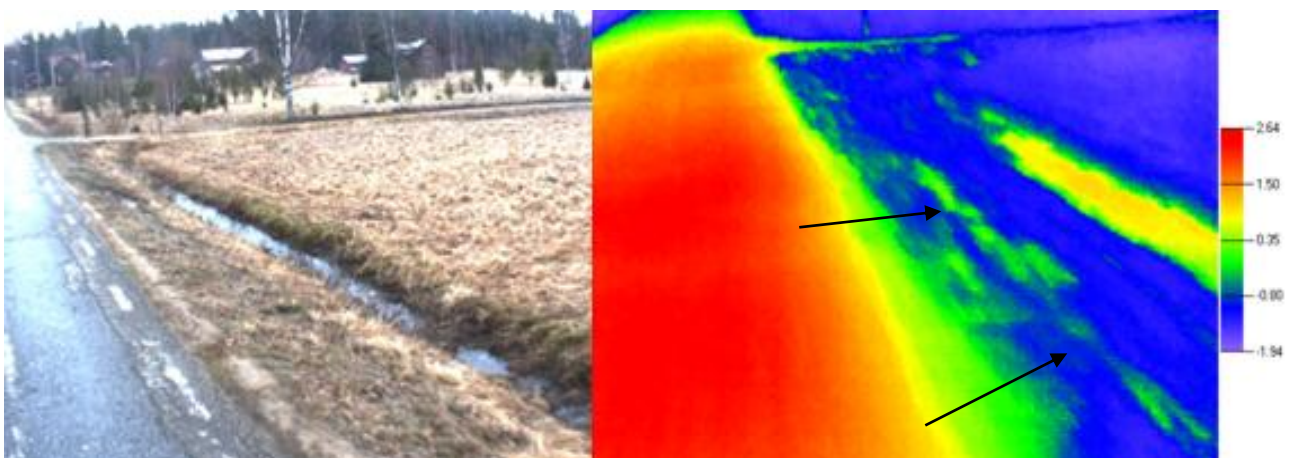


Figure 21. Road 514, chainage 7557m, right ditch; a small amount of water is standing in the ditch. The water surface is warmer in the thermal camera image. The thermal camera image also shows that the road is suffering from Mode 2 rutting and cold water is being released from the thawing frost (marked with black arrows). This is seen as cold areas (blue) in the middle of warmer areas (green).

There are also other targets that can be seen in thermal camera data but not in digital videos. Moisture which has been pumped up under heavy wheel loads can be observed in thermal camera images but not from digital video (Figure 22). Sections where the road structure is wet can also be more noticeable in thermal camera images. Figures 23 and 24 present cases where the water is pushing through the road structure or through the road shoulder. The water in these cases is being released from thawing frost.

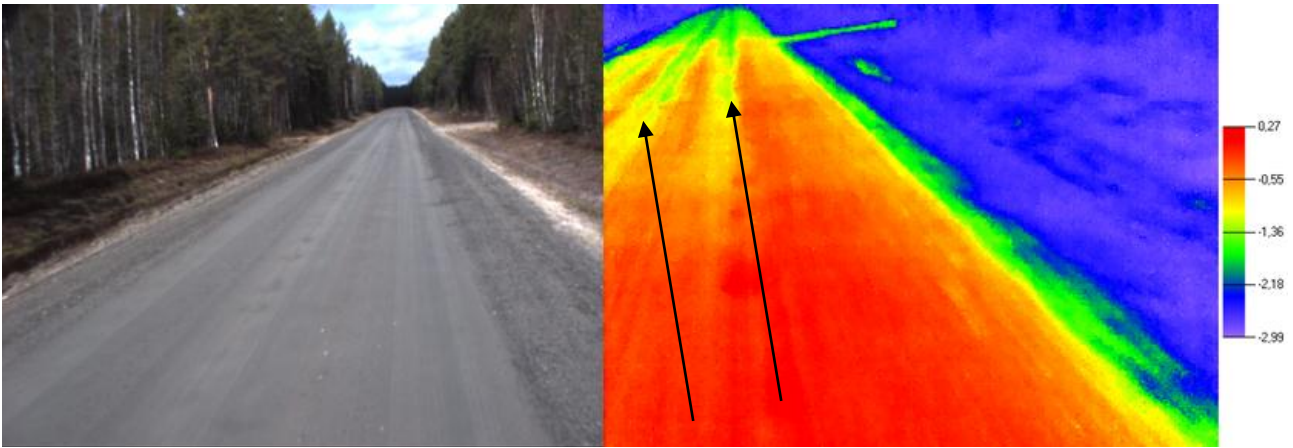


Figure 22. Road 515, chainage 4250m, gravel road section. Moisture, pumping through the road structure can be seen in the wheel paths (seen as colder lines in the thermal camera image, marked with black arrows).

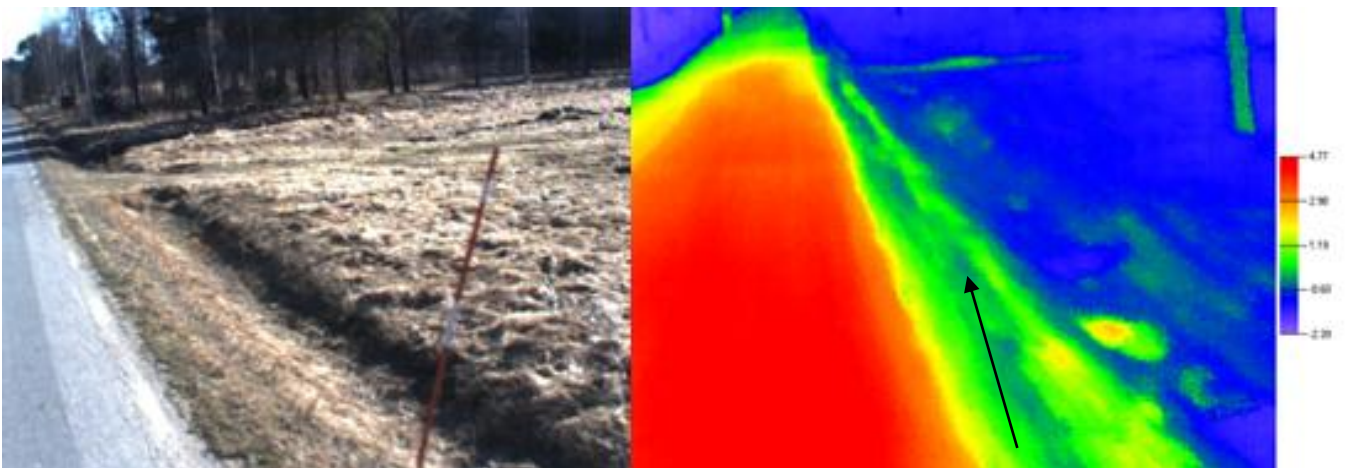


Figure 23. Road 568, chainage 9076m. Cold water, released from thawing ice, is being pushed through the inside road slope (colder section on the edge in the thermal camera image, marked with black arrow). This is a clear sign that the road is suffering from Mode 2 rutting.

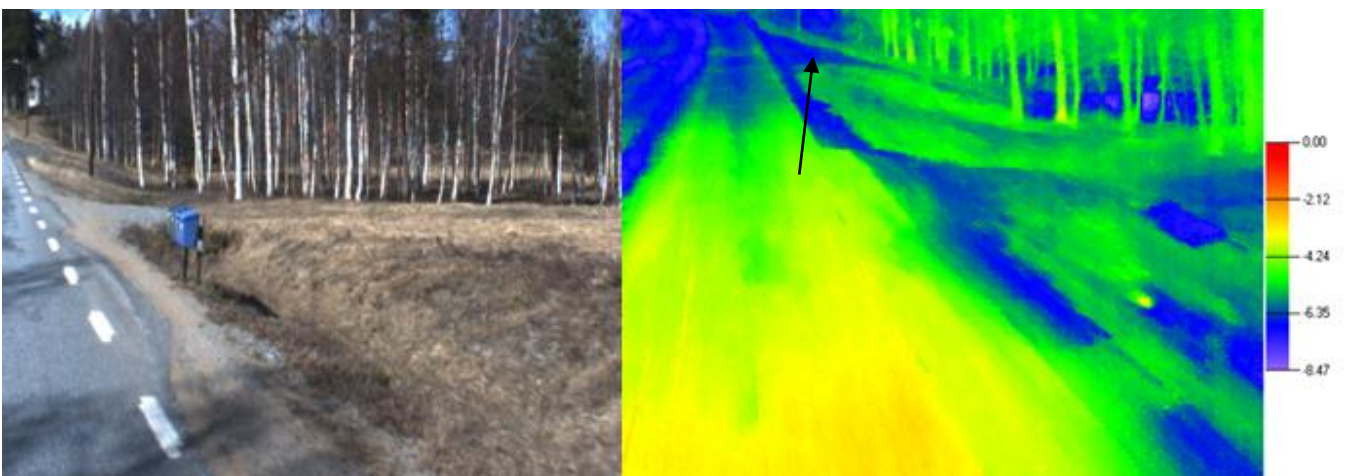


Figure 24. Road 353, chainage 22445m, right ditch. The thermal camera image shows that the road structure is wet (seen as blue in the image) and that water is pumping through the pavement. Water released from thawing ice is flowing along the inner slope towards the forest (marked with a black arrow). The data also shows a possible cable excavation close to road shoulder that is collecting water.

In some cases main road culverts can also be seen in thermal camera images. In Figure 25 a culvert under the road has been marked with black arrows. From the fact that the culvert is seen so clearly and is warmer than its surroundings, it can be concluded that culvert is not frozen and is working well. Figure 26 shows a plastic culvert that is installed too close to the pavement surface.

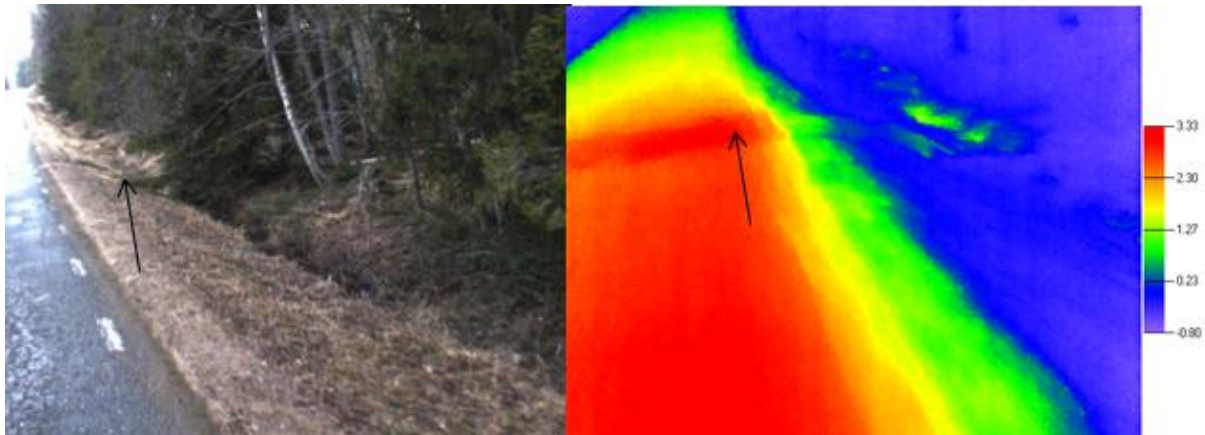


Figure 25. Road 514, chainage 7440m, left ditch; a culvert under the road is marked with black arrows.

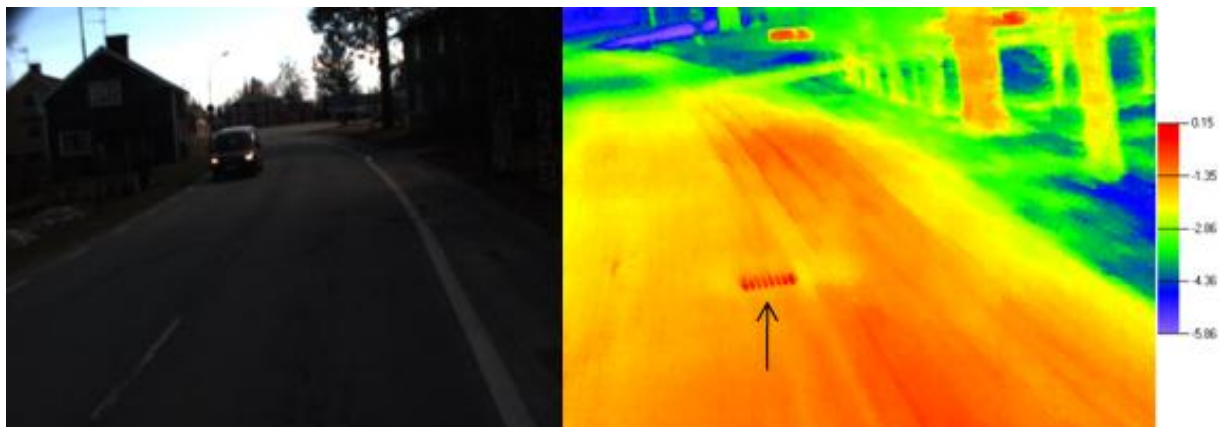


Figure 26. Road 353, point 23680m, left ditch; a plastic culvert under the road is set too high (marked with black arrow).

Figure 27 shows an example of a pothole being created in the road surface due to an ice lens developing in the road structure. When an ice lens thaws, it releases water causing the road structure to soften and a pothole is born.

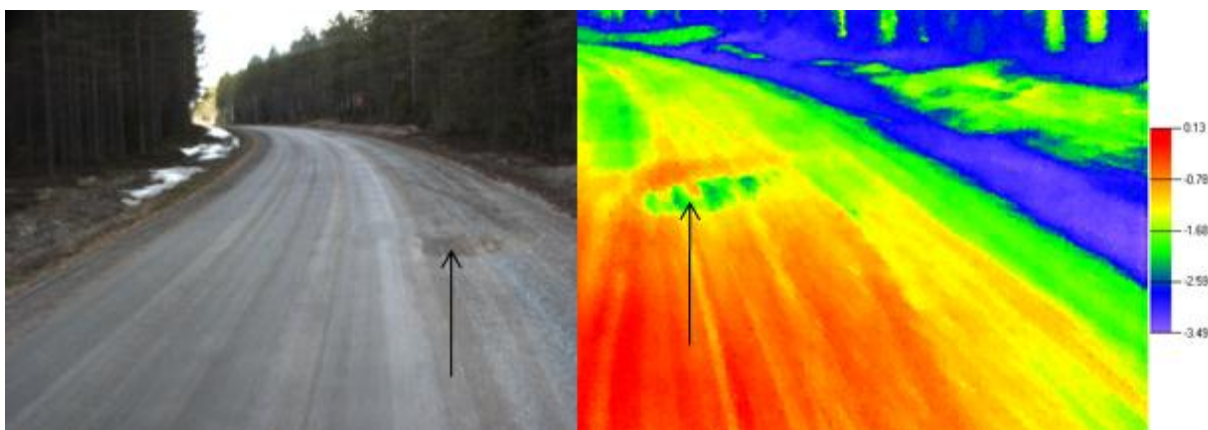


Figure 27. Road 515, chainage 5130m, pothole developing in the road surface.

In addition to visual inspection, the thermal camera results were analysed statistically. Differences in temperatures between the bottom of the ditch and the edge of the road were compared. For example in Road 353, for the most part, both of the ditches are 2-3 degrees colder than the edge of the road (Figure 28). According to results presented earlier in chapter 4.1.3 from Road 353, 30% of the left ditch and 40% of the right ditch were 20cm lower than the road structure. This information correlates well with Figure 28. When the ditch is deep enough and the drainage is in good condition the ditch is colder because well-working ditches and drier conditions cool faster in the night. It has not been possible so far to make any further conclusions or correlations regarding the significance of differences in temperatures between the edge of the road and the bottom of the ditch.

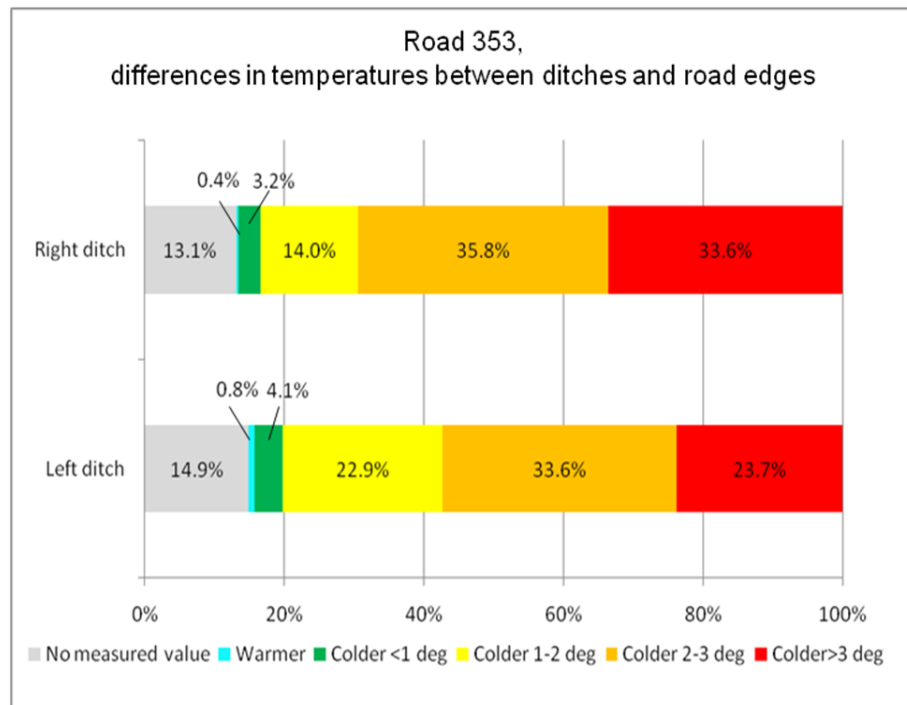


Figure 28. Road 353. Temperature differences between road edges and ditch bottoms.

5. SUMMARY AND CONCLUSIONS

This demonstration project has tested the possibilities of utilising the new survey techniques of laser scanner and thermal camera in drainage evaluations. According to the results obtained both techniques proved to be very useful.

The thermal camera is a very effective tool for detecting access road culverts and their condition (i.e. if they are well working or clogged). It is easy to find these culverts from thermal camera images even in cases where it is impossible to observe them from digital video. Usually the culvert stands out from the thermal camera image as point warmer than the surroundings. Access road culverts have a significant effect on the functionality of a road drainage system, and sections where there is a build up of water in ditches are easily observable from thermal camera images. Sections, especially on gravel roads where water is pushing through the road structure (e.g. cold water being released from thawing frost) can be distinguished using thermal camera imaging.

The laser scanner can be an effective tool in detecting verges and measuring the cross-section of a road. This can be particularly useful with GPR in measuring the ditch bottom level and road structure bottom level respectively. The results of the tests demonstrated that if the ditch bottom level is 20-30cm deeper than the bottom of the road structure, the drainage system should work well and rutting values should be substantially lower. Results of statistical analysis indicate that the condition of the ditches has the greatest significance when the thickness of the road structure is 0.6-1.0m. The analysis also showed that it is not possible to observe all of the factors affecting the condition of the drainage system with visual means. An example of this is the depth of ditch bottom compared to the base of the road structure. The depth of ditch bottom seems to have greater influence on the rutting values than roughness values. This is understandable as poor drainage can easily cause edge deformation which is measured by profilometer, but cannot be seen in the roughness values that are collected from wheelpaths.

It is concluded therefore that both the laser scanner and thermal camera could be very useful devices for use in drainage evaluations. Both methods can however be sensitive to local environmental conditions. Thermal camera measurements should only be carried out after sunset when solar radiation or shadows do not interfere with the measured results. Laser scanners are sensitive to fog, rain or dust.

The laser scanner could also provide valuable information to contractors. It may be possible to use laser scanner data during ditching and ditch improvement work to monitor the depth and inclination of the ditch.

It was found that the presence and condition of access road culverts can have a significant effect on the drainage condition of a road. In Finland the owner of access road and its culverts is usually a private person and the responsibility of maintaining the culvert belongs to that person. This situation creates problems as often these individuals neglect their responsibility with the result that the culverts may be in poor condition, too small or built incorrectly. This poses additional problems for the road drainage system which can lead to the road structure sustaining damage. In other ROADEX countries the responsible party for maintaining the access road and culverts is the road owner.

One practical problem discovered in the demonstration project was that the laser scanner and thermal camera measurements cannot be carried out at the same time. Laser scanner measurements should be done during the daytime and thermal camera measurements after

sunset. For this reason it is recommended that at least the laser scanner measurements should be carried out during drainage analysis surveys.



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Road Condition Management in the Northern Periphery
Road Condition Management of Low Traffic Volume Roads in the Northern Periphery
Winter Maintenance Practice in the Northern Periphery,
ROADEX Sub Project B Phase I Extended Summary and Conclusions
Winter Maintenance Practice in the Northern Periphery,
ROADEX Sub Project B Phase I State-of-the-Art Study Report
Generation of 'Snow Smoke' behind Heavy Vehicles

ROADEX II REPORTS (2002–2005)

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