ROADEX
Implementing Accessibility

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Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

European Union
European Regional Development Fund

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ROAD 16881 HUMALAMÄKI

Coarsening the base/sub-base course layers using only local stones

Demonstration Project Report

ABSTRACT

Rutting of the road surface due to the development of permanent deformations, both in the road structure itself and in the underlying subgrade, is in most cases the dominant distress mechanism on low volume roads of the Northern Periphery area.

From the road users' point of view rutting both lowers driving comfort and reduces traffic safety. This is particularly the case when surface water is trapped in ruts, thereby increasing the risk of aquaplaning in summertime and of icing in the wheel path in winter when temperatures fall below 0°C. In addition, rutting can also be very harmful to the structural condition of the road, as it speeds up water infiltration into the road structure, increases the effects of dynamic wheel loads etc.

Rutting can develop in a road for a number of reasons. It may develop in the structural layers due to poor quality material, or as a result of poor drainage making the material more susceptible to permanent deformations. It may also develop in a weak subgrade material if the overall thickness of the structural layers is low. This is a very typical situation on the low volume roads of the Northern Periphery area, particularly during the spring thaw if the subgrade material is frost-susceptible. Rutting mechanisms are discussed in greater detail in the ROADEX reports available at www.roadex.org, together with a new method of classifying rutting modes.

This report describes an innovative rehabilitation method carried out on a low volume road section of Road 16681 Humalamäki in Jyväskylä, Central Finland. The method is not especially designed to improve a road suffering from rutting. Rather the aim is to carry out an overall improvement of the road. The method consists of coarsening the base/sub-base course layers using local stone from the road and its surroundings, and improving the drainage. The geometry and forward visibility on the road can also be improved at the same time. In the case of the Humalamäki road described in the report, the depth of base course layer was observed to be about 0.10 metre deeper following the rehabilitation.

KEYWORDS

Rehabilitation, low volume road, drainage, permanent deformation, Northern Periphery

PREFACE

Tampere University of Technology has been responsible for the design, follow up and documentation of a number of demonstration sites carried out under the ROADEX project task D4 ‘Rutting, from theory to practice’. These demonstration sites showcase innovative solutions to various types of rutting problems on low volume roads of the Partner areas. This report presents the early results from the demonstration site located on Road 16681 Humalamäki in Jyväskylä, Central Finland. On this site the Tampere University of Technology was only responsible for collecting information about the method. The whole road section was rehabilitated using the so called “Tirkkonen method”.

The report has been compiled by Iikka Hyvönen and Nuutti Vuorimies under the supervision of Pauli Kolisoja, all from the Laboratory of Earth and Foundations Structures at the Tampere University of Technology, TUT.

Special thanks are given to Heikki Parviainen from the Centre of Economic Development, Transport and the Environment of Finland. Without his open-mined attitude the report would not have been realised. Equally important has been the very co-operative attitude of the staff of the contractor, especially that of Pasi Tirkkonen.

Petri Varin from Roadscanners Ltd organised the GPR measurements and analysed the results. Ron Munro from Munroconsult Ltd checked the language.

Finally, last but not least, the authors would like to thank the ROADEX IV Project Steering Committee for their guidance and encouragement during the 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 "Implementing Accessibility" from 2009 to 2012.

Figure 1.1 *The Northern Periphery Area and ROADEX IV Partners*

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

The aim of the project was to implement the road technologies developed by ROADEX on to the partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland. The project was awarded NPP funding in September 2009 and held its first steering Committee meeting in Luleå, November 2009.

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

D2 - “Road friendly vehicles and Tyre Pressure Control”, lead manager Pauli Kolisoja

D3 - “Forest Road policies”, lead manager Svante Johansson

D4 - “Rutting, from theory to practice”, lead manager Pauli Kolisoja

D5 - “Roads on Peat”, lead manager Ron Munro

D6 - “Health and Vibration”, lead manager Johan Granlund

1.3 D4 “RUTTING, FROM THEORY TO PRACTICE”

The aim of the “Rutting, from theory to practice” task was to demonstrate the practical applications of innovative ROADEX solutions in the rehabilitation of low volume roads suffering from permanent deformation problems in the Partner areas. The leading idea in the demonstrations was to use ‘fit for purpose’ solutions selected after a sound analysis and understanding of the reasons behind the problems encountered on the individual sites. As the name of task suggests, the main focus was on those problems that appear in the form of permanent deformations, i.e. rutting, which can be the result of different forms of underlying mechanisms. These mechanisms are dealt with in greater detail in a range of ROADEX reports available at www.roadex.org.

The first stage in the problem analysis of each site was to develop a clear understanding of the deterioration mechanisms at work using simple, low cost means of investigations, such as visual observation. This was then supplemented, when required, by Ground Penetrating Radar (GPR) measurements, easy to use site investigation methods, e.g. the Dynamic Cone Penetrometer (DCP) test, and some basic laboratory tests like grain size distribution analysis and Tube Suction (TS) tests. More sophisticated laboratory investigations were not used as these are seldom available to the ROADEX Partners due to the limitations of both budget and time.

All of the demonstrations were carried out as part of scheduled road rehabilitation projects by the local ROADEX Partners, and in practice this meant that some operational adjustments were necessary to suit their needs, i.e. none of the demonstrations were carried out just for the ROADEX project alone. This fact naturally set some limitations for the design of the demonstrations, particularly with regard to the available time for preliminary investigations, but this was accepted to be a normal fact of life in practice for most Partner roads operations, and in fact added realism to the work.

2. DESCRIPTION OF ROAD

2.1. LOCATION

Road 16881 is located in the middle part of Finland about 15 kilometres west from Jyväskylä. The location of the road is shown in Figure 2.1.

Figure 2.1 *The location of Road 16881 (Google Maps)*

2.2. BACKGROUND

This road was chosen by The ELY Centre (Centre for Economic Development, Transport and the Environment) as a pilot project to evaluate a rehabilitation method by a private entrepreneur Pasi Tirkkonen. The road section at Humalamäki was chosen as the test site due to the large amount of rock material in the road and its surroundings. ROADEX was not involved in the choice or design of the rehabilitation method. The sole role of ROADEX was to monitor the rehabilitation works on the road.

2.3. TRAFFIC

Road 16881 passes through the village of Humalamäki. The traffic volume on the road was low and mainly that of the local inhabitants. The Annual Average Daily Traffic (AADT) at the time of the work was 134 vehicles per day.

2.4. ROAD STRUCTURE

Road 16881 is a 7.1 kilometres long unpaved gravel road. The road is a typical gravel road of Central Finland with all of the typical features: narrowness, hilliness and lots of curves. The road has also been used as a World Rally Championship special stage in the 60’s and 70’s. It was known for its many “jumps”. The section includes a level railroad crossing at 1 km from the beginning of the road.

2.5. LOCAL LANDSCAPE AND TERRAIN

The landscape is generally hilly. The road passes through a variable landscape of hills, shady spruce forest and broad-leaved forests, as shown in figures 2.2 and 2.3. The terrain is mostly hard morainic soil and most of the hills are remnants of undulating bedrock. The range of topography results in the road having a range of features such as side sloping ground and bedrock hummocks. The terrain is also very rocky, a main reason why the road was chosen to be a test project for the rehabilitation method. Figure 2.4 shows an example of the amount of rock removed from the road during the rehabilitation.

***Figure 2.2** Shady spruce forest*

***Figure 2.3** Broad-leaved forest and exposed bedrock on the right*

***Figure 2.4** Rock materials removed from the road area*

3. DATA COLLECTION / AVAILABLE DATA

3.1. FIELD INVESTIGATIONS

3.1.1. Site Investigation

The overview of the road was carried out on 17 June 2010 and a video of the whole road was taken as a record of road conditions on the day of the investigation.

3.1.2. GPR Measurements

A Ground Penetrating Radar (GPR) survey was carried out using Roadscanners three dimensional 3D-radar equipment. Measurements were carried out in two directions in summer 2010 (23rd June) and winter 2012 (29th February).

GPR is a non-destructive method to investigate road structures. It is based on short electromagnetic pulses which are transmitted into the road. These travel, reflect and refract as they meet changes (e.g. surface layers) in dielectric properties. GPR equipment consists of a transmitter and receiver electronics, which are connected to an antenna and a central unit to control the data collection and store the collected data. Through the antenna an electromagnetic pulse is sent into the ground. A part of the energy of the pulse reflects back when there is a change in material electrical properties, and a part goes through this material and reflects from the next surface, etc. Electric conductivity and dielectric value are the main parameters that affect the GPR signal. The signal attenuates as a function of travel time due to geometrical spreading, scattering, reflections and thermal loss. A high amount of fine materials and salt in the structure increases electric conductivity. This weakens the GPR signal and diminishes its ability to penetrate further. The GPR data collection system records travel time and amplitude of the pulses, which are then displayed. When these measurements are repeated, it is possible to present a continuous profile of the analysed structure. [1]

Longitudinal profiles of the road were prepared from the GPR 3D-radar measurements between chainages 1/1900 - 1/2100, 1/3050 - 1/3250, 1/4725 - 1/4925, 1/5575 - 1/ 5775 and 1/6750 - 1/6950 before and after rehabilitation. A profile was also prepared for the road section between chainage 1/1600 - 1/1800 from the first measurement the rehabilitation. Five cross-sections were also analysed from the 3D-radar data for each longitudinal profile. The interpretations of these cross-sections are shown in Appendix 1. Due to the fact that the roadline was changed significantly during the rehabilitation work, especially on the first part of the road, the chainages along the road are not exactly the same before and after rehabilitation work. For this reason the cross-sections are not directly comparable to each other.

It was only possible to reliably define the depth of the base course from the GPR data collected in summer 2010, so the depth of the road structure was not confirmed before the rehabilitation. According to the GPR analysis the thickness of the wearing and base course layer was generally 0.20 – 0.25 m, but thinner between chainages 1/5575 - 1/5775 and 1/6750 - 1/6950.

3.2. LABORATORY INVESTIGATIONS

3.2.1. Grain Size Distribution

The changes in the grain size distribution of the base/sub-base course layer between the consecutive milling cycles were measured at four selected points. The samples were taken by the contractor. Point I only had the sieving result from the old road structure before milling. The selected points were at chainage 1700, 4825 5675 and 6850. The grain size distribution changes from the chainage 6850 are shown in figure 3.1. The all of the results are attached in appendix 2.

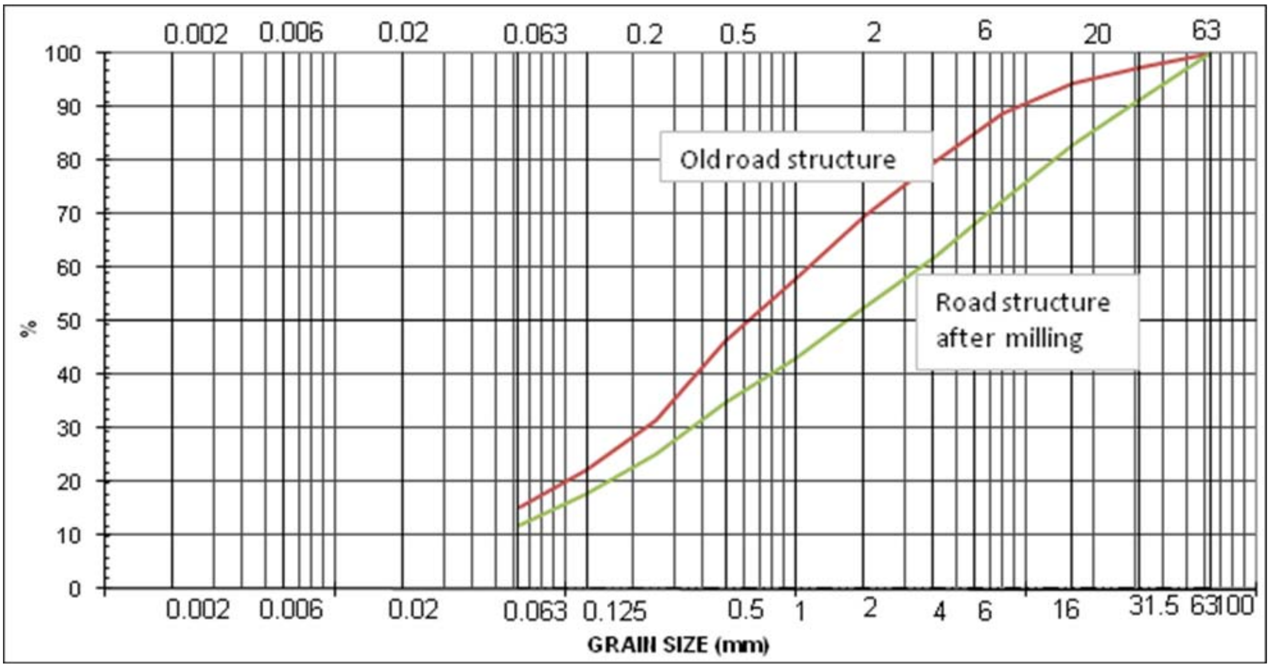

Figure 3.1 *Changes in the grain size distribution from the chainage 6850.*

The grain size distribution is the most common laboratory test in estimating the properties of materials. The grain size distribution is determined by sieving. The test gives information on the amount of fines content and the particle size distribution curve. The amount of fines content and particle size distribution have an effect on the mechanical properties of the material and the results obtained can also give information for possible rehabilitation options during the design stage. [2]

Figure 3.2 *Grain size distribution is determined by sieving [2]*

4. REHABILITATION SOLUTION

The rehabilitation solution was selected by The Centre for Economic Development, Transport and the Environment. The plan was jointly prepared with the private entrepreneur Pasi Tirkkonen. This contractor had developed his own method of rehabilitating a road by removing rocks from the road and crushing them into a new base/wearing course layer. Removing the large rocks from the road homogenizes the road structures, typically down to 0,5 metre deep. The “Tirkkonen method” then crushes rocks up to 400 mm in diameter for use in the road layers. At the same time the drainage of the road is put in order. The full method is described in section 6.3.

As a part of the plan, it was also decided to improve the geometry and forward visibility of the road. Some of the tight bends were to be straightened and rock removed from the inside of the bends to improve the visual clearance. Later it was decided that one steep hill was also to be improved by reducing its gradient to obtain good quality aggregate for use in the production of asphalt.

5. DESCRIPTION OF THE REHABILITATION WORKS

The rehabilitation works were ordered by the Centre for Economic Development, Transport and the Environment. The contractor was the private entrepreneur Pasi Tirkkonen. This contractor was the only one in Finland who had the equipment to carry out the type of rehabilitation specified, ie coarsening the base/sub-base course layers using local stone from the road and its surroundings. The purpose of the demonstration project was to represent the suitability of "Tirkkonen method" for rehabilitation works on gravel road.

The estimated duration for the rehabilitation works was from 19th of July 2010 to 30th of September 2010. However due to the heavy quarrying operations required on the road and the unusually rainy August in 2010 the works were extended to June 2011. The rehabilitation works were suspended/discontinued during the winter months.

5.1. WORKING METHODS

The rehabilitation method comprised surveying and four construction stages/phases.

Surveying: The surveying was carried out by a specially equipped road grader. The shape of the road was measured in 3D data. The compactor mounted on the grader was used to estimate the bearing capacity of the road. Based on these measurements, and some additional information, the contractor designed the rehabilitation works [3].

Stage one: All humus soil (organic material) was removed from the old road surface and road area. Trees on the road area were also cut down. Where the existing road was narrow a further area was cleared for the new road width. Temporary road lanes were occasionally provided off the new road line to keep traffic running through the site, as shown in Figure 6.1

Figure 6.1 *Cleared road area and temporary road*

Stage two: Rocks larger than 300 - 350 mm were removed from the old road structure by a backhoe excavator as shown in Figure 6.2. In this way the old road structure was homogenized typically down to 500 mm deep. Rocky material was also excavated from the ditches and any widening areas. Rocky material was put to the side of the road. Depending of the amount and size of the rocks, the rocks were mechanically crushed by other means, e.g. rammer and jaw crusher.

Figure 6.2 *Digging up rock material from the old road structure*

Stage three: The rock material produced in Stage two was spread on the road by road grader. Then the rock material was crushed and milled with a crusher mounted on the back of a tractor as shown in Figures 6.3 and 6.4. Rocks up to 300-350 mm rocks can be crushed quite easily [3]. Larger rocks can also be crushed but the operation takes more time and wears out the machine quicker [4]. The crusher used in this case was manufactured by Profiteam Holzer GES.m.b.H (PTH). The crusher was later modified by Tirkkonen. [3] This crusher mills and mixes stones down to a depth of 300 mm. The first mixing and crushing produces a material with maximum grain size of 55 - 65 mm [4]. The mixed material can be milled several times until the specified maximum grain size is achieved. Usually the specified maximum grain size is 32 - 55 mm. The crusher is stated to be able to work with any kind of material, regardless of the hardness of the stone.

Figure 6.3 *Crushing the rock material with PTH Crusher*

Figure 6.4 *Crushing chamber*

Stage four: The road was shaped and finished to the required crossfalls with a grader and compactor as shown in Figures 6.6 and 6.7. The ditches were also finished with the excavator to ensure that the drainage worked and the road was kept dry.

The compactor gave the finishing touch to the road following which the road achieved the specified bearing capacity and was opened to full traffic. The final result was a ready and easy-care road as shown in figure 6.8. This photograph was taken on 8 June 2011.

The “Tirkkonen method” offers a number of benefits. Materials for grading operations do not need to be purchased from elsewhere. The method is more ecologically sustainable and competitive than traditional construction measures, especially in challenging sites which are only passable with extremely sturdy vehicles. Where the method is used the whole road is usually rehabilitated and the drainage is put in good order. As a result the whole road will be in a good condition with the expectation of low maintenance costs for a long time.

Figure 6.6 *Finished shaping of the road*

Figure 6.7 *The grader and mounted compactor*

Figure 6.8 *Ready and easy-care road (8.6.2011)*

5.2. PROBLEMS ENCOUNTERED ON SITE

The Tirkkonen method can be sensitive to weather conditions. Light rain does not cause a problem, but persistent rainfall and short heavy rainstorms during the works can disrupt the work. Water on the road during the homogenization can soften the surface of the road and make it plastic/muddy/sludge. The road then becomes slippery and unusable. The works had to be discontinued for two weeks in August 2010 due to heavy rain. The rehabilitation works also had to be suspended/discontinued during the winter months as the winter 2010-2011 arrived much earlier than normal.

5.3. OTHER REMARKS

Before the rehabilitation works started it was known that there were places where the bedrock was near the road surface and needed to be removed by quarrying. It was also decided to improve the forward visibility along the road by quarrying the steep hills. During these operations the bedrock present was found to be of such good quality that it was decided to quarry more material for the use of the ELY Centre of Central Finland. The facilities for the blasting and crushing were transported to the area and a storage area created for the crushed aggregate. These operations are shown in Figures 6.9 to 6.16.


Figure 6.9 *Building the storage area*


Figure 6.10 *Blasted bedrock*


Figure 6.11 *Crushing*


Figure 6.12 *Quarrying on site*


Figure 6.13 *Quarrying on site*


Figure 6.14 *Blasted bedrock*


Figure 6.15 *Lowered hill*


Figure 6.16 *Filled up storage area*

6. SITE MONITORING

6.1. GPR MEASUREMENTS AND WET SIEVING

GPR measurements were carried out before the rehabilitation and repeated again later during winter time to ensure better signals. The main object of the measurements was to determine the depth of the layers. The results from the GPR measurements are shown in the appendix 1. Appendix 1 also contains some photographs taken by video camera of the GPR survey vehicle on 23rd July 2010. After the rehabilitation the depth of the base course layer varied between 0.20 and 0.40 m and the average depth of the base course layer for the analysed sections was 0.27 – 0.35 m. After the rehabilitation the wearing and base course was typically 0.10 metre thicker than before the rehabilitation. After the rehabilitation the depth of the road structure varied between 0.40 and 0.85 m and the average depth of the road structure for the analysed sections was 0.57 – 0.75 m.

The grain size distributions before and after the rehabilitation work are shown in appendix 2. Following the rehabilitation work the fines content of the aggregate was 3 - 8 % smaller than before. Also the shape of the grain size distribution curves was improved.

6.2. RECOMMENDATIONS FOR FUTURE MONITORING

Monitoring is an important part of this test project. It will be the basis for any final conclusions that can be reached on the suitability and effectiveness of the “Tirkkonen method”. In this case it is recommended that seasonal changes should be monitored through site visits. Earlier ROADEX reports have shown that the greatest amount of road damages takes place over the few days, or the few weeks, during the spring when the frost is thawing. It is therefore recommended that inventory photos are taken during future site visits for record purposes and drainage checked for any damaged sections.

It is also recommended that the 3D-Radar survey is repeated to provide a comparison of how much the new road structure changes after about five years.

Future rehabilitation works with “Tirkkonen method” could use laser scanning surveys to give an indication of how much material was transferred during the rehabilitation work. Laser scanning surveys will however require a site where the roadline will not radically change. The first survey should be done in early spring before vegetation obscures the ground profile.

7. CONCLUSIONS

This report briefly describes a new rehabilitation work method carried out on a low volume road section of Road 16681 Humalamäki in Jyväskylä, Central Finland. The method is not especially designed to improve a road suffering from rutting. Rather the aim is to put the whole road in good condition. The rehabilitation method consisted of coarsening the base/sub-base course layers using local stone from the road and its surroundings and an improvement of the road drainage. The geometry and forward visibility of the road is also normally improved during the work.

Persistent rainfall and short heavy rainstorms during the works can disrupt the rehabilitation work. Water on the road during the homogenization can soften the surface of the road and make it plastic or muddy. Where the existing road is narrow and a further area is cleared for the new road width, temporary road lanes may be needed occasionally to keep traffic running through the site.

The depth of base course layer was observed to be about 0.10 metre deeper after rehabilitation than before it. After the rehabilitation work the fines content of aggregate was 3 - 8 % smaller than before. As the grain size of the base course aggregate was also better after the rehabilitation it can be assumed that the resistance of the road against rutting will probably be markedly better.

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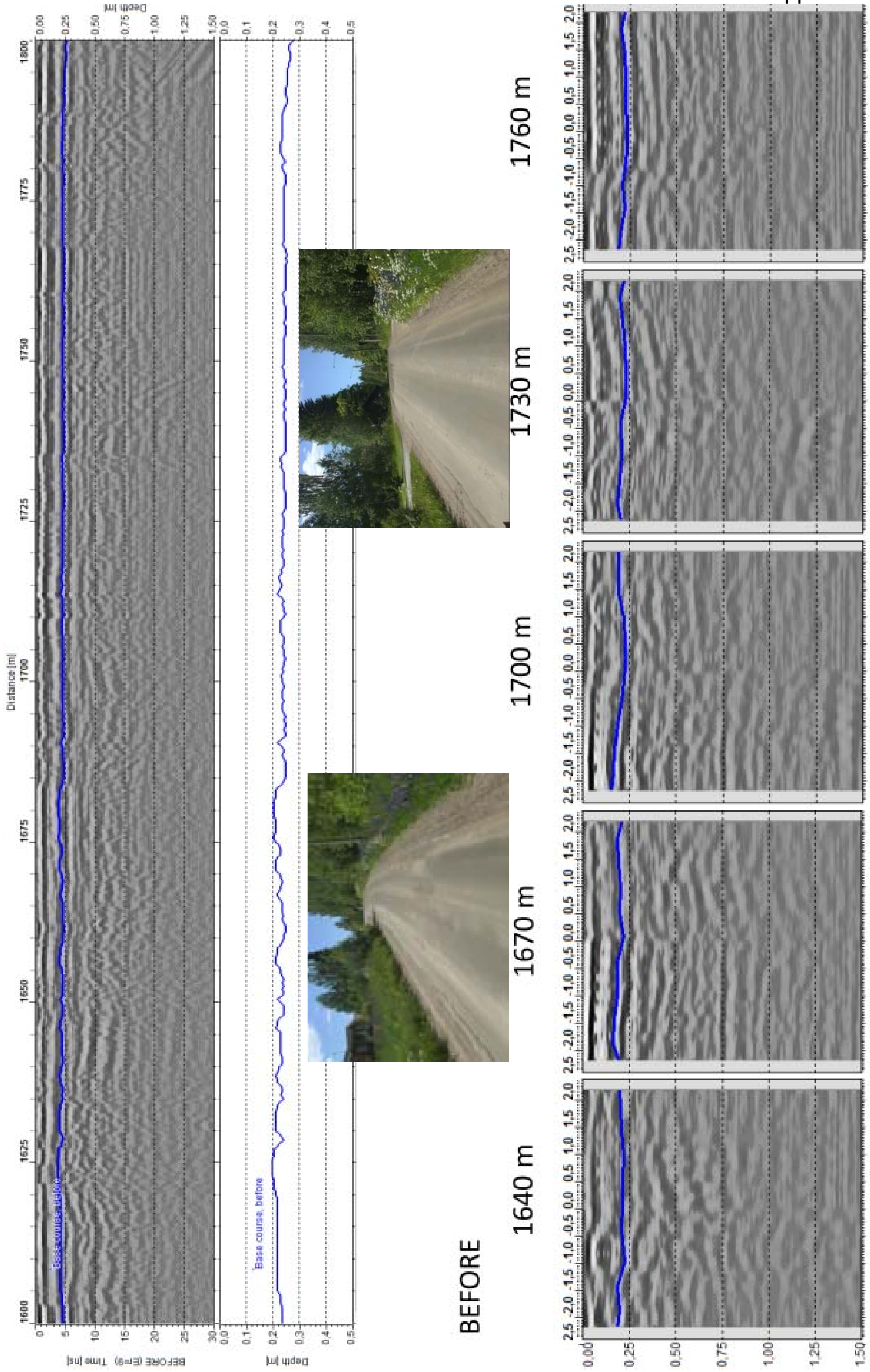
APPENDIX

Appendix 1. 1/11



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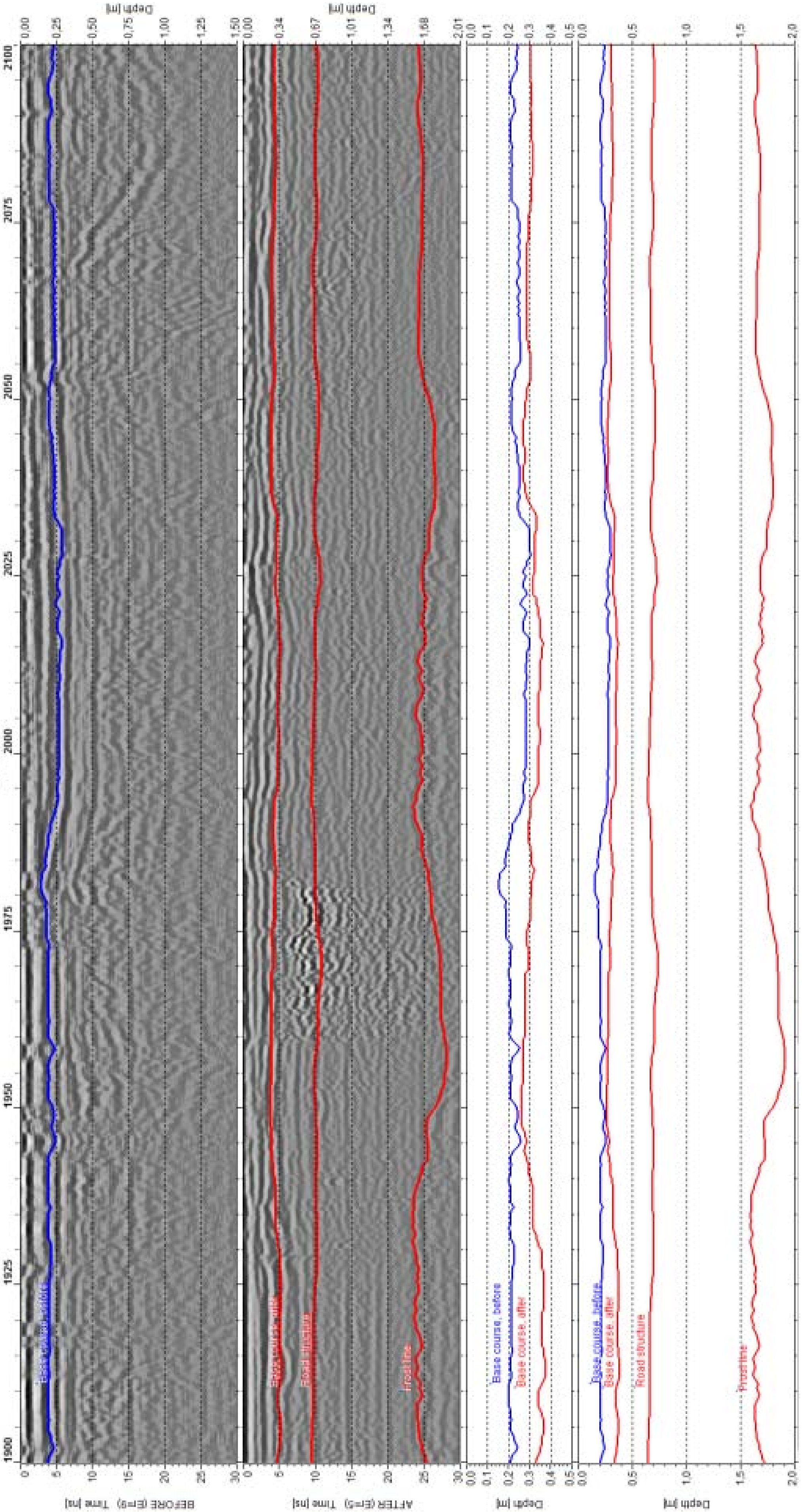

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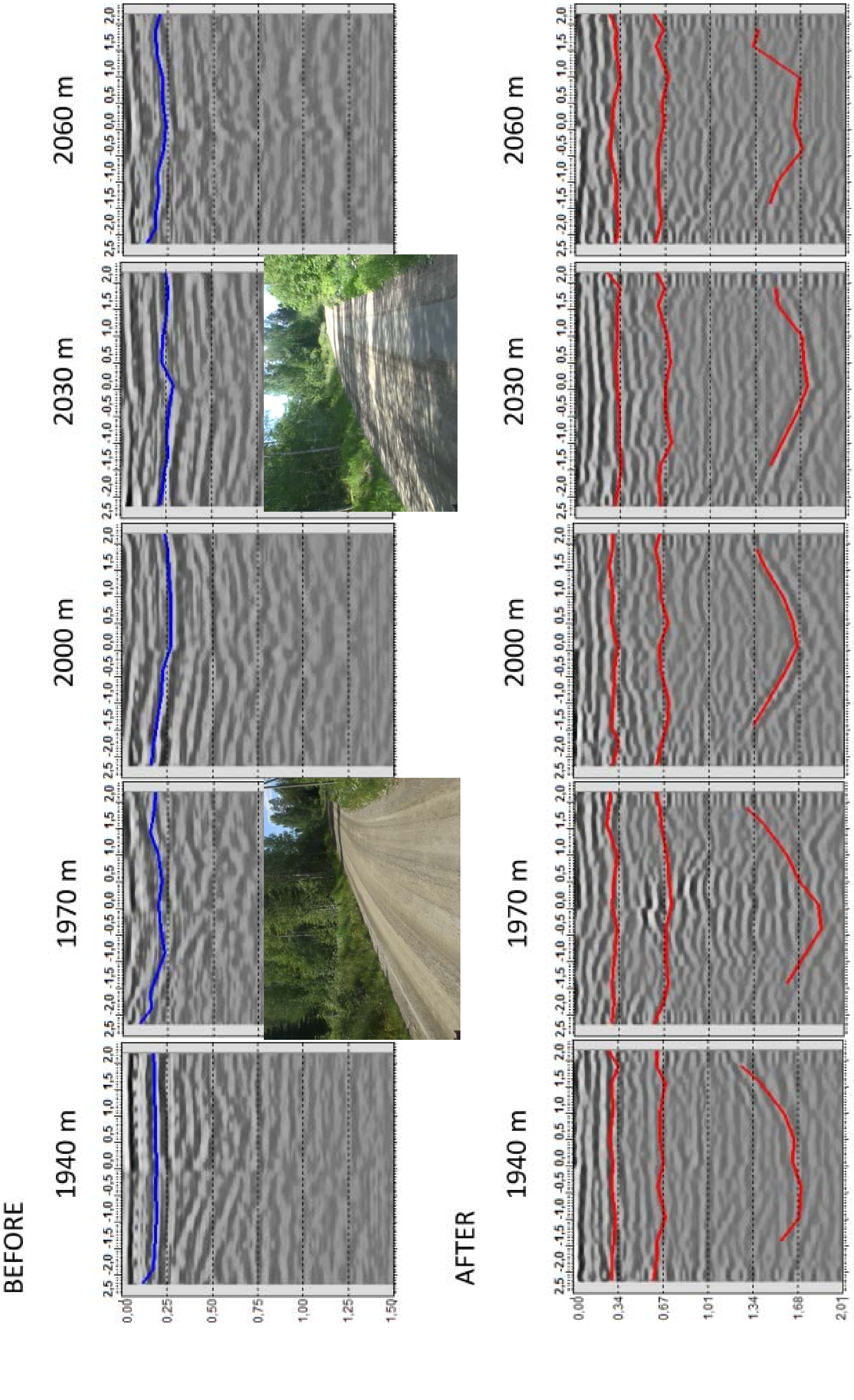

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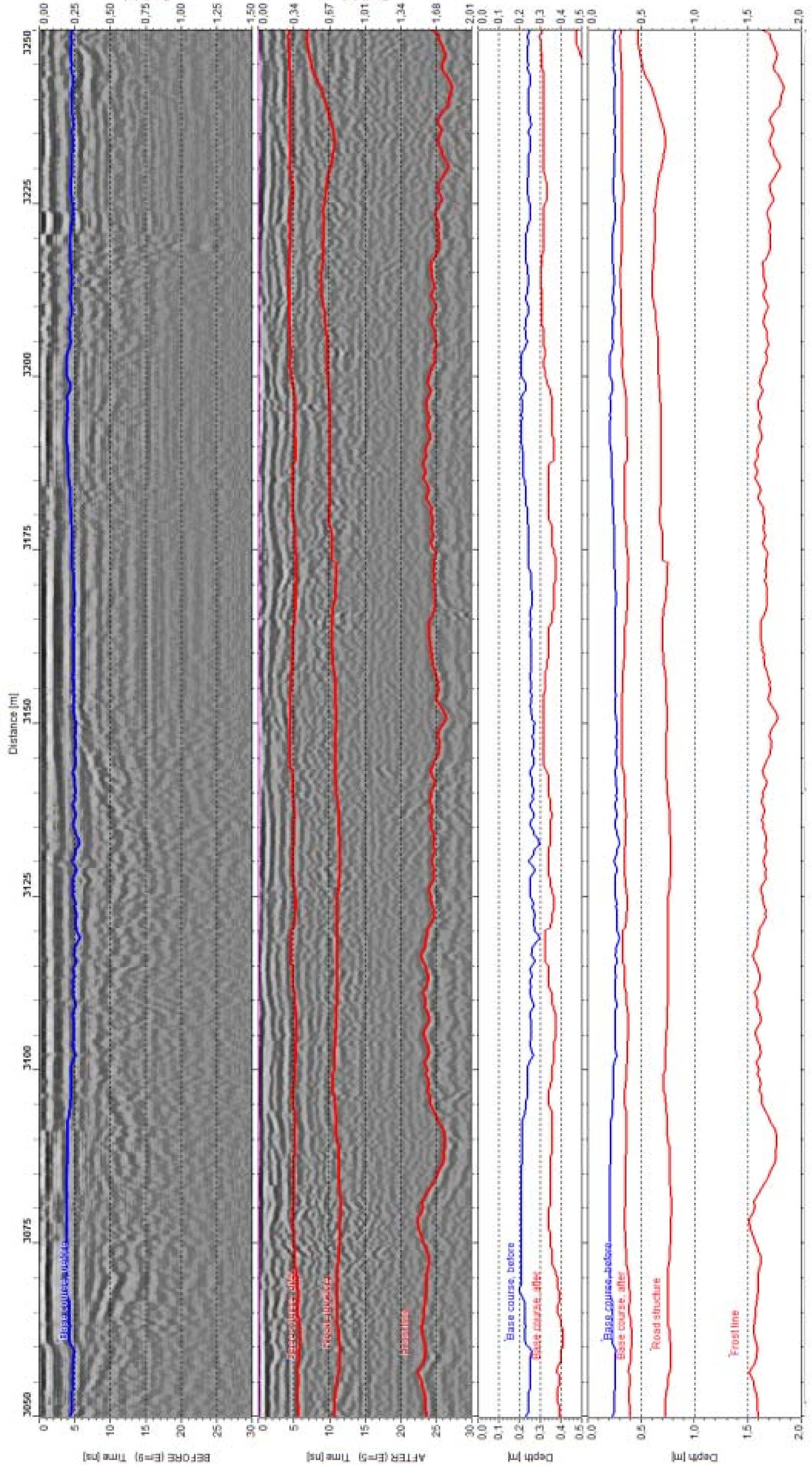

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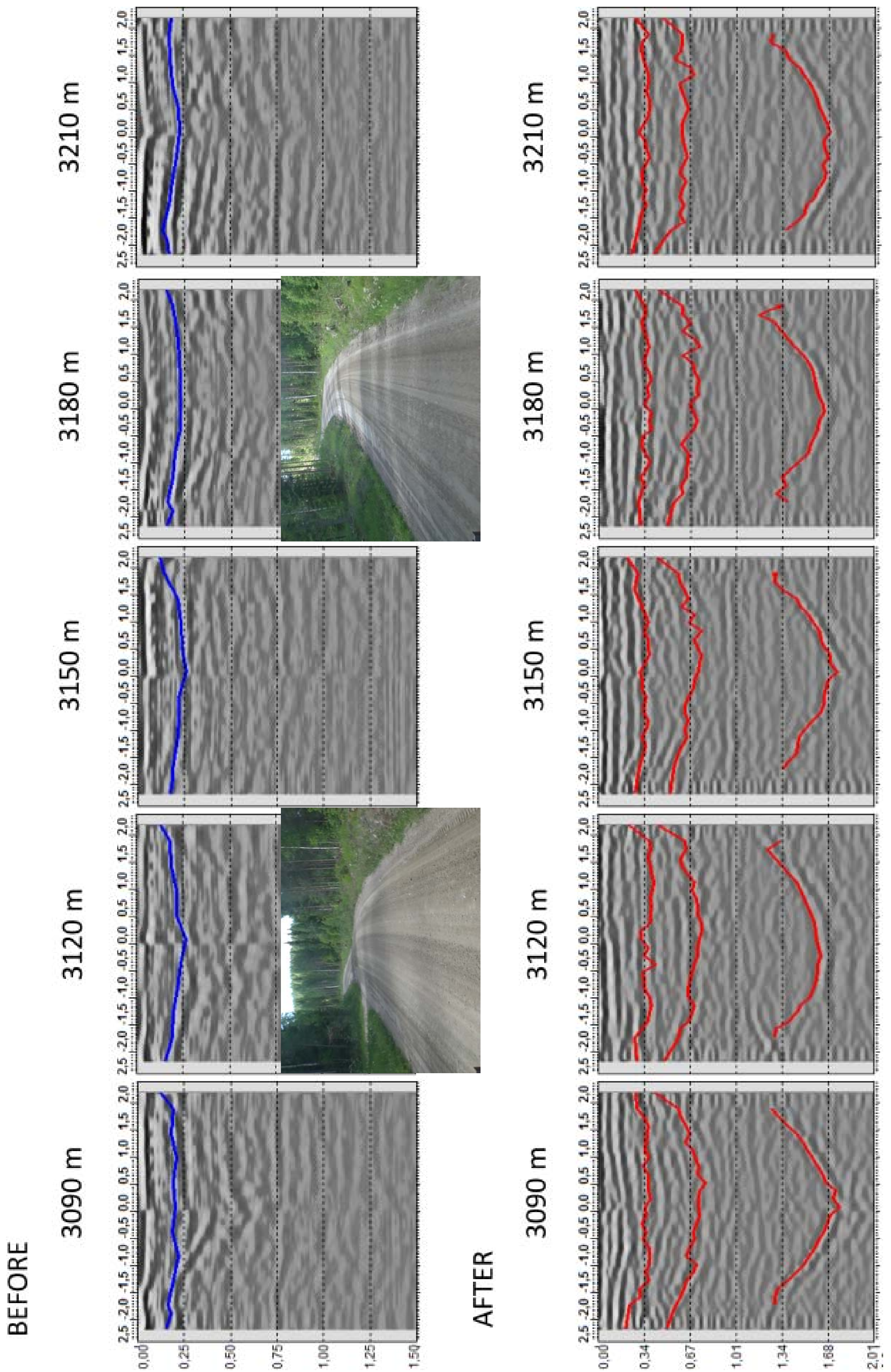

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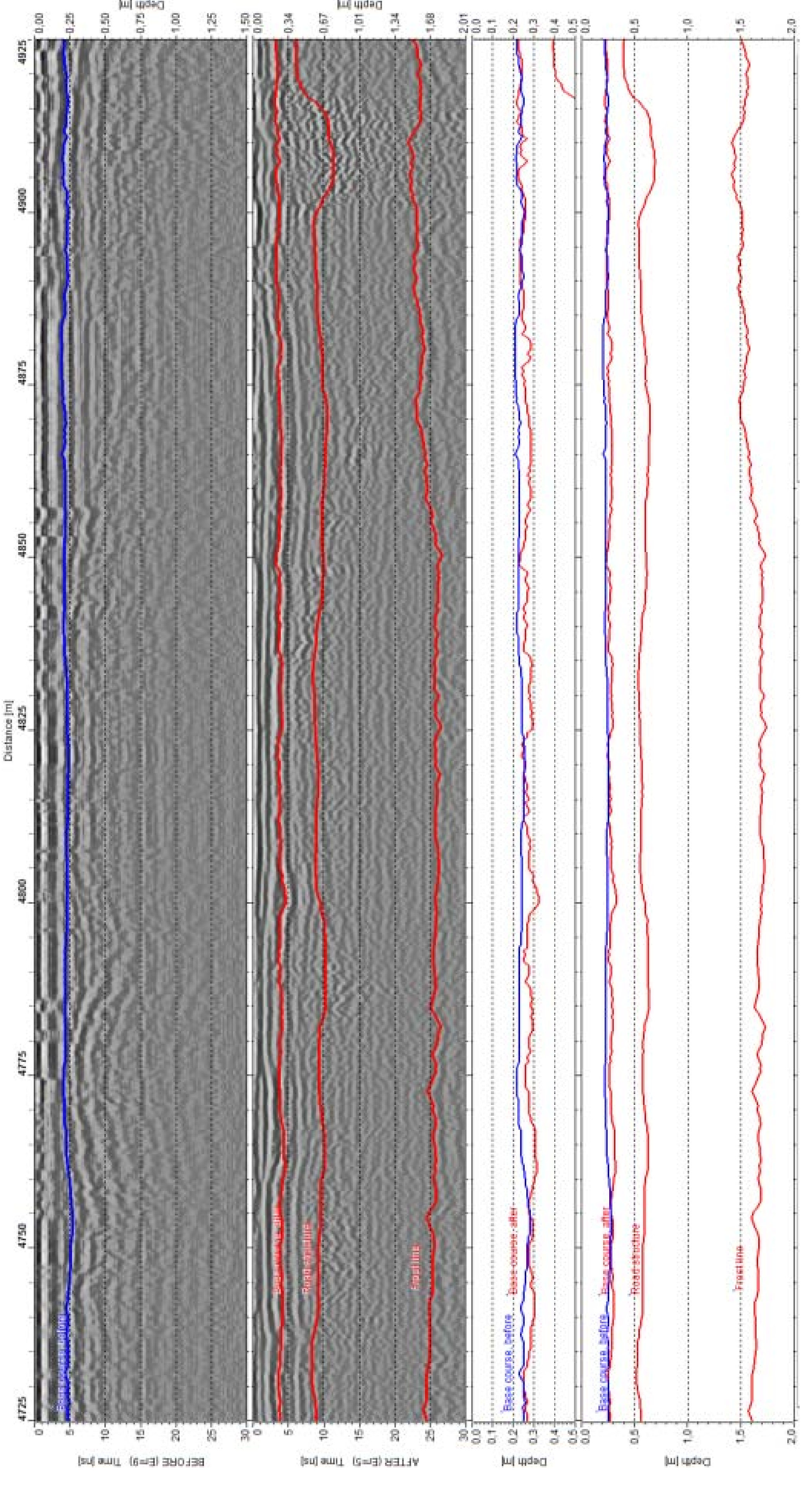

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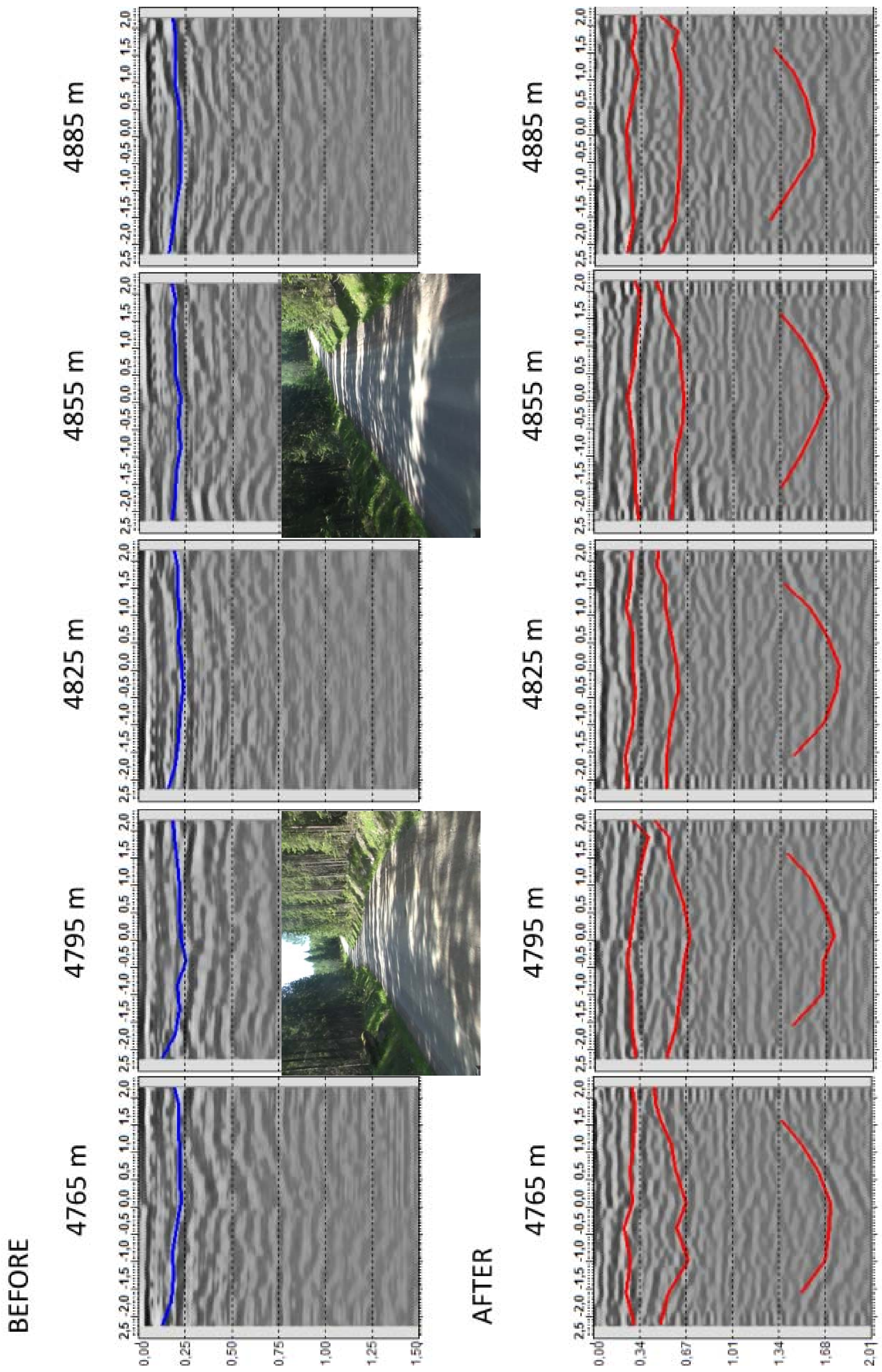

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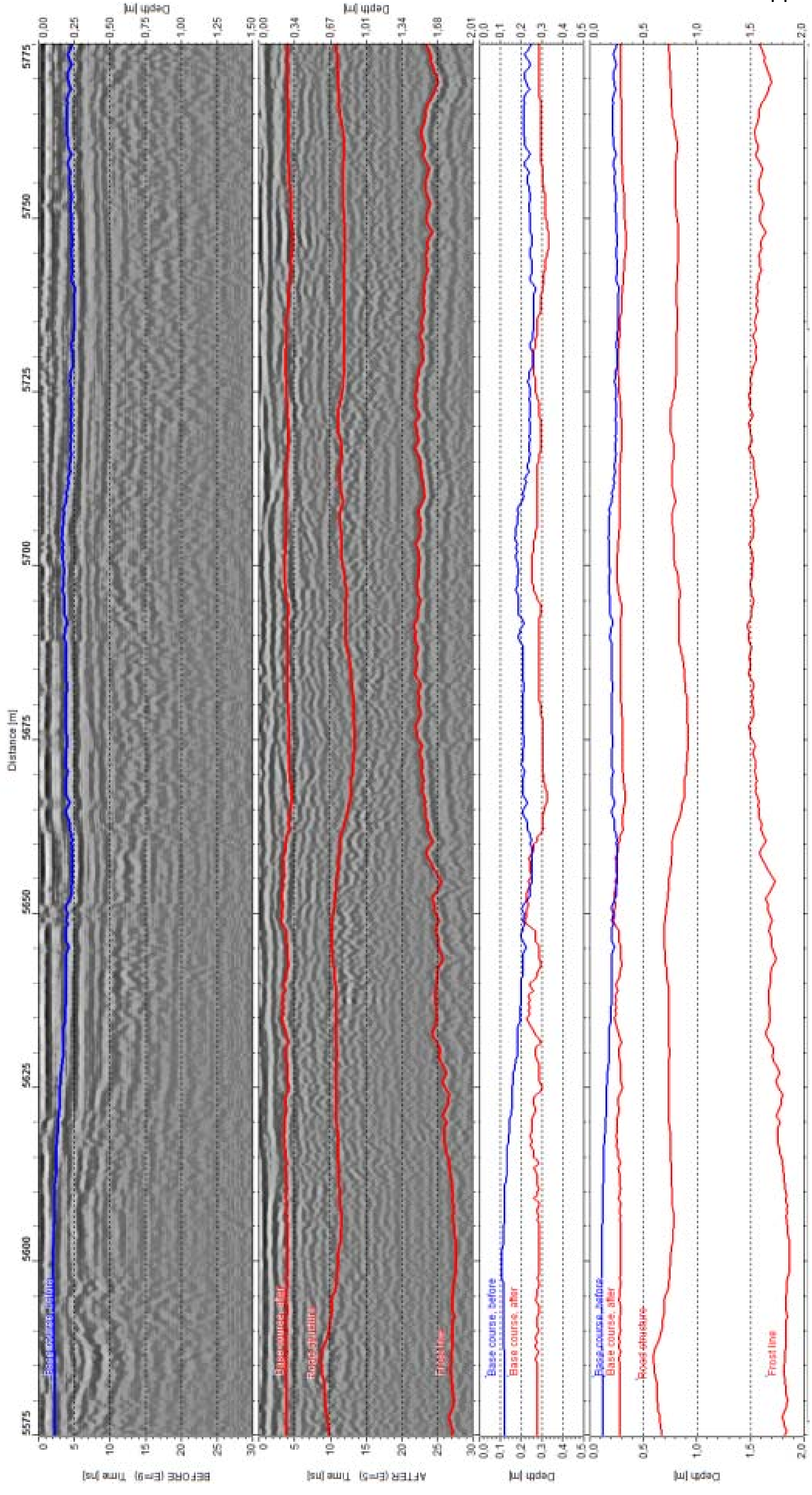

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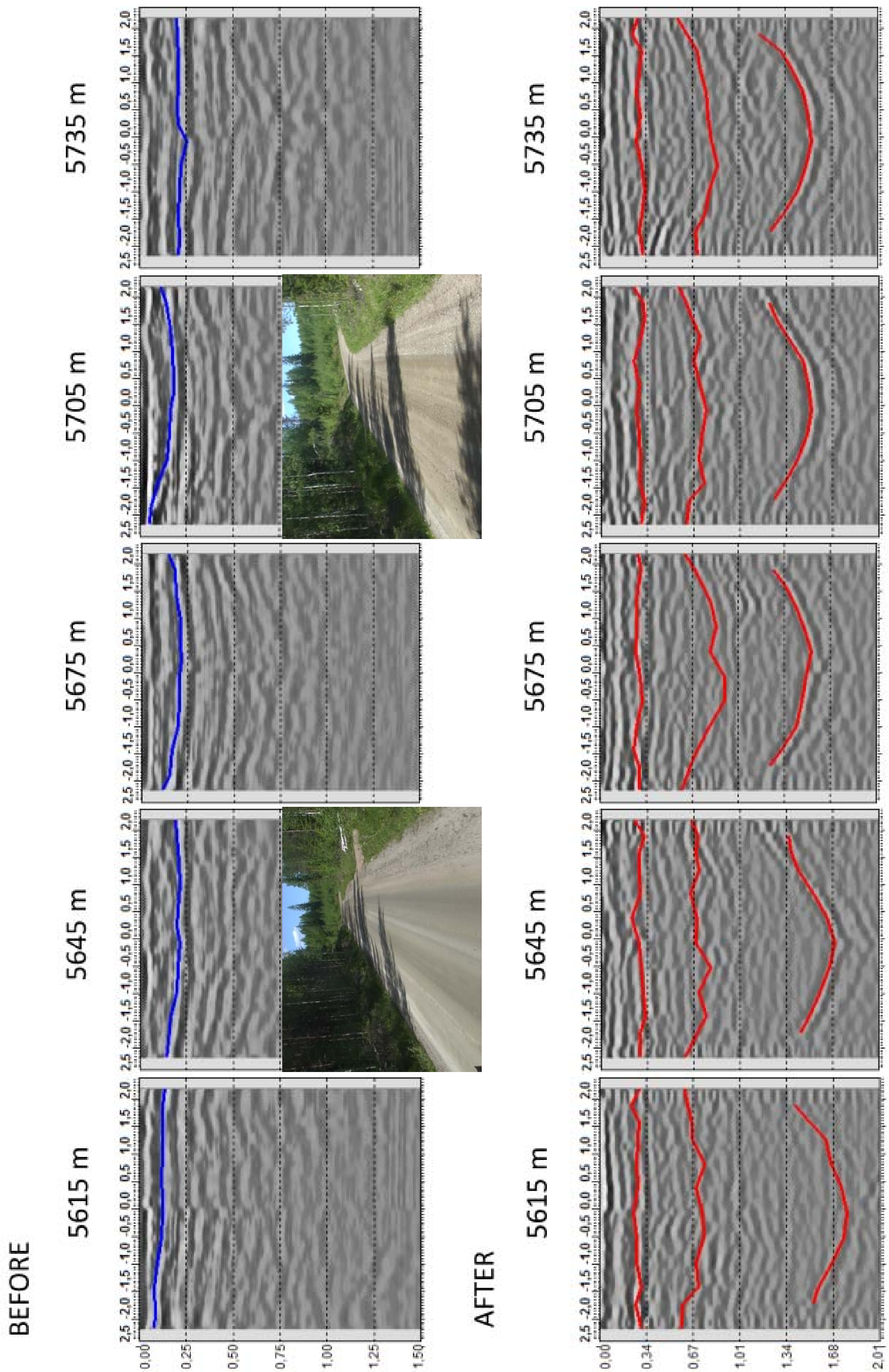

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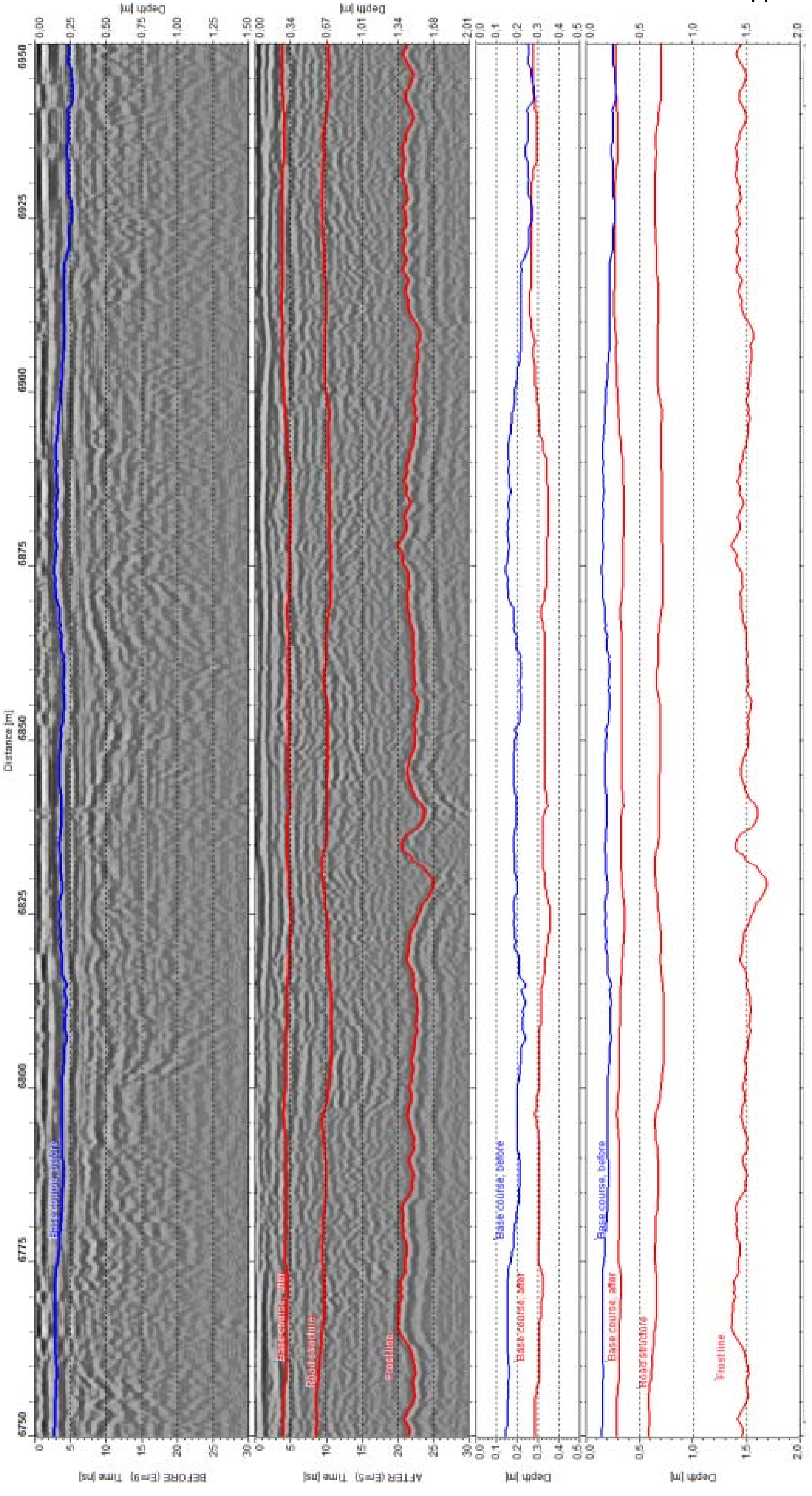

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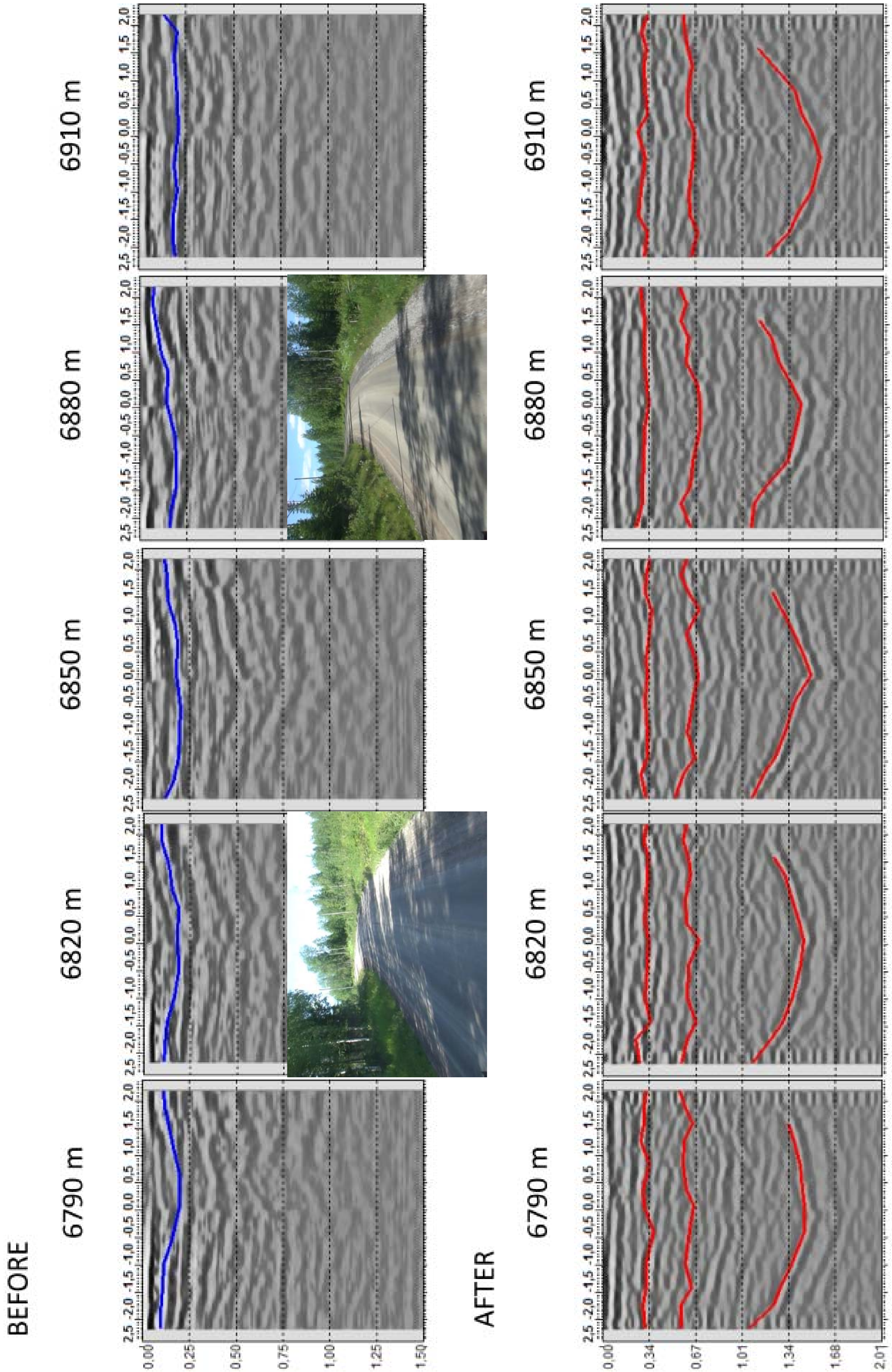

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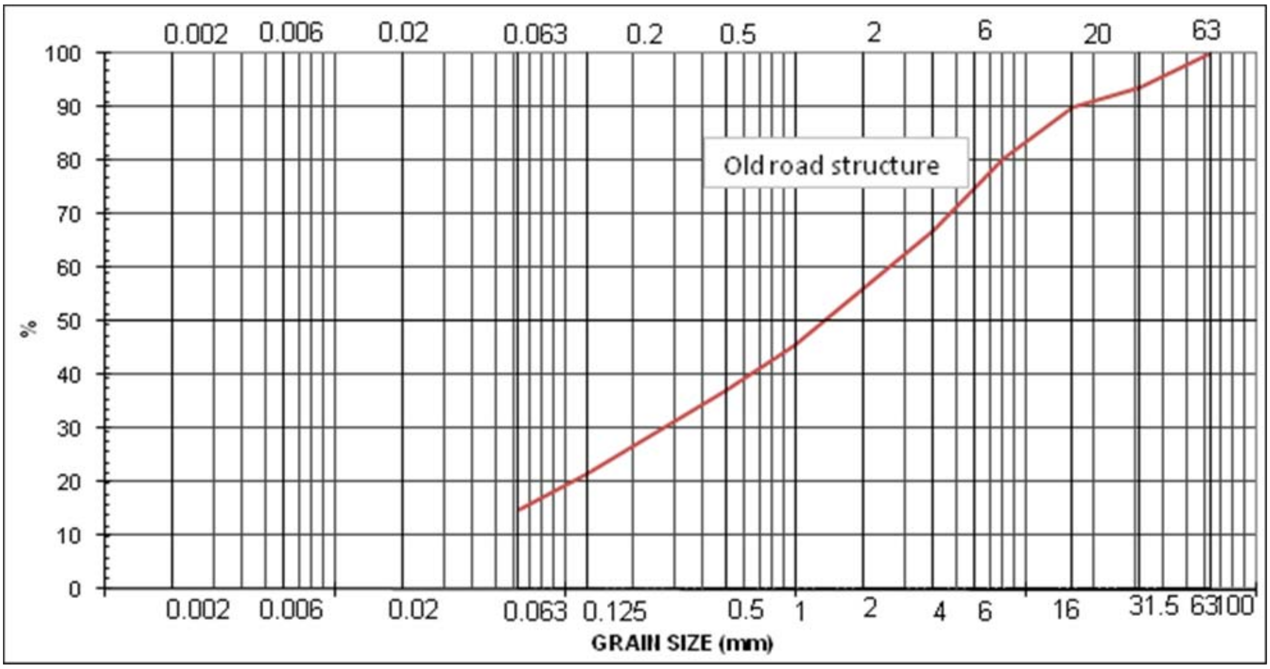
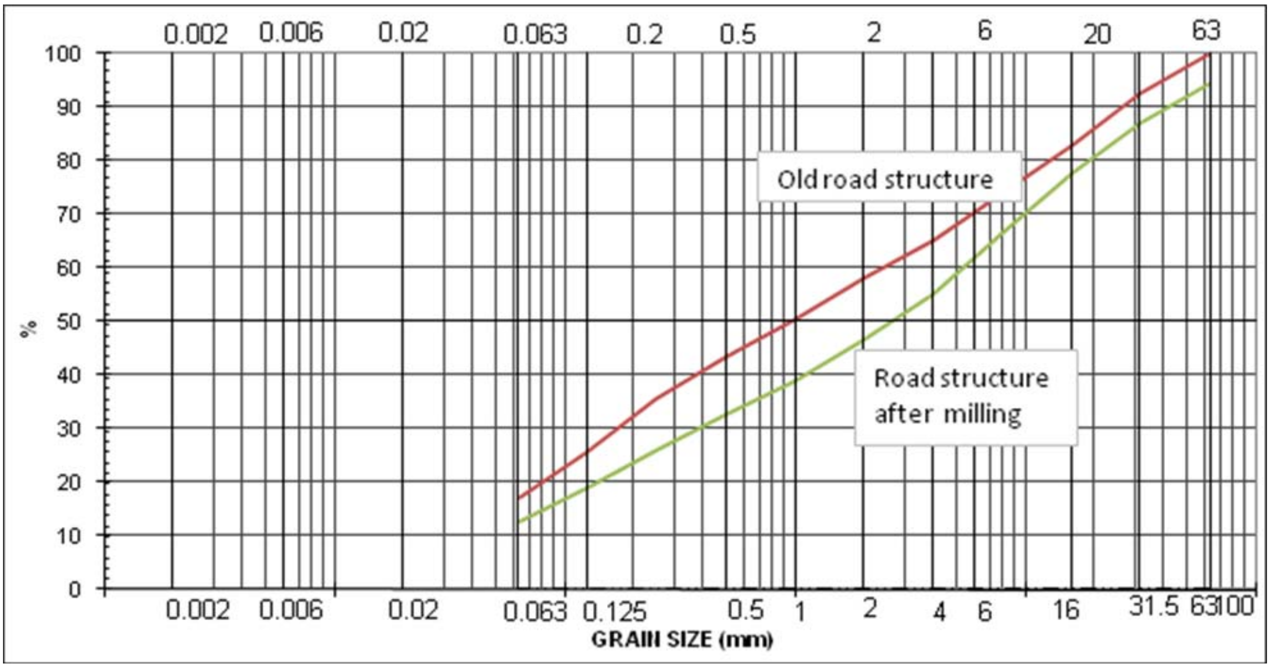


The grain size curve from chainage 1700



The grain size curves from chainage 4825

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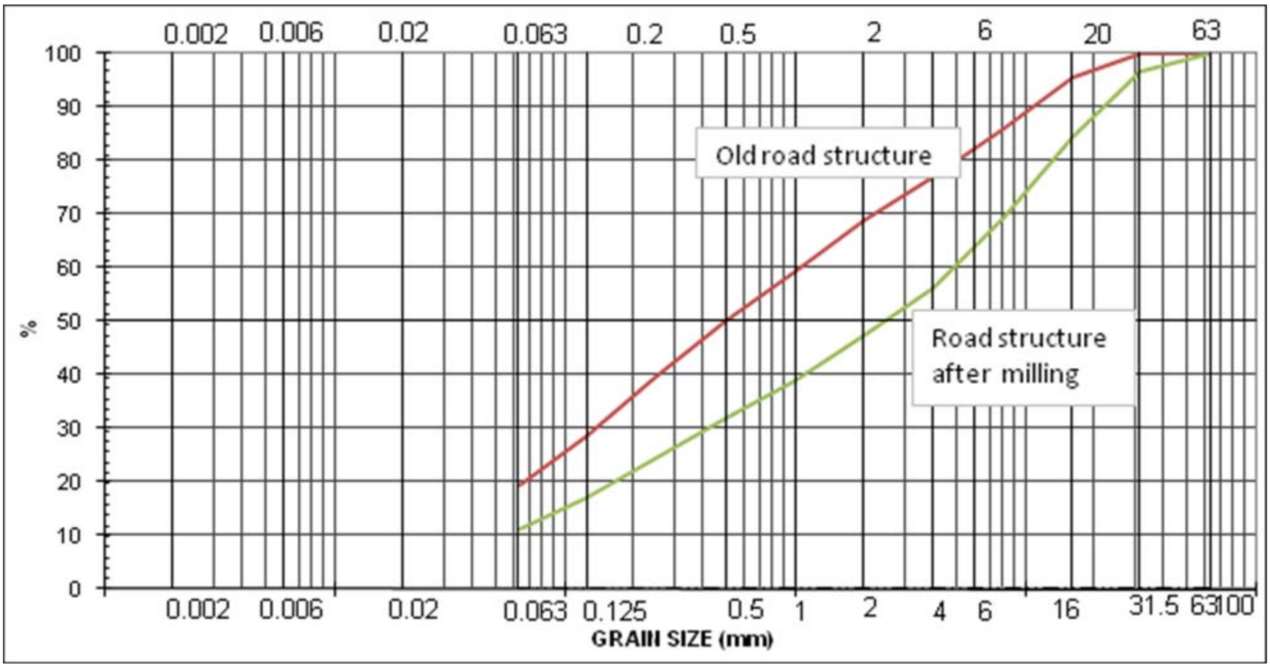
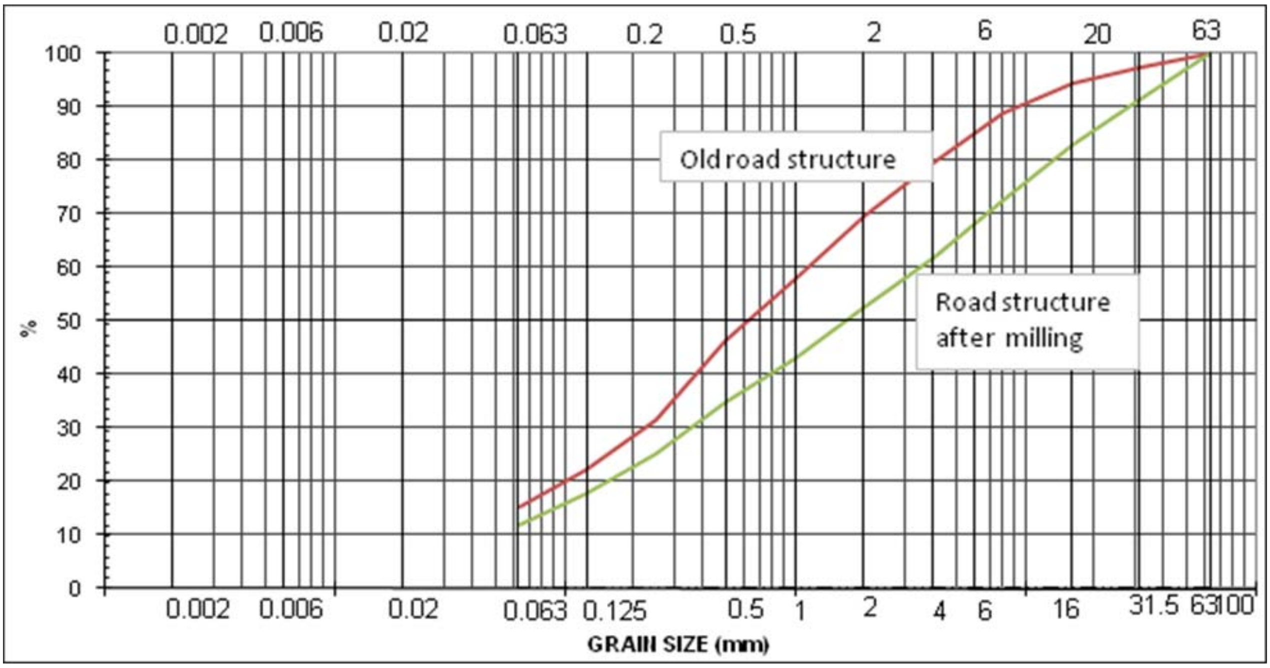


Grain size curves from chainage 5675



Grain size curves from chainage 6850

ROADEX
Implementing Accessibility

ROADEX PROJECT REPORTS (1998–2012)

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

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

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