ROADS

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SCANNER surveys for Local Roads

User Guide and Specification

Volume 5

Technical Requirements for SCANNER Survey Parameters and Accreditation

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This SCANNER User Guide has been developed from the SCANNER specification used in 2005/06 and 2006/07.

It incorporates many detailed changes based on experience of using the SCANNER specification in 2005/06 and 2006/07, the TTS specification before that in 2003/04 and 2004/05 and a wide range of comments from interested parties.

It includes the results of research on developing SCANNER commissioned on behalf of the UK Roads Board.

The previous SCANNER specifications were based on the original "TRACS Type Surveys for the Principal Road Network – Specification and Advice Note" produced for the UK Roads Board by the Chris Britton Consultancy and TRL Limited.

Extensive revisions to the 2006/7 specification were undertaken by Halcrow, leading to a draft revised specification for the 2007/8 Scanner survey year. This 2007/8 specification has been reviewed and further revised by TRL to produce the specification for Scanner surveys carried out from April 2009.

Throughout the development of the TTS and Scanner specifications, considerable assistance and support has been given by members of the SCANNER Implementation Group, including local authority representatives, by TRL Limited, by the UKPMS Development Support Consultant (Chris Britton Consultancy), by SCANNER survey contractors, by Halcrow, by Nick Lamb Consultancy Ltd and by UKPMS developers.

This volume is mainly based on work carried out by Dr Alex Wright and his team at TRL Limited, which is gratefully acknowledged.

Contents

Foreword

This document is one of a series of five describing the requirements for SCANNER Surveys (Surface Condition Assessment of the National Network of Roads).

It replaces the revised SCANNER specification first published in March 2006, and updates the draft SCANNER specification first published in February 2007.

The five Volumes are:

1. Introduction to SCANNER surveys
2. Advice to Local Authorities – Procuring Surveys
3. Advice to Local Authorities – Using SCANNER Survey Results
4. Technical requirements – SCANNER Survey Data and Quality Assurance
5. Technical requirements – SCANNER Survey Parameters and Accreditation

This volume 5, Technical requirements for SCANNER Survey Parameters and Accreditation, defines the technical requirements for the parameters provided by the machine developer, including acceptance and consistency testing and accreditation. It describes the requirements for accreditation of the Equipment. It also describes the requirements for consistency testing and for the reporting and delivery of data from SCANNER accredited surveys.

Volume 1 provides a brief introduction to the requirements for SCANNER surveys, and is intended to be read as a free standing document, as well as providing an overview of the other four volumes. It includes a glossary of terms and a list of the SCANNER parameters as annexes.

Volume 2 contains advice to Local Authorities about procuring SCANNER surveys under the SCANNER Specification and is to be read in conjunction with the other documents. It includes advice on preparing contact documents, inviting bids, assessing tenders and managing contracts. It includes a model contact document as an annex.

Volume 3, Using SCANNER data, explains the background to SCANNER Surveys and gives further guidance on the interpretation of processed SCANNER data. It contains advice on receiving and using SCANNER data, interpreting the results for local asset management and maintenance, producing and understanding performance indicators, and reporting NRMCS results.

Volume 4, SCANNER Survey Data and Quality Assurance, defines the technical requirements for the services to be provided by the survey contractor, including the Survey Data and the requirements for Quality Assurance procedures to ensure the Services are consistent and reliable. It also includes the specifications for audit processes, monitoring, calibration, and requirements for repeat surveys.

1 Introduction

1.1 Scope and Content

1.1.1 This volume 5 of the User Guide for SCANNER surveys on local roads, “Technical requirements for SCANNER Survey Parameters and Accreditation”.

- Provides a detailed specification of the technical requirements of the parameters to be derived from the Survey Data
- Describes the requirements for the reporting and delivery of data from SCANNER accredited surveys
- Describes the requirements for testing the Equipment to become accredited by site and network tests.
- Also describes the requirements for consistency testing.

1.1.2 Terms are defined in a Glossary in Volume 1 of this User Guide, Introduction to SCANNER surveys.

1.2 Derived Parameters and Data Files

1.2.1 The survey contractor uses accredited Equipment to carry out the surveys. This volume 5 defines how the Survey Data are to be analysed to produce the derived parameters.

1.2.2 Sections 2 to 7 provide definitions of the derived parameters. The definitions also specify methods for handling the Survey Data when obtaining the derived parameters (for example how to deal with invalid data).

1.2.3 The survey contractor provides the Survey Data and derived parameters in specific file formats.

- One format (Raw Condition Data, RCD) is required to enable the Accreditation tester and the Auditor to investigate the performance of the Equipment in the measurement of the Survey Data in detail.
- The other format (Highway Management Data Interchange Format, HMDIF) is required to deliver the data to the client for loading into a UKPMS accredited pavement management system.

1.2.4 Section 7 defines the RCD file format. The requirements for HMDIF files are specified as part of UKPMS and the most recent definition may be found on the UKPMS website.

1.3 Accreditation and Consistency

1.3.1 The purpose of ACCREDITATION testing is to ensure that the systems for data collection and data processing comply with the requirements of the SCANNER specification. This should give the Employer confidence that the Equipment, and its driver and operator, are capable of producing accurate, consistent and reliable results under standardised test conditions. Section 8 and 9 define the requirements for Accreditation testing.

1.3.2 The purpose of CONSISTENCY testing is to measure the repeatability of each machine and the reproducibility between different survey machines, so that accredited SCANNER survey results may be reported with confidence intervals ("error bands") and used for reporting road condition for both national statistical purposes (NRMCS, SRMCS) and local performance monitoring purposes (BVPI, SPI, LTP and CPA). Section 10 defines the requirements for Consistency testing and reporting.

1.3.3 The purpose of accreditation RE-TESTING is to ensure that the Equipment continues to comply with the requirements of the SCANNER specification, including any requirements that may have changed since the previous test. So that the Employer may have confidence that the Equipment, and its driver and operator, continue to be capable of producing accurate, consistent and reliable results under standardised test conditions. Section 11 defines the requirements for accreditation re-testing.

2 Longitudinal Profile Parameters

2.1 General requirements

2.1.1 The following parameters will be derived from the longitudinal profile data and delivered in the HMDIF file:

- Moving average longitudinal profile variance in each wheelpath
- Enhanced longitudinal profile variance in each wheelpath
- Bump measure in each wheelpath

2.1.2 These parameters are calculated from the measured longitudinal profile data before any fitting is carried out on the Survey Data (e.g. fitting to the Employer's network).

2.1.3 Before the parameters are calculated checks must be carried out on the validity of the longitudinal profile, as described in Section 2.2.

2.1.4 Following the checking of the validity of the longitudinal profile data the parameters are calculated from the longitudinal profile data separately, i.e. the input data to the calculation of each parameter (moving average variance, enhanced variance, bump measure) is the checked longitudinal profile data.

2.1.5 The following processes are applied separately to the longitudinal profile data recorded in the nearside and offside wheelpaths, to obtain the parameters for each wheelpath.

2.2 Checking the longitudinal profile data

2.2.1 Any parameter derived from the longitudinal profile data over any length L shall be considered invalid (and therefore not output in the HMDIF file) if any single profile point used to calculate that parameter over that length was invalid.

2.2.2 During the acceptance tests the Equipment is assessed to determine the minimum speed and maximum levels of acceleration and deceleration under which surveys can be carried out from which valid measurements of the derived parameters can be calculated.

2.2.3 The acceptance tests determine the minimum speed ($\mathbf{V}_3$ and $\mathbf{V}_{10}$) and the maximum levels of acceleration and deceleration for the calculation of valid 3m variance, 10m variance and the bump measure, which are defined as $\mathbf{A}_{max3}$ and $\mathbf{A}_{max10}$.

2.2.4 The acceptance tests also determine the length of survey required following the end of a period of acceleration or deceleration that must
2.2.4 elapse before the survey measurements can be considered valid, defined as $\mathbf{L}_{Recovery}$.

Checking survey speed

2.2.5 The bump measure, 3m moving average Longitudinal Profile Variance and 3m Enhanced Longitudinal Profile Variance over any length L are considered invalid (and therefore not reported in the HMDIF file) if the percentage of speed values recorded over that length as below $\mathbf{V}_3$ exceeds a predefined limit (typically 5%).

2.2.6 The 10m moving average Longitudinal Profile Variance and 10m Enhanced Longitudinal Profile Variance over any length L are considered invalid (and therefore not reported in the HMDIF file) if the percentage of speed values recorded over that length as below $\mathbf{V}_{10}$ exceeds a predefined limit (typically 5%).

Checking survey acceleration and deceleration

2.2.7 The speed values are averaged over each reporting length (the default is 10m) and the following relationship is applied:

$$a = \frac{v^2 - u^2}{2s}$$

where v is average speed over the reporting length,
u is average speed over the preceding reporting length,
a is the acceleration and
s is the reporting length over which the speed changed from u to v.
a is then expressed as the absolute acceleration $\mathbf{a}_{abs}$

2.2.8 The absolute acceleration at the start of the survey is assumed to be zero as there is no “previous” value of **u**, although this should not affect the data if there has been a run–in before the start of the first section.

2.2.9 For each (10m) reporting length the maximum absolute value of acceleration is calculated, $\mathbf{a}_{max}$, measured in the length $\mathbf{L}_{Recovery}$ before the end of that reporting length. For example if $\mathbf{L}_{Recovery}$ =70m, then at **d**=200m (the end of reporting length 190 to 200), $\mathbf{A}_{max200}$ is the maximum acceleration calculated between **d**=130 and **d**=200 (i.e. the maximum value of $\mathbf{a}_{abs140}$, $\mathbf{a}_{abs150}$ … $\mathbf{a}_{abs200}$).

2.2.10 At the start of the survey there may not be sufficient data for a length of $\mathbf{L}_{Recovery}$ before the current point, so the length is reduced as appropriate. For example if $\mathbf{L}_{Recovery}$ =70m, at **d**=30 only the accelerations over the first 30m are checked (i.e. the maximum value of $\mathbf{a}_{abs10}$, $\mathbf{a}_{abs20}$ … $\mathbf{a}_{abs30}$).

2.2.11 The bump measure, 3m moving average Longitudinal Profile Variance and 3m Enhanced Longitudinal Profile Variance over any reporting length **L** are considered invalid (and therefore not reported in the HMDIF file) if $\mathbf{a}_{max} > \mathbf{A}_{max3}$ at the end of that reporting length (as absolute acceleration is used and as the acceleration and deceleration thresholds are the same, only one check is made).

2.2.12 The 10m moving average Longitudinal Profile Variance and 10m Enhanced Longitudinal Profile Variance over any reporting length **L** are considered invalid (and therefore not reported in the HMDIF file) if $\mathbf{a}_{max} > \mathbf{A}_{max10}$ at the end of that reporting length. (As absolute acceleration is used and as the acceleration and deceleration thresholds are the same only one check is made).

2.3 Moving Average Longitudinal Profile Variance

2.3.1 The moving average longitudinal profile variance is calculated as follows.

2.3.2 The number of profile points corresponding to a moving average length (e.g. 3m, and 10m) is calculated as:

$$m = \frac{(MovingAverageLength)}{l}$$

rounded to the nearest odd integer (exact even numbers rounded up)
where *l*= interval between profile point readings
e.g. For 3m and 10m moving average lengths, with a readings interval of exactly 0.1m, the number of points would be 31 and 101 respectively.

2.3.3 The number of profile points corresponding to the length L over which LPV is to be reported (e.g. 10m) is calculated as:

$$J = \frac{L}{l}$$

rounded to the nearest odd integer (exact even numbers rounded up)
where *l* = interval between profile point readings
e.g. For 3m and 10m moving average lengths, with a readings interval of exactly 0.1m, the number of points would be 31 and 101 respectively.

2.3.4 For each point k on the survey run, a moving average is calculated as:

$$\overline{Y}_k = \frac{1}{m} \sum_{j=i}^{j=i+m-1} Y_j$$

where:

$$i = k - \frac{(m-1)}{2}$$

$\mathbf{Y_j}$ = Profile amplitude at point **j**

k ranges from $\frac{m+1}{2}$ to $M-\frac{m-1}{2}$

and **M** =total number of readings in the run.

2.3.5 For each point **k** on the survey run, a “profile amplitude deviation” from its corresponding moving average is calculated as:

$$d_k = Y_k - \overline{Y}_k$$

where $\mathbf{Y_k}$ = profile amplitude at point **k**

2.3.6 The moving average Longitudinal Profile variance (LPV) over each reporting length **L** starting at point "**i**" is calculated as:

$$LPV_i = \frac{10^6}{J}\sum_{k=i}^{i+J-1}(d_k)^2$$

The term $\mathbf{10^6}$ is included to convert the result from m^2 to mm^2.

2.3.7 Where the reporting length is not an exact multiple of the reading interval there will be more readings than required within some reporting lengths. e.g. With a reporting length of 10m and a reading interval of 0.09925m, **J** will be calculated as (10/0.09925) = 100.75567, rounded down to 100; however the number of readings lying within each 10m reporting length will be as shown in Table 2.1.

Reporting Length	Number of Readings
0-10	100
10-20	101
20-30	101
30-40	101
40-50	100
Etc.	

Table 2.1: Reporting length versus number of readings

2.3.8 In such situations, the “extra” readings (at the end of the reporting lengths) are used in calculating moving averages, $\overline{Y}_k$; however a profile amplitude deviation need not be calculated for those points and is not included in the calculation of moving average Longitudinal Profile variance (LPV). The speed values associated with the “extra” readings also are not included in the speed checks described in paragraphs 2.2.6 and 2.2.7, but are included in the calculation of average speeds as described in paragraph 2.2.9.

2.3.9 When a reading falls exactly on the boundary between two reporting lengths, it is deemed to lie within the former of those lengths. E.g. With a reporting length of 10m and a reading interval of exactly 0.1m, the 100th reading (at chainage 10m) is deemed to lie within the 0-10m reporting length. Note also that the first reading is deemed to be at a small value of chainage "**l**" (e.g. 0.1m), not at zero.

2.3.10 At the start and end of the survey, there will be lengths over which it is not possible to calculate moving averages, e.g. for a 3m moving average, it is not possible to calculate a value until 1.5m into the survey. Reporting lengths that include these are considered invalid and therefore not reported in the HMDIF file (although this should not affect the data if there has been a run–in before the start of the first section and a run-out after the end of the last section).

2.4 Enhanced Longitudinal Profile Variance

2.4.1 The calculation of 3m and 10m Enhanced Longitudinal Profile Variance can be summarised as follows:

- The raw longitudinal profile is filtered, using a high pass filter that attenuates frequencies below 3m and 10m (as appropriate)
- The Enhanced Longitudinal Profile Variance is calculated from the filtered profile over the reporting length.

Filtering

2.4.2 The filter is defined by a set of (**m** plus one) coefficients.

$m = \frac{R}{f_L * \Delta}$ where:

- Δ is the interval between profile points (approximately 0.1m);
- $\mathbf{1/f_L}$ is expressed in the same units as Δ;
- For the calculation of 3m enhanced profile variance $\mathbf{f_L}$ is $0.3333m^{-1}$
- For the calculation of 10m enhanced profile variance $\mathbf{f_L}$ is $0.1m^{-1}$
- **R** is the "Filter Order", which should have a default value of 3 but which should be parameterised in the software.
- The calculated value of **m** should be rounded up to the next even integer.

2.4.3 There are **m+1** high-pass coefficients, $\mathbf{bhp_i}$ The values of $\mathbf{bhp_i}$ are initially determined by:

$\mathbf{bhp_i = H_i * sinc(2*\pi*fL*\Delta)}$,

for **i= -m/2, -m/2+1,…, m/2** where:

- $\mathbf{H_i}$ are the coefficients of a Hamming window, given by:

$$H_i = 0.54 - 0.46 * \cos(2 * \pi * (i + m/2)/m)$$

- **sinc(x) = sin(x)/x if x≠0** OR **sinc(x)=1 if x=0**
- **π** = 3.14159
- f_L is expressed in the same units as **1/**Δ and
- the trigonometric functions are defined such that the arguments are in radians.

2.4.4 The coefficients, bhp_i, are then normalised as:

$$bhp_i = \frac{bhp_i}{n}, \; where\; n = \sum_{i=-m/2}^{m/2} bhp_i$$

2.4.5 Following the normalisation of the coefficients, the following transformation is performed:

- bhp_i = - bhp_i for i=-m/2,-m/2+1,…,1 and i=1,…,m/2
- bhp_i =1- bhp_i for i=0

2.4.6 The value of the filtered longitudinal profile height, z_i', at each position, **i**, is obtained by multiplying the profile heights between $z_{(i-m/2)}$ and $z_{(i+m/2)}$ by the corresponding **m+1** filter coefficients and then summing the resulting products. Hence:

$$z_i' = \sum_{j=-m/2}^{m/2} z_{i+j} * bhp_j$$

Enhanced Variance

2.4.7 The Enhanced Variance is calculated as:

$$Enhanced\ Variance = \frac{1}{N}\sum_{1}^{N}(z_j)^2$$ where :

- **N** is the number of filtered profile points within each reporting length.
- z_j is the height of the filtered longitudinal profile point **j** in mm.

2.4.8 The principles described in paragraphs 2.3.7 through 2.3.9 also apply when calculating Enhanced Variance. i.e.:

- The “extra” readings, as defined in paragraph 2.3.7, are used in calculating the filtered longitudinal profile heights; however a filtered longitudinal profile height need not be calculated for those points and is not included in the calculation of Enhanced Variance.
- When a reading falls exactly on the boundary between two reporting lengths, it is deemed to lie within the former of those lengths.

- At the start and end of the survey, there will be lengths over which it is not possible to calculate filtered longitudinal profile heights. Reporting lengths that include these is considered invalid and therefore not reported in the HMDIF file.

2.5 The Bump Measure

2.5.1 The calculation of the Bump Measure can be summarised as follows:

- The Central Difference Method is applied twice to the longitudinal profile, to produce two separate datasets.
- Thresholds are applied to these datasets to obtain a value for the Bump Measure over the reporting length.

The Central Difference Method.

2.5.2 Given a set of data points, {$\mathbf{d_j, z_j}$} , where $\mathbf{z_j}$ is the raw profile height (in millimetres), measured at distance dj (in metres), then the value obtained when the Central Difference Method at point **j**, is defined as:

$$P_j' = \frac{z_{j+1} - z_{j-1}}{d_{j+1} - d_{j-1}}$$

2.5.3 The Central Difference Method is applied to all points, to obtain the set of values, {$\mathbf{P_j'}$}.

2.5.4 The Central Difference Method is applied once more to {$\mathbf{P_j'}$} to give the set of values {$\mathbf{P_j''}$}, where $\mathbf{P_j''}$ is defined as:

$$P_j'' = \frac{P_{j+1}' - P_{j-1}'}{d_{j+1} - d_{j-1}} = \frac{1}{d_{j+1} - d_{j-1}}\left(\frac{z_{j+2} - z_j}{d_{j+2} - d_j} - \frac{z_j - z_{j-2}}{d_j - d_{j-2}}\right) = \frac{(d_j - d_{j-2})(z_{j+2} - z_j) - (d_{j+2} - d_j)(z_j - z_{j-2})}{(d_{j+2} - d_j)(d_{j+1} - d_{j-1})(d_j - d_{j-2})}$$

2.5.5 The datasets {$\mathbf{P_j'}$} and {$\mathbf{P_j''}$} are then reduced as follows:

- Calculate the maximum absolute value of {$\mathbf{P_j'}$} over each 1m length, to give a dataset {$\mathbf{F_i'}$}, containing values for each 1m length.
- Calculate the maximum absolute value of {$\mathbf{P_j''}$} over each 1m length, to give a dataset {$\mathbf{F_i''}$}, containing values for each 1m length.

Applying thresholds

2.5.6 Generate a further intermediate dataset, {$\mathbf{B_i}$} with data spaced at 1m intervals.

2.5.7 Any 1m length where **F′**≥78.6 mm/m and **F″**≥487.4 mm/m2 is considered to contain a bump.

Note that these values should be parameterised in software to enable future revisions to the thresholds

The value of $\mathbf{B_i}$ for this length is assigned a value of 1. Remaining values of $\mathbf{B_i}$ are assigned a value of 0.

2.5.8 The Bump Measure is reported over 10m lengths

Note that 10m is the default length but should be parameterised in software

Any 10m reporting length containing a non-zero value of $\mathbf{B_i}$ will be reported as a Bump Value of 1. Remaining lengths are reported to have a Bump Value of 0.

2.5.9 The principles described in paragraphs 2.3.7 through 2.3.9 also apply when calculating the Bump Measure. i.e.:

- The “extra” readings, in this case lying at the end of any 1m length, are used in applying the Central Difference Method; however {$\mathbf{P_j'}$} and {$\mathbf{P_j''}$} need not be calculated for those points and are not considered when determining the maximum absolute values ({$\mathbf{F_i'}$} and {$\mathbf{F_i''}$}).
- When a reading falls exactly on the boundary between two 1m lengths, it is deemed to lie within the former of those lengths.
- At the start and end of the survey, there will be lengths over which it is not possible to calculate {$\mathbf{P_j'}$} and {$\mathbf{P_j''}$}. Reporting lengths that include these are considered invalid and therefore not reported in the HMDIF file.

2.6 Typical Values (Checks and Limits)

2.6.1 Typical values, to be confirmed during acceptance tests, for the checks and limits to be placed on the longitudinal profile data are given in Table 2.2

Parameter	Typical Value
Minimum speed for 3m LPV, 3m ELPV and bump measure (km/h)	20 km/h
Maximum speed for 3m LPV, 3m ELPV and bump measure (km/h)	120 km/h
Maximum number of invalid speeds within 3m LPV, 3m ELPV and bump measure averaging length (%)	5 %
Minimum speed for 10m LPV and 10m ELPV (km/h)	20 km/h
Maximum speed for 10m LPV and 10m ELPV (km/h)	120 km/h
Maximum number of invalid speeds within 10m LPV and 10m ELPV averaging length (%)	5 %
Acceleration effective length (m)	70 m
Acceleration threshold – 3m LPV, 3m ELPV and bump measure (ms^{-2})	3 ms^{-2}
Acceleration threshold – 10m LPV and 10m ELPV	2 ms^{-2}

Table 2.2: Limits for the calculation of longitudinal profile parameters

3 Transverse Profile Parameters

3.1 General Requirements

3.1.1 The following parameters will be derived from the transverse profile and delivered in the HMDIF file:

- Transverse profile unevenness
- Cleaned rut depth (nearside and offside)
- Edge Roughness
- Road Edge Step
- Transverse Variance

3.1.2 These parameters are calculated from the measured transverse profile data before any fitting is carried out on the Survey Data (e.g. fitting to the Employer’s network).

3.1.3 Before the parameters are calculated checks must be carried out on the validity of the transverse profile, as described in Section 3.2.

3.1.4 The calculation of the transverse profile parameters is carried out in a step by step process outlined in Figure 3.1:

3.2 Checking the transverse profile

3.2.1 If any single profile point within a transverse profile is invalid (i.e. outside the permitted range), that profile is also defined as invalid and is not used in calculation of the parameters described in the following sections. If more than a defined percentage (typically 25%) of the profiles within a reporting length is invalid, the parameters calculated for that reporting length are considered invalid (and therefore not reported in the HMDIF file).

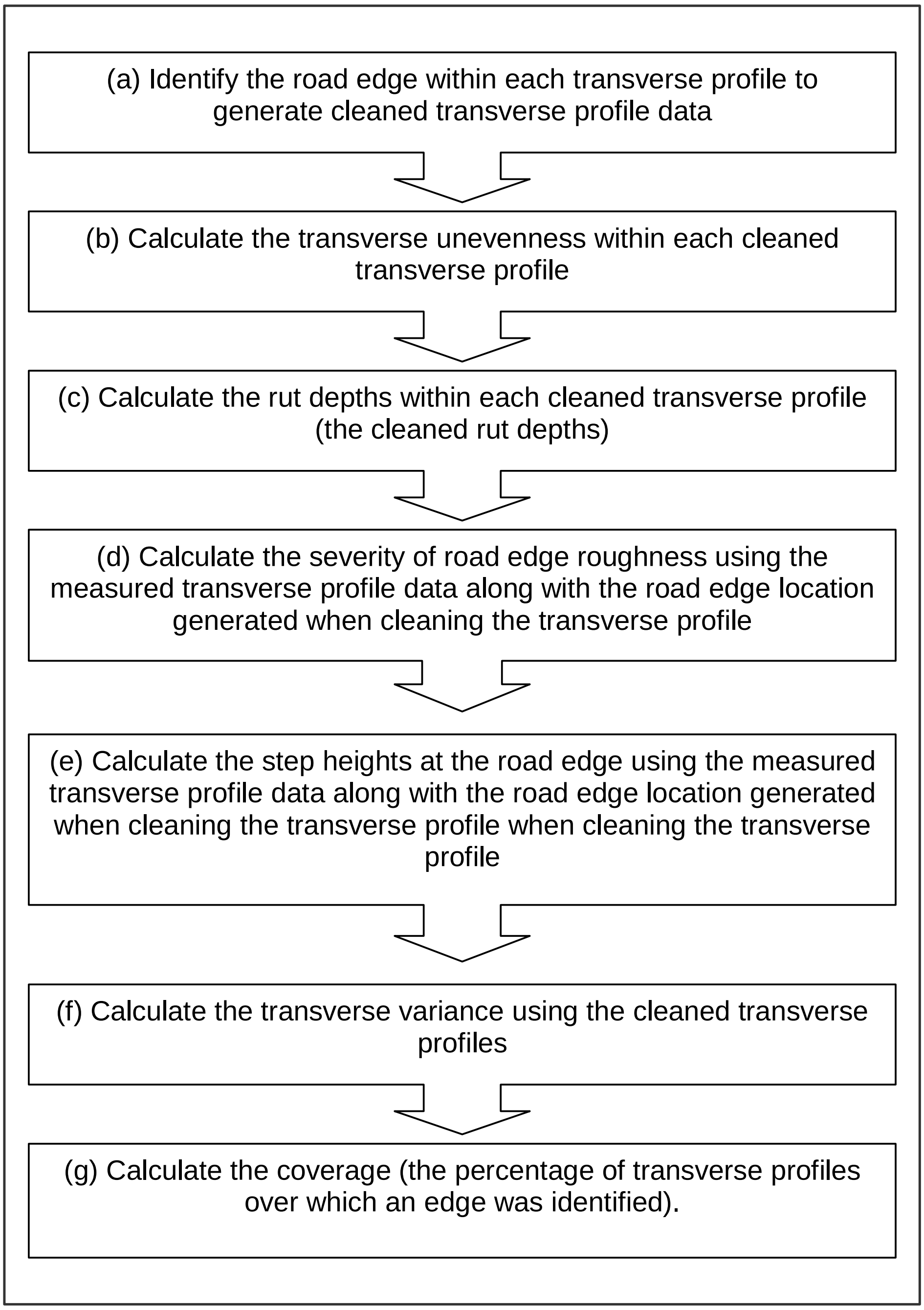


Figure 3.1: Calculation of the transverse profile parameters

3.3 Definitions

3.3.1 The following definitions apply in the calculation of the transverse profile parameters, except where specific local definitions are provided.

3.3.2 Transverse profile data points are defined as starting from 0, which is the first measurement point at the extreme nearside (left) of the profile.

y	= individual recorded (original) transverse profile, normalised transverse profile (see paragraph 3.4.5), or smoothed transverse profile (see paragraph 3.4.8).
$\mathbf{x_i}$	= measurement point position.
q	= number of data points in the measured transverse profile.
h	= transverse sampling interval in the measured transverse profile data $h = x_i - x_{i-1}$ The value of h may vary between measurement positions across the profile.
$\tilde{y}$	= re-sampled individual transverse profile.
$\tilde{x}_i$	= position of the re-sampled point.
N	= number of data points in the re-sampled profile.
t	= transverse sampling interval in the re-sampled transverse profile data, $t = \tilde{x}_i - \tilde{x}_{i-1}$ (*Note: This should be parameterised; the recommended default value is 25mm.*)
$\mathbf{q_L}$	= number of points to include in moving average calculations from the left of current point in **y**.
$\mathbf{q_R}$	= number of points to include in moving average calculations from the right of current point in **y**.
D	= longitudinal spacing between successive transverse profiles, typically approximately 0.1m.
$\mathbf{L_{ave}}$	= Averaging Length. (*Note: This should be parameterised; the recommended default value is 1m.*)

$\mathbf{T_{ave}}$	= number of transverse profiles in an averaging length ($\mathbf{T_{ave}}$ = ($\mathbf{L_{ave}/D}$) rounded down to the nearest integer).
$\bar{y}$	= Averaged (best) re-sampled transverse profile in length $\mathbf{L_{ave}}$.
$\dot{y}$	= First derivative of the averaged (best) re-sampled transverse profile.
$\ddot{y}$	= Second derivative of the averaged (best) re-sampled transverse profile.
L	= reporting length, which must be an exact integer multiple of $\mathbf{L_{ave}}$. (*Note: This should be parameterised, the recommended default value is 10m.*)
$\mathbf{T_C}$	= total number of transverse profiles in reporting length L ($\mathbf{T_C}$ = $\mathbf{T_{ave}}$ * (**L/** $\mathbf{L_{ave}}$)).
n	= index for the transverse profiles within the survey or reporting length, as applicable.
$\mathbf{e_n}$	= road edge position in millimetres from the nearside end of the measured transverse profile.

Table 3.1 Definitions for Transverse Profile Parameters

3.3.3 Where the averaging length ($\mathbf{L_{ave}}$) and reporting length (**L**) are not exact multiples of the longitudinal spacing between successive transverse profiles (**D**) there will be more transverse profiles than required within some reporting lengths.

e.g. With an averaging length of 1m, a reporting length of 10m and a spacing of 0.09925m
$\mathbf{T_{ave}}$ will be calculated as (1/0.09925) = 10.075567, rounded down to 10, and $\mathbf{T_C}$ will be calculated as 10*(10/1) = 100; however the number of transverse profiles lying within each 10m reporting length will be as shown in Table 3.2

Reporting Length	Number of Profiles
0-10	100
10-20	101
20-30	101
30-40	101
40-50	100
Etc.	

Table 3.2: Reporting length versus number of readings

In such situations, the “extra” profiles (at the end of the reporting lengths) are not be used in any of the calculations.

3.3.4 When a transverse profile falls exactly on the boundary between two reporting lengths, it is deemed to lie within the former of those lengths.

3.3.4

e.g. With a reporting length L of 10m and an spacing D of exactly 0.1m,
the 100th profile (at chainage 10m) is deemed to lie within the 0-10m reporting length.

3.4 Cleaning the transverse profiles (identifying the road edge)

3.4.1 The overall process can be summarised as shown in Figure 3.2

3.4.2 The output from the algorithm is:

- The location of the edge of the road as found in the re-sampled transverse profile **n**, reported as “$\mathbf{e_n}$”, the distance from the first sensor position (nearside).
- The “cleaned” transverse profile, the re-sampled profile with profile heights to the left of position “$\mathbf{e_n}$” reset to zero.

3.4.3 For definitions relating to this algorithm see section 3.3

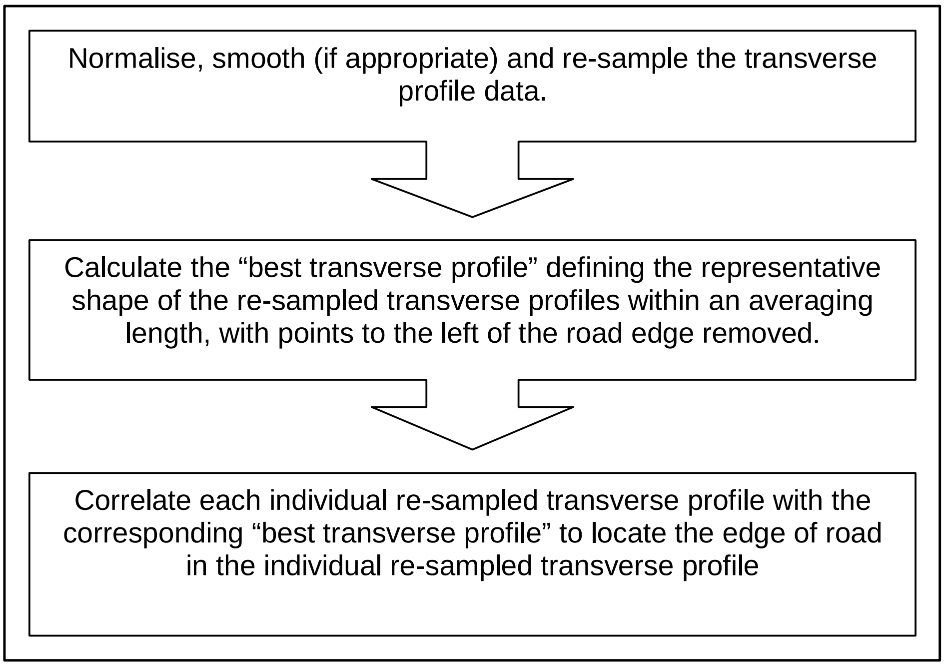


Figure 3.2: Cleaning the transverse profiles (identifying the road edge)

3.4.4 The following paragraphs summarise in further detail the steps for locating the road edge and removing non-road features from the transverse profile.

- Normalise each transverse profile by determining the lowest profile height and subtracting that value from all the profile heights within that profile (paragraph 3.4.5).
- If the horizontal spacing between any adjacent profile points is less than t (normally 25mm), the “noise” in each transverse profile is removed by applying a moving average in the transverse direction, (paragraphs 3.4.7 through 3.4.8).
- Each transverse profile is re-sampled using a cubic spline (paragraphs 3.4.9 through 3.4.13) to provide transverse profiles with points spaced (transversely) at a distance t (typically 25mm).
- A longitudinal averaging length ($\mathbf{L_{ave}}$) is defined from which the number of profiles per averaging length ($\mathbf{T_{ave}}$) is determined. Successive $\mathbf{T_{ave}}$ transverse profiles are used to calculate the “average profile” for each averaging length within a reporting length (**L**) (paragraphs 3.4.14 through 3.4.16).
- The position of the edge of the road ($\mathbf{e_{BP}}$) is determined in the “average profile”, producing a “best transverse profile” for the averaging length (paragraphs 3.4.17 through 3.4.23).
- Each valid individual transverse profile within the averaging length is correlated with the “best transverse profile”. This determines the size and direction of the shift required for each transverse profile to obtain the optimum correlation (paragraphs 3.4.24 through 3.4.32)

- The position of the edge of the road in each individual transverse profile ($\mathbf{e_n}$) is found using the size and direction of the shift established in step (f) above (paragraphs 3.4.33 through 3.4.39). Data to the left of this point is defined as being off the road (verge, kerb, etc.), data to the right of this point is defined as being on the road.
- The transverse profile is now defined as “cleaned”. The cleaned transverse profile does not contain data defined as being recorded off the road.

3.4.5 The process is summarised in the flow diagram of figure 3.3.

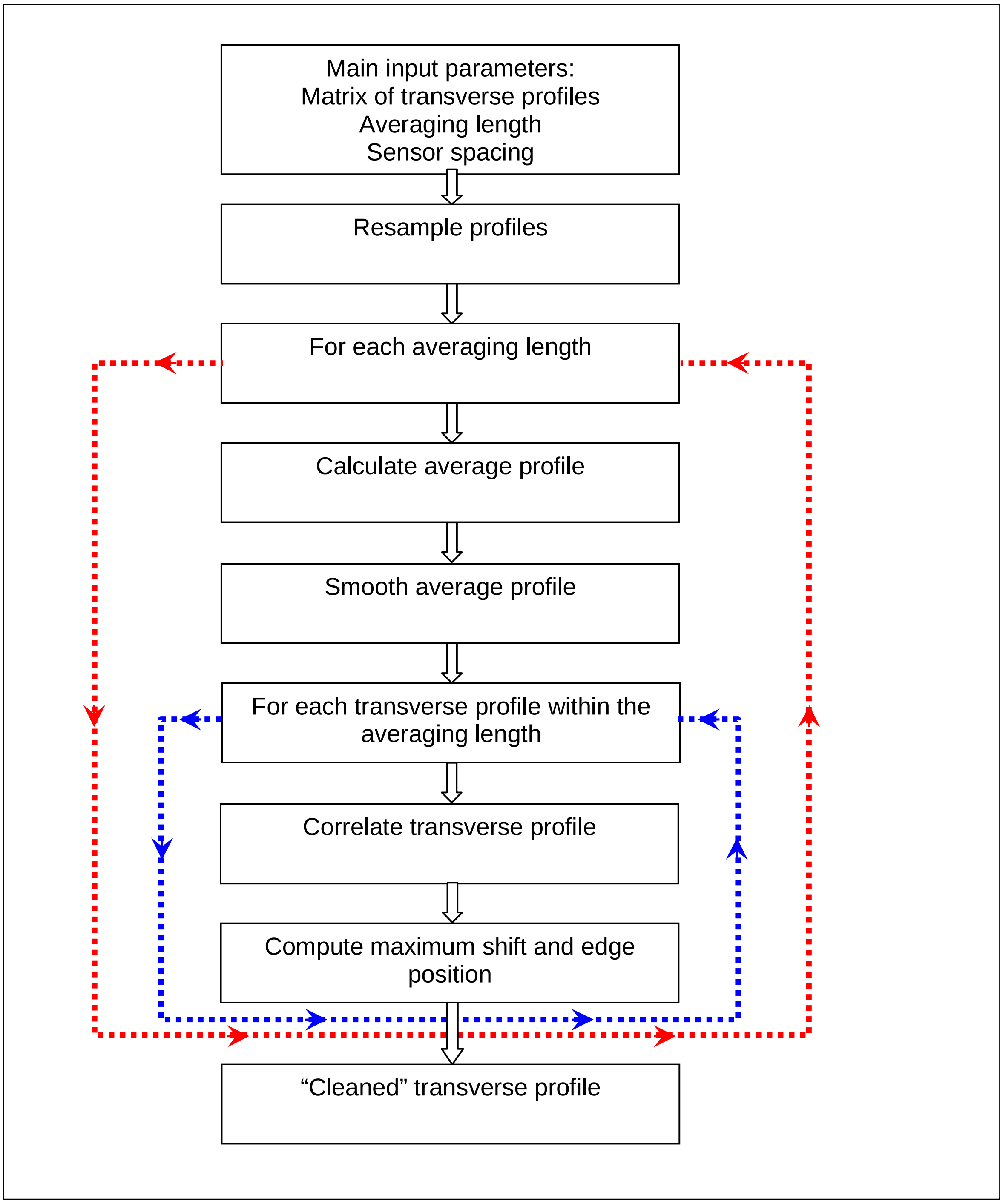


Figure 3.3: Flow chart for the cleaning algorithm

Normalising

3.4.6 For each valid transverse profile within the survey, the lowest profile height is found. This value is then subtracted from all of the profile heights $\mathbf{y_i}$ within that profile.

$$y_i = y_i - Min(y_0,...,y_{q-1}), \quad i = 0,..,q-1$$

Note, from this point onwards within section 3.4 reference to 'y' ('individual recorded transverse profile data') refers to profile data that has been normalised as specified in paragraph 3.4.5.

Smoothing

3.4.7 Smoothing of the transverse profile is carried out when the transverse spacing of the measured points in the transverse profile is less than **t**.

Note: smoothing is only likely to be required for a "scanned" profile, and not for a profile generated from a number of individual lasers. Smoothing the transverse profile is intended to remove noise from the transverse profiles.

3.4.8 To smooth the transverse profile a moving average filter of length 2**t** is used. This method uses a moving average window to model a data point as the average of $\mathbf{q_{Li}}$ points on the left of the data point and $\mathbf{q_{Ri}}$ points on the right of each data point as:

$$g_i = \frac{1}{1 + q_{Li} + q_{Ri}} \sum_{j=i-q_{Li}}^{i+q_{Ri}} y_j$$

where q_{Li} and q_{Ri} should be calculated for the i^{th} transverse position as follows:

$$q_{Li} = \max\Delta \ \textit{for which} \quad x_{i-\Delta} \geq 0 \quad \textit{and} \quad x_{i-\Delta} >= x_i - t$$
$$q_{Ri} = \max\Delta \ \textit{for which} \quad x_{i+\Delta} < q \quad \textit{and} \quad x_{i+\Delta} \leq x_i + t$$

3.4.9 If smoothing of the transverse profile data takes place as described in Section 3.4.7, then each value of $\mathbf{y_i}$ in subsequent analyses is replaced with the corresponding value of $\mathbf{g_i}$.

Re-sampling

3.4.10 If **q** is the number of data points in a transverse profile,

(x_i, y_i) is a set of data points comprising an individual transverse profile,

the cubic spline is applied as follows:

$$\frac{\sigma_{i-1}}{6} h_{i-1} + \frac{\sigma_i}{3}\left(h_i + h_{i-1}\right) + \frac{\sigma_{i+1}}{6} h_i = \frac{1}{h_i}(y_{i+1} - y_i) - \frac{1}{h_{i-1}}(y_i - y_{i-1})$$

with i = 1, 2, 3,…, **q**-2

where

$h_i = x_{i+1} - x_i$ is the spacing between two adjacent profile points.

σ_i = the second derivative of the profile at ***i***.

The second derivatives are calculated in order to ensure second order continuity.

3.4.11 The equation above requires boundary conditions which are the actual transverse profile height at points **i** = 0 and **i** = **q**-1. At these points the first and second derivatives are assumed to be equal to zero.

3.4.12 The equations above (in paragraph 3.4.10) defining a set of algebraic equations are solved for unknown value σ_i. The algorithm recommended for solving a tri-diagonal matrix is given in Section 3.4.14.

3.4.13 The re-sampled profile defined by $(\tilde{x}_j, \tilde{y}_j)$ is calculated by computing the following coefficients:

$$a_i = (\sigma_{i+1} - \sigma_i)/6h_i$$

$$b_i = \sigma_i/2$$

$$c_i = ((y_{i+1} - y_i)/h_i) - ((\sigma_{i+1} + 2\sigma_i)h_i/6)$$

$$d_i = y_i$$

with **i** = 0, 1, 2,…, **q**-2 and $h_i = x_{i+1} - x_i$ as in paragraph 3.4.10.

Then the re-sampled profile is calculated as:

$$\tilde{y}_j = ((a_i(\tilde{x}_j - x_i) + b_i)(\tilde{x}_j - x_i) + c_i)(\tilde{x}_j - x_i) + d_i$$

where **j** is an index, representing the points in the re-sampled profile,

with **j** = 0,1,2,3,…,N-1,

where the appropriate value for *i* depends upon each re-sampling position $\mathbf{x_j}$, for each position **i** should be taken as the largest **i** for which $\mathbf{x_i} \le -\mathbf{x_j}$.

Solving algebraic equations with a tri-diagonal matrix

3.4.14 A system of equations with a tri-diagonal matrix is written as:

$$d_1x_1 + c_1x_2 = b_1$$

$$a_2x_1 + d_2x_2 + c_2x_3 = b_2$$

$$a_3x_2 + d_3x_3 + c_3x_4 = b_3$$

$$\dots\dots\dots\dots$$

$$\dots\dots\dots\dots$$

$$a_{n-1}x_{n-2} + d_{n-1}x_n + c_{n-1}x_n = b_{n-1}$$

$$a_nx_{n-1} + d_nx_n = b_n$$

Set $d'_1 = d_1$ and $b'_1 = b_1$

Calculate:

$$m_i = a_{i+1}/d'_i$$

$$d'_{i+1} = d_{i+1} - m_ic_i$$

$$b'_{i+1} = b_{i+1} - m_ib'_i$$

where **i** = 1, 2, 3,…, **n**-1

Set $x_n = b'_n / d'_n$

Calculate $x_i = (b'_i - c_i x_{i+1}) / d'_i$, where **i** = **n**-1, **n**-2,…,1

Note: Sample code in C is available from TRL Limited, demonstrating the iterative procedures to be followed in order to resample the transverse profile using the cubic spline.

Average profile

3.4.15 The average profile is calculated from the arithmetic mean of valid re-sampled transverse profiles within the averaging length, $\mathbf{L_{ave}}$.

3.4.16 For a particular $\mathbf{L_{ave}}$ averaging length, the value of the average profile height at transverse location *i* in the average profile is calculated using the number of transverse profiles within each averaging length $\mathbf{T_{ave}}$ as follows:

$$\bar{y}_i = \frac{\sum_{n=1}^{T_{ave}} \tilde{y}(n)_i}{T_{aveval}}$$

where $\tilde{y}(n)$ is the **n**th individual re-sampled transverse profile within the averaging length. Any invalid profile is excluded from the summation, and $\mathbf{T_{aveval}}$ is the number of (summed) valid profiles.

3.4.17 The “average profile” obtained best represents the shape of the road within the averaging length.

Locating the road edge in the average profile

3.4.18 The first derivatives of the average profile are calculated as $\Delta y/\Delta x$, and the second derivatives are calculated as $\Delta^2 y/\Delta x^2$, as follows:

$$\dot{\bar{y}} = \frac{\Delta \bar{y}}{\Delta \tilde{x}} \Rightarrow \dot{\bar{y}}_i = \frac{\bar{y}_i - \bar{y}_{i-1}}{t}, \quad i = 1,..., N-1$$

$$\ddot{\bar{y}} = \frac{\Delta^2 \bar{y}}{\Delta \tilde{x}^2} \Rightarrow \ddot{\bar{y}}_i = \frac{\dot{\bar{y}}_i - \dot{\bar{y}}_{i-1}}{t}, \quad i = 2,..., N-1$$

$\dot{\bar{y}}_0 = 0$, $\ddot{\bar{y}}_0 = 0$ and $\ddot{\bar{y}}_1 = 0$.

3.4.19 The first and second derivatives are used to locate the road edge. The sign of the second derivative at the location where the first derivative tends to zero is used to determine the nature of the kerb / feature (whether it is the top or bottom of a feature). Depending on the type of curvature the algorithm searches for a minimum or a maximum. The minimum will indicate the top of a kerb, or rut, and the maximum will indicate the bottom of a kerb, or rut.

3.4.20 The algorithm distinguishes between the descending step of a kerb and of a rut by calculating the ratio between the maximum second derivative in the left third of the profile according to the procedures below, and the maximum second derivative in the right third of the profile. The ratio is calculated as the absolute value of the larger of these two second derivative maxima divided by the smaller value. This ratio is then compared to a threshold **r** in order to determine how the road edge location is selected for each profile.

Note, A value for the threshold of **r** = 5 is recommended, but this value should be parameterised.

3.4.21 The edge is therefore located as follows:

3.4.22 The labels $\mathbf{p}_{\mathbf{subscript}}$ are used in the following procedure to refer to positions across the average profile, such that the position $\mathbf{p}_{\mathbf{subscript}}$ corresponds to the re-sampled transverse position $\tilde{x}_{Psubscript}$ and averaged profile height $\bar{y}_{Psubscript}$. Where the subscript is a number **n**, then $\mathbf{p}_{\mathbf{n}}$ = **n**, where **n** is the (**n+1**)th re-sampled position across the profile.

Define the leftmost point in the average profile as position $\mathbf{p}_{\mathbf{0}}$.
Check the sign of the first derivative (the sign of $\dot{y}_6$) at $\mathbf{p}_{\mathbf{6}}$, the seventh point in the average profile.
Find the first position in the interval $\mathbf{p}_{\mathbf{6}}$,…,$\mathbf{p}_{\mathbf{(N/6-1)}}$ (where **N/6-1** is rounded down to an integer value), where the first derivative $\dot{y}$ has the opposite sign to that found in $\mathbf{p}_{\mathbf{6}}$ then let the preceding point be $\mathbf{p}_{\mathbf{a}}$. If the first derivative does not change sign in the interval, then:
For $\dot{y}$ ≥ 0 find the minimum value of $\dot{y}$ in the range p7 to p(N/6-1). If that minimum value is less than $\dot{y}_6$, $\mathbf{p}_{\mathbf{a}}$ is set to the location of that minimum value. If the minimum value is NOT less than $\dot{y}_6$, $\mathbf{p}_{\mathbf{a}}$ is set to p(N/6-2) (rounded down to the nearest integer).
For $\dot{y}$ < 0 find the maximum value of $\dot{y}$ in the range **p7** to $\mathbf{p}_{\mathbf{(N/6-1)}}$. If that maximum value is more than $\dot{y}_6$, $\mathbf{p}_{\mathbf{a}}$ is set to the location of that maximum value. If the maximum value is NOT more than $\dot{y}_6$, $\mathbf{p}_{\mathbf{a}}$ is set to $\mathbf{p}_{\mathbf{(N/6-2)}}$ (rounded down to the nearest integer).

3.4.23 For locating minimum and maximum derivative values below, a minimum absolute value **Q** is applied so that derivative values of smaller magnitudes are ignored. Xfbx

Note, a value of **Q** = 0.00025mm^{-1} should be used.

3.4.24 Find the sign of the second derivative of the transverse profile at position $\mathbf{p_a}$.

3.4.25 If the second derivative at $\mathbf{p_a}$ is negative:

Look for the minimum second derivative with a value lower than **-Q** occurring within the interval $\mathbf{p_2}$ to $\mathbf{p_{N/3}}$ (inclusive), where $\mathbf{p_{N/3}}$ is the index for re-sampled position **N/3** rounded down to the nearest integer.
Define $\mathbf{p_b}$ as the position at which the minimum second derivative $\ddot{y}$ with a value lower than **-Q** (from $\mathbf{p_2}$ to $\mathbf{p_{N/3}}$) occurs. If such a minimum is not found, $\mathbf{p_b}$ =0.
Look for the maximum second derivative $\ddot{y}$ with value higher than **Q** (to the right of $\mathbf{p_b}$ b) between position $\mathbf{p_b}$ and $\mathbf{p_{N/3}}$.
Let the position at which the maximum second derivative with value higher than **Q** (between position $\mathbf{p_b}$ and $\mathbf{p_{N/3}}$**)** occurs be $\mathbf{p_c}$. If such a maximum is not found, $\mathbf{p_c}$ =0 and **Q** is used for the ratio calculation described in 3.4.19
Find the maximum second derivative in the right third of the profile, between position $\mathbf{p_{2N/3}}$ and $\mathbf{p_{(N-1)}}$ inclusive, with value higher than **Q**. If such a maximum is not found, **Q** is used for the ratio calculation described in 3.4.19. Note that $\mathbf{p_{2N/3}}$ is the index for re-sampled position **2*N/3** rounded up to the nearest integer, and $\mathbf{p_{(N-1)}}$ is position index **N-1**.
Calculate the ratio between maximum second derivatives as per 3.4.19.
If the ratio is lower than or equal to **r** (defined in 3.4.19):
If $\mathbf{p_a}$ ≥ 400/**t**, set $\mathbf{p_a}$ = (400/t)-1.
Calculate **slope₀** as $slope_0 = \lvert \bar{y}_j - \bar{y}_0 \rvert / (\tilde{x}_j - \tilde{x}_0)$
Ensuring **t** and $\bar{y}$ are expressed in the same units, where **j** is the index for the re-sampled point corresponding to the second measurement laser position such that $\tilde{x}_j$ ≥ x1 and $\tilde{x}_{j-1}$ < x1, the edge position $\mathbf{p_{ebp}}$ is calculated as
If $\mathbf{slope_0}$ < 0.11, $\mathbf{p_{ebp}}$ = the smaller of $\mathbf{p_a}$ and $\mathbf{p_b}$.
If $\mathbf{slope_0}$ ≥ 0.11, $\mathbf{p_{ebp}}$ = $\mathbf{p_a}$.
If the ratio is greater than **r** the edge position $\mathbf{p_{ebp}}$ is the greater of $\mathbf{p_a}$ and $\mathbf{p_c}$.

3.4.26 If the second derivative at $\mathbf{p_a}$ is positive

Look for the maximum second derivative with value higher than Q occurring over the length **N/3** (from $\mathbf{p_2}$ to $\mathbf{p_{N/3}}$), where $\mathbf{p_{N/3}}$ is the index for re-sampled position **N/3** rounded down to the nearest integer.
Define $\mathbf{p_d}$ as the position at which the maximum second derivative with value higher than **Q** (from **p2** to $\mathbf{p_{N/3}}$) occurs. If such a maximum is not found, $\mathbf{p_d}$ = 0 and Q is used for the ratio calculation described in 3.4.19.
The minimum second derivative with value lower than **-Q** is looked for (to the right of $\mathbf{p_d}$) between position $\mathbf{p_d}$ and $\mathbf{p_{N/3}}$.
Let the position at which the minimum second derivative with value lower than -Q (between position $\mathbf{p_d}$ and $\mathbf{p_{N/3}}$) occurs be $\mathbf{p_e}$. If such a minimum is not found, $\mathbf{p_e}$ = 0.
Find the maximum second derivative in the right third of the profile, between position $\mathbf{p_{2N/3}}$ and $\mathbf{p_{(N-1)}}$ inclusive, with value higher than **Q**. If such a maximum is not found **Q** is used for the ratio calculation described in 3.4.19. Note that $\mathbf{p_{2N/3}}$ is the index for re-sampled position **2*N/3** rounded up to the nearest integer, and $\mathbf{p_{(N-1)}}$ is position index **N-1**.
Calculate the ratio between maximum second derivatives as per 3.4.19.
If the ratio is lower than or equal to **r** (defined in 3.4.19)
If $\mathbf{p_a} \geq 400/\mathbf{t}$, set $\mathbf{p_a}$ = (400/t)-1.
The edge position $\mathbf{p_{ebp}}$ is calculated as:
If $\mathbf{p_d} \leq 400/\mathbf{t}$, $\mathbf{p_{ebp}} = \mathbf{p_d}$
If $\mathbf{p_d} > 400/\mathbf{t}$, $\mathbf{p_{ebp}}$ = the smaller of $\mathbf{p_a}$ and $\mathbf{p_d}$
If the ratio is greater than **r**, $\mathbf{p_{ebp}}$ is defined as the greater of $\mathbf{p_d}$ and $\mathbf{p_e}$.

3.4.27 If the second derivative at $\mathbf{p_a}$ is zero, $\mathbf{p_{ebp}}$ =0.

3.4.28 3.4.27 If the calculated edge position, $\mathbf{e_{BP}}$, is not the position $\mathbf{P_0}$ then the slopes between adjacent measurement laser positions are examined as a further check for removal of the verge. Where the re-sampled profile does not contain a point co-incident with a laser position, the nearest re-sampled point to the right of each laser position is used.

3.4.29 This procedure is carried out as follows:

Determine the original laser location $\mathbf{x_A}$ that satisfies $\mathbf{x_A} \le \tilde{x}_{e_{bp}}$ and $\mathbf{x_{A+1}} > \tilde{x}_{e_{bp}}$.
Determine the original laser location $\mathbf{x_B}$ that satisfies $\mathbf{x_B} \le \mathbf{x_A}$ +1000mm and $\mathbf{x_{B+1}} > \mathbf{x_A}$ +1000mm
Evaluate ***slope*** corresponding to each original laser location $\mathbf{x_i}$ from i = A to i = B-1 (A and B determined above), as follows, $slope_i = \left\|\bar{y}_{j2} - \bar{y}_{j1}\right\| / \left(\tilde{x}_{j2} - \tilde{x}_{j1}\right)$ Note that $\boldsymbol{slope_i}$ is calculated with $\bar{y}$, $\tilde{x}$ and **t** expressed in the same units: and where $\mathbf{j_1}$ and $\mathbf{j_2}$ are the indexes for the re-sampled points corresponding to the measurement laser positions as follows $\tilde{x}_{j1-1} < \mathbf{x_i}$, $\tilde{x}_{j1} \ge \mathbf{x_i}$, $\tilde{x}_{j2-1} < \mathbf{x_{i+1}}$, $\tilde{x}_{j2} \ge \mathbf{x_{i+1}}$,
The edge position, $\mathbf{e_{BP}}$ is adjusted further as $\mathbf{e_{BP}} = \tilde{x}_{j2}$ where $\tilde{x}_{j2-1} < x_{i+1}$, $\tilde{x}_{j2} \ge x_{i+1}$, where **i** is the largest value between A and B-1 inclusive for which the value $\boldsymbol{slope_i}$ is greater than 0.11.
If no value of $\boldsymbol{slope_i}$ exceeds 0.11, for the values of **i** evaluated, the value $\mathbf{e_{BP}}$ is not adjusted.
The 'best transverse profile' now takes the value at $\bar{y}_{P_{ebp}}$ as its first value: $\bar{y}_i = \bar{y}_{i+P_{ebp}}, \quad i = 0,...,N - P_{ebp} - 1$ $\bar{y}_i = 0, \quad i = N - P_{ebp},...,N-1$

Locate the road edge in each transverse profile in the average length

3.4.30 Once $\mathbf{e_{BP}}$, the road edge in the "best transverse profile", has been located this is used to locate $\mathbf{e_n}$, the road edge in each valid transverse profile which was used to obtain the "best transverse profile". To do this each valid transverse profile used to obtain the "best transverse profile" is compared with the "best transverse profile" to determine the amount by which the individual transverse profile must be shifted to obtain optimum alignment with the "best transverse profile". This shift is used to calculate the road edge position in each individual valid transverse profile, $\mathbf{e_n}$.

3.4.31 This shift is found using cross correlation theory. The approach used is described within the following paragraphs (3.4.26 to 3.4.32).

Note: A sample implementation for this part of the algorithm can be supplied by TRL Limited.

3.4.32 For any two profiles a correlation curve is defined. This correlation curve is defined formally by calculating at a given lag **d** the product of two profiles being compared.

The value, **R**, of the correlation curve for any given lag value, **d**, is given as: $R(d) = \sum \bar{y}_{i+d}\tilde{y}_i$ where:
$\bar{y}$ is the "best transverse profile".
$\tilde{y}$ is the re-sampled transverse profile.
Index **i** varies from 0 to (N-1).
d represents the lag value, which indicates the number of re-sampled data points by which the "best transverse profile" must be shifted, in order to provide the optimal correlation with any individual re-sampled transverse profile.
Note: The above definition for calculating the correlation curve is described in more detail in sections 3.4.29 to 3.4.32.

3.4.33 The highest correlation value, **R**, corresponds to an optimum shift $\mathbf{d_{max}}$.

3.4.34 Figure 3.4 illustrates the principle behind the cleaning algorithm, based on the cross correlation of the best profile with an individual transverse profile. The calculation is iterative. The correlation value **R** is calculated for each shift of the best profile with respect to the raw profile. A maximum correlation corresponds to an optimum shift, $\mathbf{d_{max}}$, for which the optimum alignment of the best profile and the individual transverse profile is obtained.

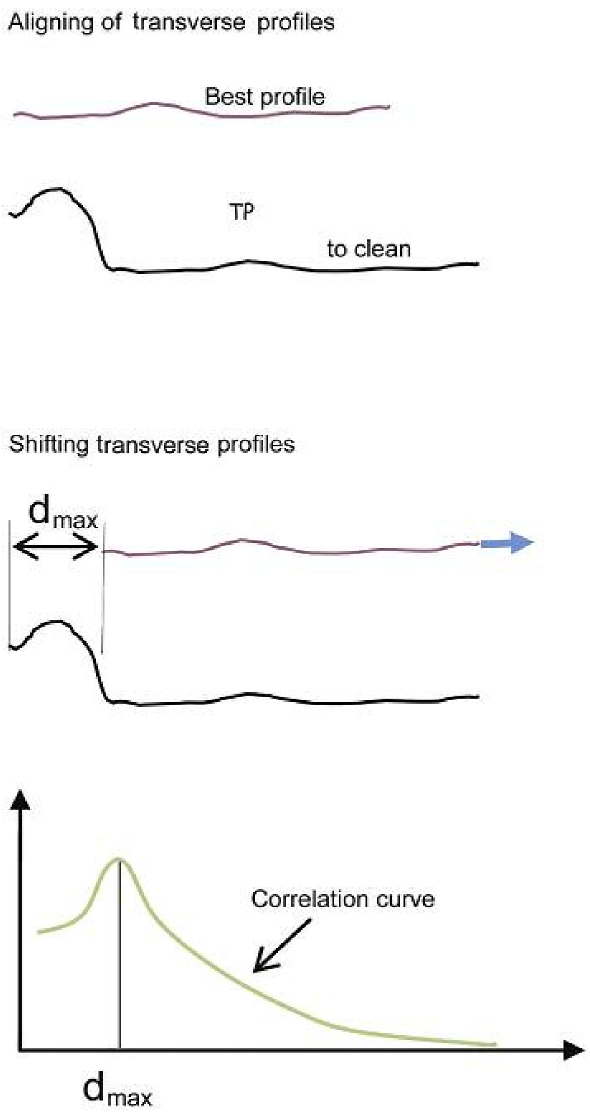


Figure 3. 4: Principle of the cleaning algorithm

3.4.35 The process required to calculate $\mathbf{d_{max}}$ is described in the following paragraphs.

3.4.36 The discrete correlation of two real pairs is defined as:

$$r(d)=corr(\tilde{y}(i),\bar{y}(i),d)=\frac{\sum_{i=0}^{i=N-d-1}(\tilde{y}(i)-\mu_{\tilde{y}})(\bar{y}(i+d)-\mu_{\bar{y}})}{(N-d)\sigma_{\tilde{y}}\sigma_{\bar{y}}}$$

with:

$$\mu_{\tilde{y}}=\frac{\sum_{i=0}^{i=N-d-1}\tilde{y}(i)}{\mathrm{N-d}}$$

$$\mu_{\bar{y}} = \frac{\sum_{i=d}^{i=N-1} \bar{y}(i)}{\mathrm{N - d}}$$

$$\sigma_{\tilde{y}}^{2} = \frac{\sum_{i=0}^{i=N-d-1} \left(\tilde{y}(i) - \mu_{\tilde{y}}\right)^{2}}{N - d}$$

$$\sigma_{\bar{y}}^{2} = \frac{\sum_{i=d}^{i=N-1} \left(\bar{y}(i) - \mu_{\bar{y}}\right)^{2}}{N - d}$$

where:

$\tilde{y}(i)$ is the indicial form of the re-sampled transverse profile.
$\bar{y}(i)$ is the indicial form of the “best transverse profile”.
i is the index for the re-sampled transverse positions, with range 0,1,…,N-1.
the parameter **N** is taken as per the definition in paragraph 3.3.1.
r(d), is the correlation vector (as calculated in paragraph 3.3.30).

3.4.37 The correlation at zero lag (d = 0) is in r(0), the correlation at lag 1 (d = 1) is in r(1) and so on. The components of r(d) are the values of the correlation at different lags d. A maximum value of **r(d)**, $\mathbf{r_{max}(d)}$ is sought by calculating **r(d)** for all 0 < **d** < N/2.

3.4.38 $\mathbf{d_{max}}$ is defined as the lowest value of **d** where $\mathbf{r_{max}(d)}$ occurs, as shown in Figure 3.4.

Note, sample code in C is available from TRL Limited, demonstrating the procedures to be followed in order to calculate $\mathbf{d_{max}}$.

Compute the maximum shift and the edge position

3.4.39 The following defines the method for locating the edge of the road in each transverse profile:

3.4.40 The shift value is defined as the lag where the maximum correlation occurs, $\mathbf{d_{max}}$, as found in 3.4.32.

3.4.41 $\mathbf{d_{max}}$ defines how many re-sampling steps from the position of the first sensor on the transverse profile have measured features to the left of the road edge (verges, kerbs, etc.).

3.4.42 $\mathbf{d_{max}}$, multiplied by the re-sampling interval, **t**, defines the edge position along the transverse profile, $\mathbf{e_n}$, where **n** indicates the re-sampled transverse profile being considered.

$\mathbf{e_n = d_{max}.t}$

3.4.43 Data from measurements made to the left of $\mathbf{d_{max}}$ are not used in subsequent calculations for assessment of transverse profile, and are set to 0 (zero).

3.4.44 The re-sampled transverse profile, with data from the left of $\mathbf{d_{max}}$ set to zero is known as the “cleaned” transverse profile.

3.4.45 The position of the road edge within the transverse profile, e_n, is a floating point number with a value between 0.0 and half of the measurement width of the transverse profile. Where the edge of the road surface cannot be detected within the profile, the edge position is given as 0.0 (zero).

3.5 Transverse Profile Unevenness

3.5.1 The overall process to obtain the transverse profile unevenness can be summarised as shown in Figure 3.5.:

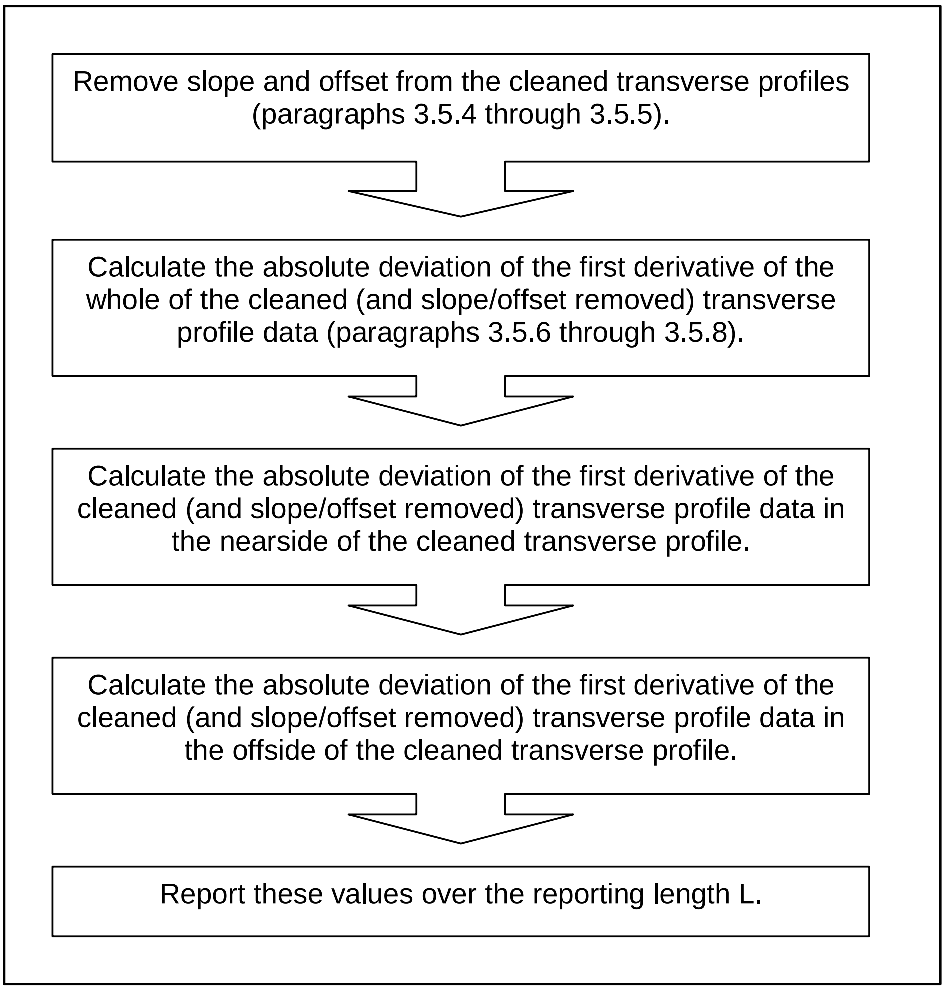


Figure 3.5: Obtaining the transverse profile unevenness

3.5.2 For definitions relating to this algorithm see section 3.3.

3.5.3 The outputs from the algorithm are:

The value of the absolute deviation of the first derivative of transverse profile data for the whole transverse profile $\mathbf{Dev_{FD(ave)}}$.
The value of the absolute deviation of the first derivative of the transverse profile in the nearside of the profile $\mathbf{Dev_{FDNS(ave)}}$.
The value of the absolute deviation of the first derivative of the transverse profile in the offside of the profile $\mathbf{Dev_{FDOS(ave)}}$.
Note, the algorithms are applied to every valid individual re-sampled transverse profile, and are concerned only with points to the right of $\mathbf{e_n}$

Slope and offset suppression

3.5.4 Slope and offset suppression is done by determining the best fitting straight line through the re-sampled profile, based on a least squares fit, and subtracting that line from the profile.

3.5.5 Given the total number of valid data points, **N'** = **N-d** $\mathbf{N\text{-}d_{max}}$, in the re-sampled profile, and the re-sampled profile , the best fitting straight line through the profile is defined by:

$$slope = \frac{12\sum_{i=d_{max}}^{N-1} i * \tilde{y}_i - 6(N'+1)\sum_{i=d_{max}}^{N-1}\tilde{y}_i}{(N')(N'+1)(N'-1)}$$

$$offset = \frac{2*(2N'+1)\sum_{i=d_{max}}^{N-1}\tilde{y}_i - 6\sum_{i=d_{max}}^{N-1} i * \tilde{y}_i}{(N')(N'-1)}$$

First derivative of transverse profile

3.5.6 The first derivative of the transverse profile data (minus the slope and offset) is calculated. The procedure is as follows:

$$\dot{\tilde{y}} = \frac{\Delta\tilde{y}}{\Delta\tilde{x}} \Rightarrow \dot{\tilde{y}}_i = \frac{\tilde{y}_i - \tilde{y}_{i-1}}{t}, \quad i = d_{max} + 1, \ldots, N-1$$

$$\dot{\tilde{y}}_i = 0 \quad for \quad i \le d_{max}$$

3.5.7 The absolute deviation of the first derivative of the whole transverse profile is:

$$Dev_{FD} = \frac{1}{N - d_{max} - 1}\sum_{i=d_{max}+1}^{N-1}\left(\left|\dot{\tilde{y}}_i - \frac{1}{N - d_{max} - 1}\sum_{k=d_{max}+1}^{N-1}\dot{\tilde{y}}_k\right|\right)$$ where:

N = Number of data points in the re-sampled profile,
i = position index on the transverse profile,
k = position index used to calculate average value of first derivative of re-sampled profile, and
$\dot{\tilde{y}}_i$ = the first derivative calculated at position defined by the index **i**.

3.5.8 The absolute deviation of the first derivative of the transverse profile data (minus the slope and offset) is calculatedfor the nearside of the profile as:

$$Dev_{FDNS} = \frac{1}{H - d_{max}}\sum_{i=d_{max}+1}^{H}\left(\left|\dot{\tilde{y}}_i - \frac{1}{H - d_{max}}\sum_{k=d_{max}+1}^{H}\dot{\tilde{y}}_k\right|\right)$$

where:

$$H = \text{int}\left(\frac{(N-1)+d_{\max}}{2}\right)$$

For the offside of the profile, the calculation is:

$$Dev_{FDOS} = \frac{1}{N-H-1}\sum_{i=H+1}^{N-1}\left|\left(\tilde{\hat{y}}_i - \frac{1}{N-H-1}\sum_{k=H+1}^{N-1}\tilde{\hat{y}}_k\right)\right|$$

Reporting

3.5.9 **Dev_{FD}**, **Dev_{FDNS}** and **Dev_{FDOS}** are calculated for all valid individual transverse profiles within each reporting length. The mean of these (up to **T_c**) values are then found and defined as **$Dev_{FD(ave)}$**, **$Dev_{FDNS(ave)}$** and **$Dev_{FDOS(ave)}$**.

3.5.10 The reported value, **$Dev_{FD(ave)}$**, is the average of **Dev_{FD}** for valid profiles within the reporting length:

$$Dev_{FD(ave)} = \frac{1}{T_{Cval}}\sum_{n=1}^{T_C}(\text{Dev}_{\text{FD}})_{\text{n}}$$

where any invalid profile is excluded from the summation, and **T_{Cval}** is the number of (summed) valid profiles.

3.5.11 The reported value, **$Dev_{FDNS(ave)}$**, is the average of **Dev_{FDNS}** for valid profiles within the reporting length:

$$Dev_{FDNS(ave)} = \frac{1}{T_{Cval}}\sum_{n=1}^{T_C}(\text{Dev}_{\text{FDNS}})_{\text{n}}$$

where any invalid profile is excluded from the summation, and **T_{Cval}** is the number of (summed) valid profiles.

3.5.12 The reported value, **$Dev_{FDOS(ave)}$,** is the average of **Dev_{FDOS}** for valid profiles within the reporting length:

$$Dev_{FDOS(ave)} = \frac{1}{T_{Cval}}\sum_{n=1}^{T_C}(\text{Dev}_{\text{FDOS}})_{\text{n}}$$

where any invalid profile is excluded from the summation, and **T_{Cval}** is the number of (summed) valid profiles.

3.6 Cleaned Rut Depths

3.6.1 The overall process can be summarised as:

- Calculate the rut depth in the nearside of the slope and offset suppressed cleaned transverse profile.
- Calculate the rut depth in the offside of the slope and offset suppressed cleaned transverse profile.

3.6.2 The outputs from the algorithm are:

- The average value of the nearside rut depth in the cleaned transverse profiles $\mathbf{Rut_{NSC(ave)}}$, in the reporting length.
- The average value of the offside rut depth in the cleaned transverse profiles $\mathbf{Rut_{OSC(ave)}}$, in the reporting length.

3.6.3 For definitions relating to this algorithm see section 3.3.

3.6.4 The algorithm should be applied to each cleaned profile, with the slope and offset suppression (3.5.4) applied, using only the points from position $\mathbf{d_{max}}$ to position **N-1**. This width becomes the full width '**W**' referred to in the following rut depth algorithm. The size and boundaries of the quarters used by the algorithm will vary according to the edge location $\mathbf{d_{max}}$.

General principles

3.6.5 The general principle is to replicate the use of a 2m straight edge with one end positioned close to the left edge of the lane for the cleaned nearside rut and close to the right edge of the lane for the cleaned offside rut, as shown in Figure 3.6. Cleaned rut depths are measured perpendicular to the straight edge.

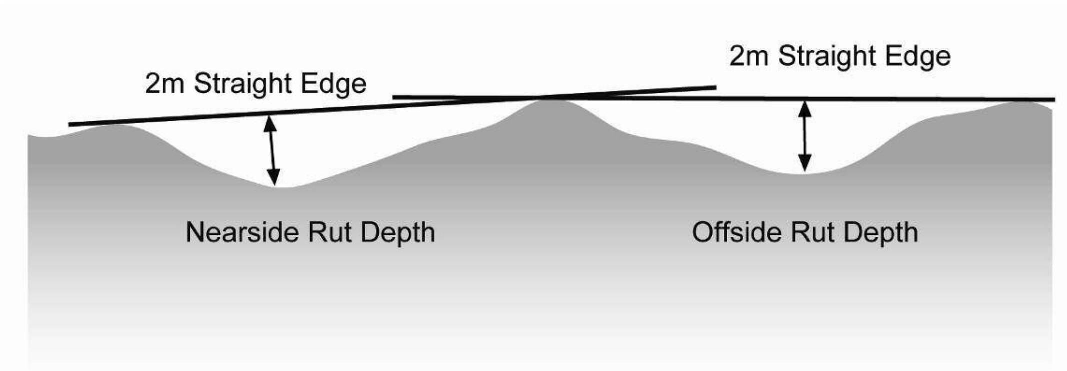


Figure 3.6: Measurement of rut depth using 2m straight edge

3.6.6 However, before the cleaned rut depths can be calculated, some basic checks are needed to eliminate unwanted sensor measurements and to identify inadequately measured profiles. Unwanted measurements may be caused by the sensors overlapping a feature such as a kerb. Inadequately measured profiles may be caused by there being insufficient sensors outside the wheel path. The operation of determining each individual cleaned rut depth can therefore be broken down into three stages as shown in Figure 3. 7.

Identify and eliminate any unwanted sensor measurements

↓

Identify and exclude any inadequately measured profile (inadequately measured profiles shall be excluded from the rut depth calculation for the side evaluated as inadequate, invalid profiles as defined in paragraph 3.2.1 shall be excluded from the rut depth calculation for both sides).

↓

Determine the cleaned rut depth below an appropriately positioned 2m straight edge

Figure 3. 7: Determining individual cleaned rut depth

Calculating individual cleaned rut depths

3.6.7 The slope and offset suppressed cleaned valid transverse profile is defined as covering a lane of width of **W**. The points relate to relative distance with each such distance being labelled $\mathbf{D_1}$ to $\mathbf{D_z}$, in accordance with the corresponding transverse profile point, where $\mathbf{D_1}$ is the left-most point and $\mathbf{D_z}$ is the right-most point, in the direction of travel.

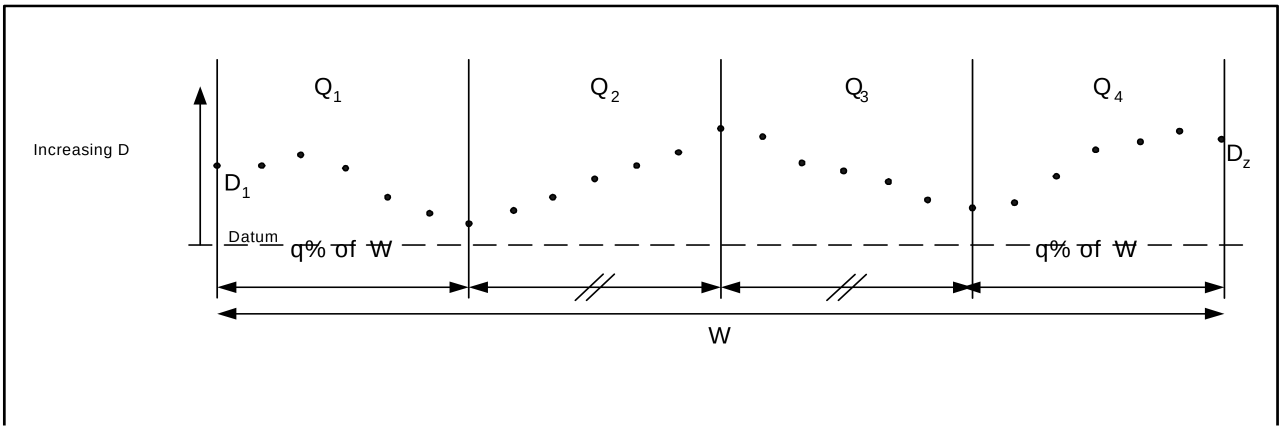


Figure 3.8: Transverse profile points for calculating rut depth

3.6.8 The lane width is subdivided into four parts, $\mathbf{Q_1}$ being that from the left-most edge to a pre-defined percentage **q** (typically 25%) of distance **W** from the left most edge. $\mathbf{Q_4}$ is that from the right most edge to **q**% of **W** from the right most edge. $\mathbf{Q_2}$ and $\mathbf{Q_3}$ equally subdivide the remaining width between $\mathbf{Q_1}$ and $\mathbf{Q_4}$.

3.6.9 Points are reported vertically relative to an artificial ‘horizontal’ datum, with increasing value being upward.

3.6.10 For the purposes of analysis, points that fall exactly on the boundary between $\mathbf{Q_1}$ and $\mathbf{Q_2}$ are deemed to lie within $\mathbf{Q_1}$. Points that fall exactly on the boundary between $\mathbf{Q_3}$ and $\mathbf{Q_4}$ are deemed to lie within $\mathbf{Q_4}$. (Sensor measurements within $\mathbf{Q_2}$ and $\mathbf{Q_3}$ are always considered together.)

3.6.11 Unwanted points may be caused by measurements overlapping a kerb or footway, as shown in Figure 3.9, where d is a pre-defined height (typically 20mm).

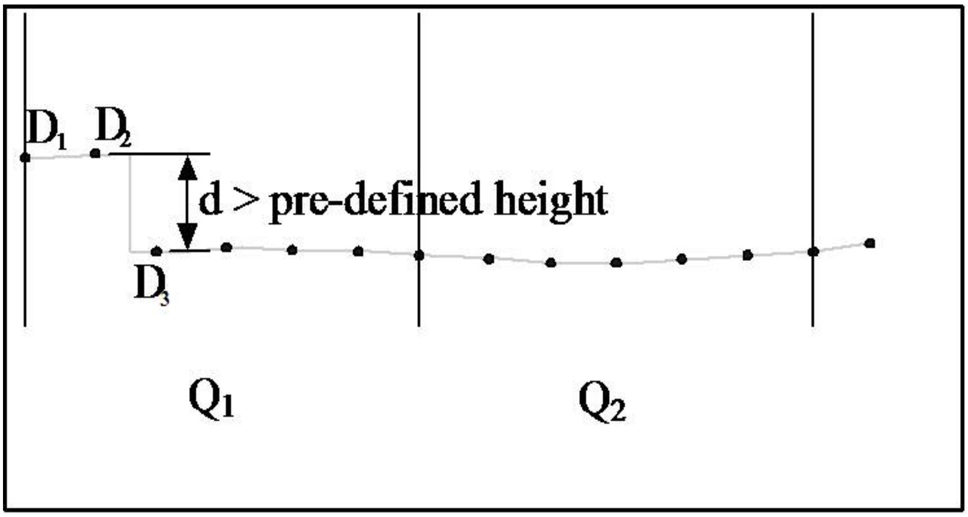


Figure 3.9: Eliminating unwanted points

3.6.12 In the situation shown in Figure 3.9, points $\mathbf{D_1}$ and $\mathbf{D_2}$ should be eliminated, i.e. excluded from the calculation of the nearside cleaned rut depth.

3.6.13 In the general case, when calculating the nearside cleaned rut depth:

> All points from $\mathbf{D_1}$ to $\mathbf{D_{(n-1)}}$ should be eliminated where ($\mathbf{D_{(n\ 1)}}$-$\mathbf{D_n}$) > **d** and $\mathbf{D_n}$ is within $\mathbf{Q_1}$.

3.6.14 Similarly when calculating the offside cleaned rut depth:

> All points from $\mathbf{D_{(n+1)}}$ to $\mathbf{D_z}$ should be eliminated where ($\mathbf{D_{(n+1)}}$-$\mathbf{D_n}$) > **d** and $\mathbf{D_n}$ is within $\mathbf{Q_4}$.

Identification of an inadequately measured profile

3.6.15 An inadequately measured profile may be caused by there being insufficient points outside the wheel path, as shown in Figure 3.10, where **s** is a pre-defined slope (typically 15%).

3.6.16 In the situation shown in Figure 3.10, the profile should be considered as “inadequate”, and the nearside cleaned rut depth should not be calculated.

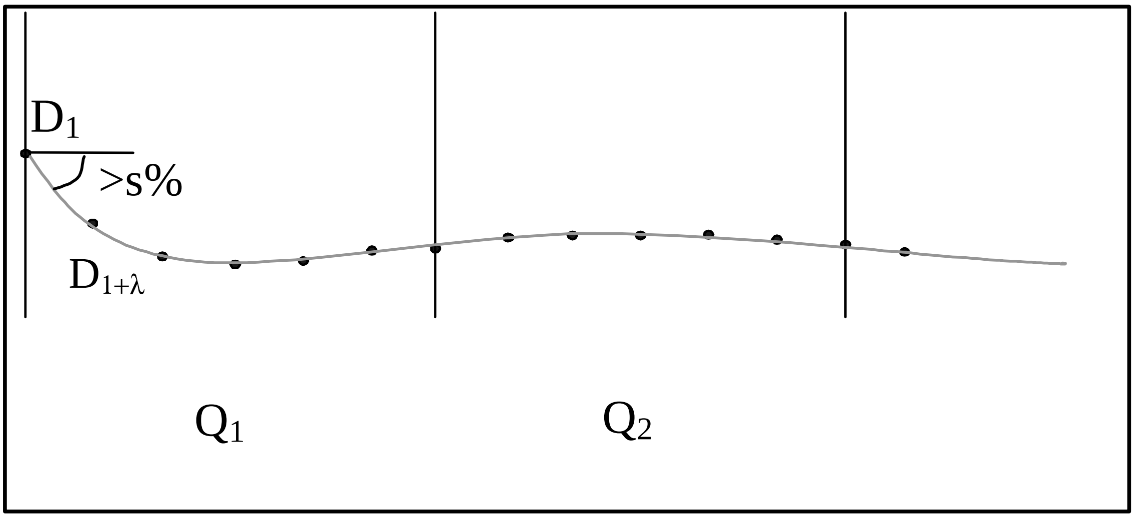


Figure 3.10: Example of inadequate profile for cleaned rut depth calculation

3.6.17 In the general case, when calculating the nearside cleaned rut depth, if the slope from $\mathbf{D_1}$ to $\mathbf{D_{(1+\lambda)}}$ exceeds **s**% (downwards) the profile should be considered "inadequate" and the individual cleaned rut depth should not be calculated.

3.6.18 Similarly when calculating the offside cleaned rut depth, if the slope from $\mathbf{D_z}$ to $\mathbf{D_{(z-\lambda)}}$ exceeds **s**% (downwards) the profile should be considered "inadequate" and the individual cleaned rut depth should not be calculated.

3.6.19 The value for **λ** is obtained by dividing 100mm by the transverse spacing of the re-sampled data points, rounded down to the nearest integer. Where this indicates a value of **λ** =0, **λ** =1 should be used. For 25 mm re-sampled profile point spacing, this gives **λ** = 4.

- When calculating the nearside cleaned rut depth, if point $\mathbf{D_1}$ has been eliminated as defined in paragraphs 3.6.12 through 3.6.14, the check for an inadequately measured profile should not be carried out.
- Similarly, when calculating the offside cleaned rut depth, if point $\mathbf{D_z}$ has been eliminated as defined in paragraphs 3.6.12 through 3.6.14, the check for an inadequately measured profile should not be carried out.

3.6.20 In such cases the measured profile is always considered as adequate.

Calculation of nearside cleaned rut depth

3.6.21 Having eliminated any unwanted points (as described in paragraphs 3.6.12 through 3.6.14) and assuming that the profile is not considered "inadequate" (as described in paragraphs 3.6.15 through 3.6.20) the nearside cleaned rut depth is calculated as follows:

Position of notional straight edge

3.6.22 Within the following paragraph, distance **L** is the length of a notional straight edge (typically 2m).

This length **L** and minimum distance **l** (typically 0.6m) should be configurable within the applications software

3.6.23 For each point $\mathbf{D_n}$, (**n** = 1, 2, 3 etc., but excluding unwanted points) within $\mathbf{Q_1}$, ascertain whether there is a corresponding point $\mathbf{D_p}$

- which is to the right of, within distance **L** of, and at least distance **l** from point $\mathbf{D_n}$, and
- such that all points to the right of and within distance **L** of point $\mathbf{D_n}$ lie on or below a line of length **L** drawn from point $\mathbf{D_n}$ and passing thought point $\mathbf{D_p}$.

3.6.24 Once a pair of points $\mathbf{D_n}$ and $\mathbf{D_p}$ has been found that satisfies the conditions, the searching process stops (see Figure 3.11).

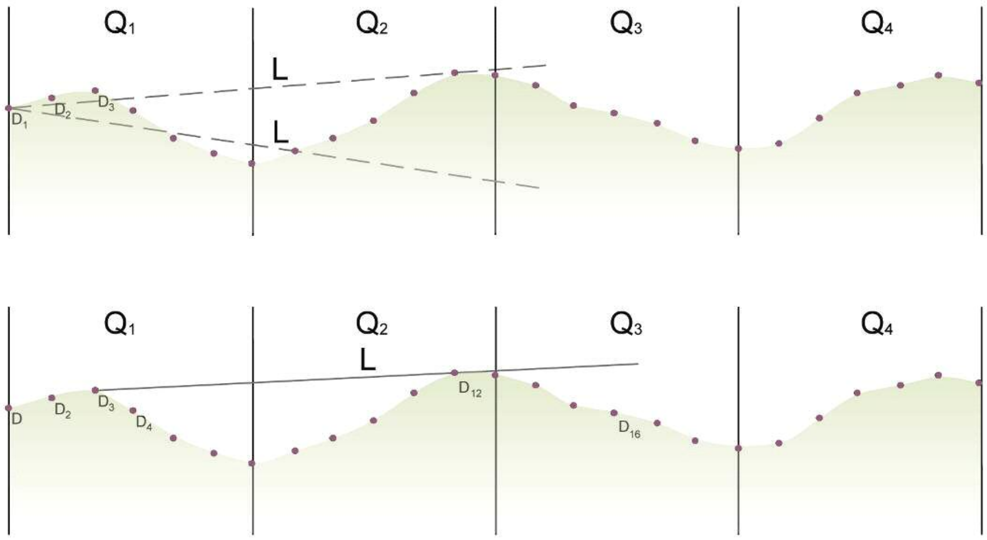


Figure 3.11: Criteria for positioning nominal straight edge

- Figure 3.11 (upper) demonstrates that there is no point corresponding to point $\mathbf{D_1}$ that satisfies the stated criteria (points $\mathbf{D_2}$ and $\mathbf{D_3}$ lie above all lines from point $\mathbf{D_1}$). Similarly, there is no point corresponding to point $\mathbf{D_2}$ that satisfies the stated criteria (point $\mathbf{D_3}$ lies above all lines from point $\mathbf{D_2}$).
- Figure 3.11 (lower) shows that there is a point ($\mathbf{D_{12}}$) corresponding to point $\mathbf{D_3}$ that satisfies the stated criteria (all points from $\mathbf{D_4}$ to $\mathbf{D_{16}}$ inclusive lie either on or below the line of length **L** from point $\mathbf{D_3}$

passing through point $\mathbf{D_{12}}$). This therefore represents the correct position for the notional straight edge.

3.6.25 If no pair of points can be found that satisfies the stated criteria, the nearside cleaned rut depth is set to zero.

Calculation of depth and offset to each intervening point

3.6.26 The depth (**d**) and offset (**l**) of each point lying between $\mathbf{D_n}$ and $\mathbf{D_p}$, relative to the notional straight edge, can be calculated as follows:

$$S = \sqrt{(y_p - y_n)^2 + (x_p - x_n)^2}$$

$$h_a = \sqrt{(y_a - y_n)^2 + (x_a - x_n)^2}$$

$$d_a = \frac{(x_p - x_n)(y'_a - y_a)}{S}$$

$$y'_a = y_n + \frac{(x_a - x_n)(y_p - y_n)}{(x_p - x_n)}$$

$$l_a = \sqrt{{h_a}^2 - {d_a}^2}$$

($\mathbf{x_n}$,$\mathbf{y_n}$) = Offset and height (within transverse profile) of point $\mathbf{D_n}$
($\mathbf{x_p}$,$\mathbf{y_p}$) = Offset and height (within transverse profile) of point $\mathbf{D_p}$
($\mathbf{x_a}$,$\mathbf{y_a}$) = Offset and height (within transverse profile) of point $\mathbf{D_a}$
($\mathbf{x_a}$,$\mathbf{y'_a}$) = Offset and height (within transverse profile) of the point on the notional straight edge vertically above point $\mathbf{D_a}$

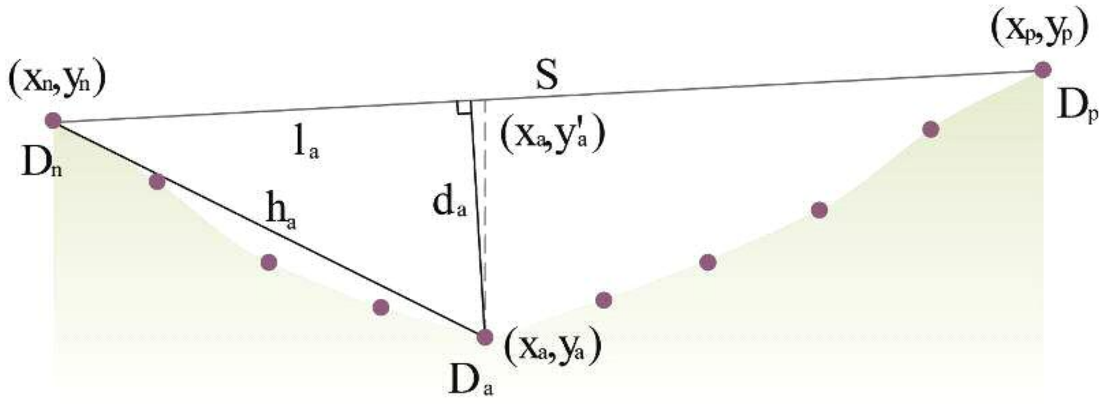


Figure 3.12: Definition of rut depth

Calculation of cleaned nearside rut depth

3.6.27 The cleaned rut depth Rut_{NSC} is calculated as the maximum value of **d**.

Calculation of offside cleaned rut depth

3.6.28 The offside cleaned rut depth Rut_{OSC} is calculated in the same way as, but a mirror image of, the nearside cleaned rut depth, i.e. working from the right edge of the transverse profile.

Average cleaned rut depths

3.6.29 For each wheel path, the average cleaned rut depth over the prescribed length **L** (e.g. 10m) is calculated by averaging the individual cleaned rut depths for that wheel path, including zero cleaned rut depths but excluding inadequate or invalid transverse profiles, as follows:

$$Rut_{NSC(ave)} = \frac{1}{T_{Cval}} \sum_{n=1}^{T_C} (\mathrm{Rut}_{\mathrm{NSC}})_n \quad if \quad T_{Cval} > 0$$

$$Rut_{NSC(ave)} = 0 \quad if \quad T_{Cval} = 0$$

$$Rut_{OSC(ave)} = \frac{1}{T_{Cval}} \sum_{n=1}^{T_C} (\mathrm{Rut}_{\mathrm{OSC}})_n \quad if \quad T_{Cval} > 0$$

$$Rut_{OSC(ave)} = 0 \quad if \quad T_{Cval} = 0$$

where $\mathbf{T_{Cval}}$ is the number of (summed) valid profiles.

3.7 Edge roughness

3.7.1 The edge roughness is derived for each reporting length (**L**) from valid measured transverse profiles within that reporting length.

Note that the **original** measured transverse profiles (prior to normalising, smoothing, re-sampling and cleaning) are used when calculating edge roughness.

3.7.2 For definitions relating to this algorithm see section 3.3. However, the following further definition applies:

$\mathbf{V_{Lim}}$ = Edge roughness longitudinal profile variance threshold.
A typical value for $\mathbf{V_{Lim}}$ is $3mm^2$, however this should be parameterised.

3.7.3 The output value is

"R" = Edge roughness value, proportion taking a value between 0 and 1 inclusive.

3.7.4 Figure 3.13 may aid in visualising the edge roughness measure. The requirement is that an (approximately) 0.6m moving average longitudinal profile variance (**MALPV**) is calculated for those points which are within the edge strip, extending, within each transverse profile, from $\mathbf{e_n}$ (as defined in paragraph 3.4.36) to $\mathbf{e_n}$+500mm.

3.7.5 **MALPV** values are calculated for points which lie exactly at $\mathbf{e_n}$ or $\mathbf{e_n}$ +500mm within their transverse profile.

3.7.6 **MALPV** values are not calculated for transverse profiles lying within the first (approximately) 0.3m or last (approximately) 0.3m of the reporting length (as there are insufficient points to do so). **MALPV** values are also not calculated where to do so would involve an invalid transverse profile.

3.7.7 Edge roughness (**R**) is calculated as the proportion of **MALPV** values, calculated within the reporting length, that exceed $\mathbf{V_{Lim}}$.

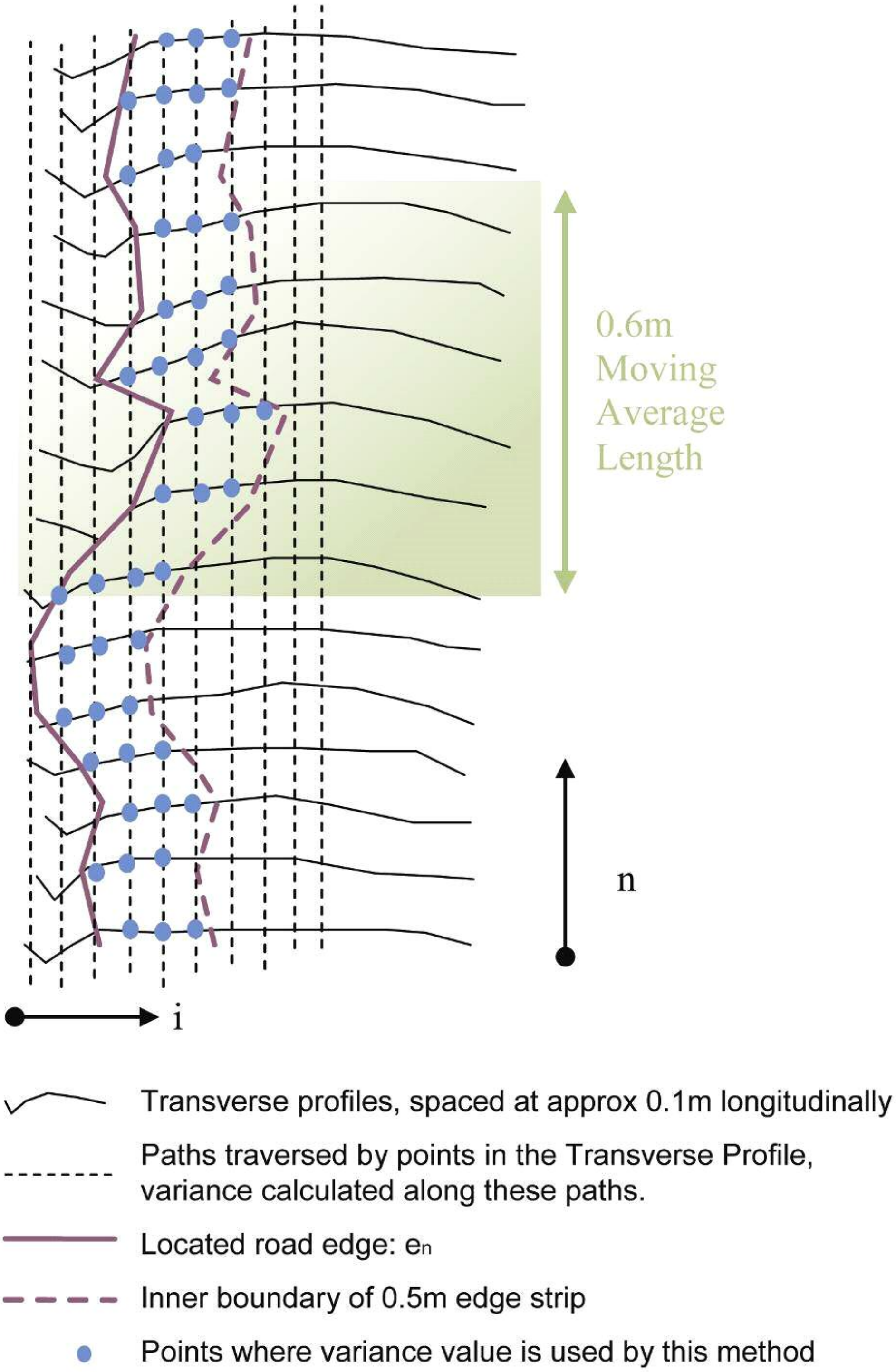


Figure 3. 13: Calculation of the edge roughness – defining the area of interest

3.7.8 For a reporting length of **L** metres, let $\mathbf{y_{i(n)}}$ represent a particular transverse profile height measurement (height in mm), where **i** is the number of the point in the transverse profile, (ranging from **0** (being the leftmost point) to **q-1**) and **n** is the number of the transverse profile in the reporting length (ranging from **0** to $\mathbf{T_{c-1}}$).

e.g. for a 10m reporting length (**L**) with 20 point (**q**) transverse profiles longitudinally spaced at 0.09925m intervals (**D**)
$\mathbf{T_c}$ will be calculated as 100 and there will be 2000 transverse profile height measurements
labelled $\mathbf{y_0(0)}$ … $\mathbf{y_{19}(0)}$; $\mathbf{y_0(1)}$ … $\mathbf{y_{19}(1)}$; ………; $\mathbf{y_0(99)}$ … $\mathbf{y_{19}(99)}$.

3.7.9 The number of transverse profiles used in each **MALPV** calculation is (2M+1) where:

$$M = \begin{vmatrix} 2 & \cdots & D > 0.12m \\ 3 & \cdots & 0.09m \le D < 0.12m \\ 4 & \cdots & 0.07m \le D < 0.09m \\ \mathrm{int}(0.3/D) & \cdots & D \le 0.07m \end{vmatrix}$$

3.7.10 For each transverse profile (**n**) where **n ≥ M** and **n** < $\mathbf{(T_c\text{-}M)}$:

- Determine whether any of the transverse profiles in the range (**n-M**) to (**n+M**) are invalid. If so, **MALPV** values are not calculated for points within the current transverse profile (i.e. the next three stages should be skipped for the current transverse profile) and both $\boldsymbol{\alpha_n}$ and $\boldsymbol{\beta_n}$ are set to zero ($\boldsymbol{\alpha_n}$ and $\boldsymbol{\beta_n}$ as defined below);
- Determine the range of points within the current transverse profile that lie within the edge strip, i.e. at offsets between $\mathbf{e_n}$ and $\mathbf{e_n}$**+500**mm (including any that lie exactly at $\mathbf{e_n}$ or $\mathbf{e_n}$**+500**mm). The number of transverse profiles so determined, for profile n, is defined as $\boldsymbol{\alpha_n}$;
- For each point **i** lying within the edge strip, calculate the **MALPV**, $\mathbf{y'_i(n)}$, in units of mm^2 defined as:

$$y'_i(n) = \left[y_i(n) - \left(\frac{1}{2M+1} \right) \sum_{j=n-M}^{j=n+M} y_i(j) \right]^2$$

- determine the number of **MALPV** values greater than $\mathbf{V_{Lim}}$. For profile **n**, this number is defined as $\boldsymbol{\beta_n}$.

3.7.11 For the reporting length:

- the number of transverse profile points within the edge strip for which a **MALPV** has been calculated is denoted as **A**, where:

$$A = \sum_{n=M}^{n=T_c-M-1} a_n$$

- the number of transverse profile points within the edge strip with **MALPV** values greater than $\mathbf{V_{Lim}}$, is denoted as **B**, where:

$$B = \sum_{n=M}^{n=T_c-M-1} \beta_n$$

- edge roughness is reported as R where:

  R = **B**/**A**.

3.8 Road edge step

3.8.1 The road edge step is derived for each reporting length (**L**) from the valid measured transverse profiles within that reporting length that have an edge position ($\mathbf{e_n}$) greater than zero.

Note that it is the **original** measured transverse profiles (prior to normalising, smoothing, re-sampling and cleaning) that are used when calculating the road edge step.

3.8.2 The algorithm delivers:

- "$\mathbf{L_{SL1}}$" – Small step down at the road edge, percentage of reporting length.
- "$\mathbf{L_{SL2}}$" – Large step down at the road edge, percentage of reporting length.

3.8.3 For definitions relating to this algorithm see section 3.3. However, the following further definitions apply.

V is the number of the first transverse profile point located to the left of, or at, the edge position $\mathbf{e_n}$.
$\mathbf{R_1}$ is the number of the first transverse profile point located to the right of (and not equal to) the edge position $\mathbf{e_n}$.
$\mathbf{R_2}$ is the number of the last (or rightmost) transverse profile point located to the left of or at a position 1m to the right of the position defined by $\mathbf{e_n}$ (i.e. at the position $\mathbf{e_n}$ +1000mm).

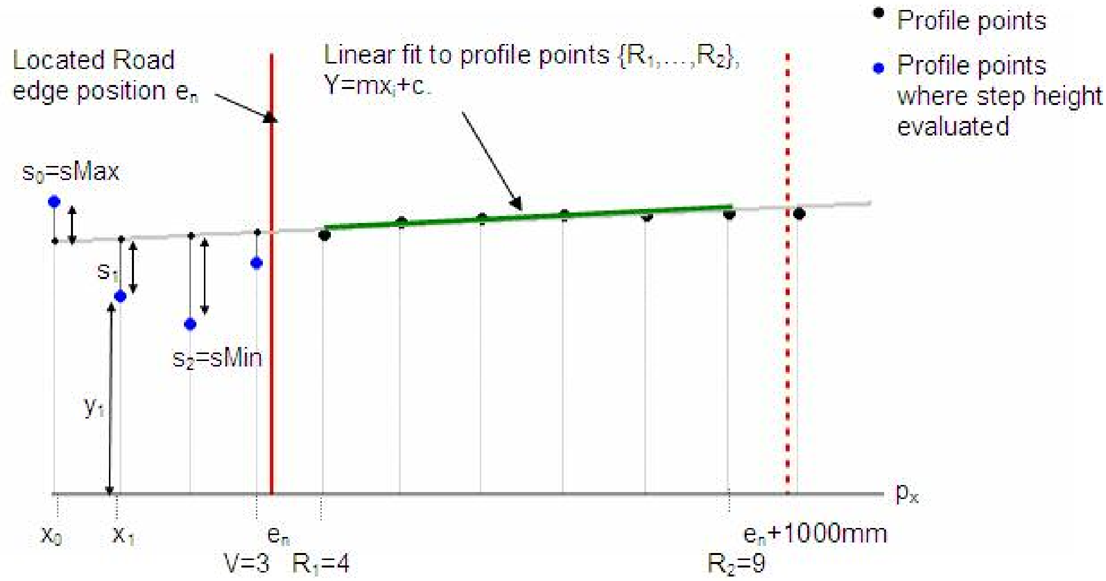


Figure 3.14: Calculation of the edge step height – measurements obtained from the transverse profile

3.8.4 Obtain the least-squares best fit line for the transverse profile measurements recorded between position $\mathbf{x_{R1}}$ and position $\mathbf{x_{R2}}$ (shown in Figure 3.15 in green). The least squares fit will define a line $\mathbf{Y=mx_i+c}$ (where **Y** is the line height value at any transverse position $\mathbf{x_i}$, **m** is the gradient of the line and **c** is the value of **Y** at transverse position $\mathbf{x_0}$).

$$m = \frac{XY - (R_2 - R_1 + 1)\overline{X}\,\overline{Y}}{X^2 - (R_2 - R_1 + 1)\overline{X}^2} \quad , \quad c = \overline{Y} - m\overline{X}$$

$$Where: \quad XY = \sum_{i=R_1}^{i=R_2} x_i \cdot y_i, \quad X^2 = \sum_{i=R_1}^{i=R_2} x_i^2$$

$$\overline{Y} = \frac{1}{(R_2 - R_1 + 1)} \sum_{i=R_1}^{i=R_2} y_i, \quad \overline{X} = \frac{1}{(R_2 - R_1 + 1)} \sum_{i=R_1}^{i=R_2} x_i$$

3.8.5 This best fit line is then extrapolated from $\mathbf{x_0}$ to $\mathbf{x_{q-1}}$.

3.8.6 The difference between the measured profile height at $\mathbf{x_i}$, and the height predicted by the best fit line is defined as $\mathbf{s_i}$.

3.8.7 For each point in the transverse profile from position $\mathbf{x_0}$ to $\mathbf{x_V}$ (i.e. from the nearside of the transverse profile to the point immediately to the left of the edge position), calculate the values $\mathbf{s_0}$ to $\mathbf{s_V}$ measured relative to the datum line **Y**, defined above, $\mathbf{s_i} = \mathbf{y_i} - \mathbf{Y(x_i)}$.

A positive step is defined as one where the measured profile height is greater than the profile height predicted by the best fit line.
A negative step is defined as one where the measured profile height is less than the profile height predicted by the best fit line.

3.8.8 Record the largest positive value (step up, $\mathbf{s_{Max}}$ ($\mathbf{s_0}$ in Figure 3.14.)) and largest negative value (step down, $\mathbf{s_{Min}}$ ($\mathbf{s_2}$ in Figure 3.14.)) from the dataset obtained in paragraph 3.8.7.

If no positive step values of $\mathbf{s_i}$ occur, $\mathbf{s_{Max}} = 0$,
if no negative step values of $\mathbf{s_i}$ occur, $\mathbf{s_{Min}} = 0$.

3.8.9 As paragraph 3.8.8 evaluates the maximum and minimum values in the region to the left of the edge point, the value $\mathbf{s_{Max}}$ is the largest step upwards from the best fit line in the verge region of the profile, and the value $\mathbf{s_{Min}}$ is the largest step downwards from the best fit line in the verge region of the profile. $\mathbf{s_{Min}}$ will have a negative value if a downwards step exists from the road to the verge.

3.8.10 The transverse position where $\mathbf{s_{Max}}$ occurs is defined as $\mathbf{p_{Max}}$, and the position where $\mathbf{s_{Min}}$ occurs is defined as $\mathbf{p_{Min}}$.

In Figure 3.14, $\mathbf{p_{Max}} = \mathbf{x_0}$, $\mathbf{p_{Min}} = \mathbf{x_2}$

- If $\mathbf{s_{Max}} = 0$, $\mathbf{p_{Max}} = 0$
- If $\mathbf{s_{Min}} = 0$, $\mathbf{p_{Min}} = 0$

3.8.11 The step height, **S**, is:

$\mathbf{S} = \mathbf{s_{Max}}$ if $\mathbf{p_{Max}} > \mathbf{p_{Min}}$ OR $\mathbf{S} = \mathbf{s_{Max}}$ if ($\mathbf{p_{Max}} = \mathbf{p_{Min}} = 0$ AND $\mathbf{s_{Max}} > 0$)
$\mathbf{S} = \mathbf{s_{Min}}$ if $\mathbf{p_{Min}} > \mathbf{p_{Max}}$ OR $\mathbf{S} = \mathbf{s_{Min}}$ if ($\mathbf{p_{Min}} = \mathbf{p_{Max}} = 0$ AND $\mathbf{s_{Min}} < 0$)
$\mathbf{S} = 0$ if $\mathbf{p_{Min}} = \mathbf{p_{Max}} = 0$ AND $\mathbf{s_{Max}} = \mathbf{s_{Min}} = 0$
S is given the value $\mathbf{S} = 0$ for any invalid transverse profile or where the road edge position, $\mathbf{e_n}$, is reported as 0, indicating that no edge was found within the profile.

Reporting the edge step height

3.8.12 For the reporting length:

- The number of downward steps between -20mm and -50mm, including steps of -50mm, but excluding steps of -20mm exactly (50mm $\leq \mathbf{S} <$ -20mm) is denoted as $\mathbf{S_{L1}}$.

- The number of downward steps greater than 50mm (**S** < 50mm) is denoted as $\mathbf{S_{L2}}$.
- Small step down at the road edge is reported as $\mathbf{L_{SL1}}$ where: $\mathbf{L_{SL1}}$ = 100*$\mathbf{S_{L1}}$/$\mathbf{T_c}$
- Large step down at the road edge is reported as $\mathbf{L_{SL2}}$ where: $\mathbf{L_{SL2}}$ =100*$\mathbf{S_{L2}}$/$\mathbf{T_c}$

3.9 Transverse variance

3.9.1 The transverse variance for each reporting length (**L**) is obtained from the valid cleaned transverse profiles, with the slope and offset suppression (Section 3.5.4) applied, within that length.

3.9.2 For definitions relating to this algorithm see section 3.3. However, the following further definitions apply.

$\tilde{y}$ = 'cleaned' transverse profile.
$\mathbf{d_{max}}$ = position index of the road edge location within the cleaned transverse profile.
$\mathbf{T_{DIFFave}}$ = Difference between the left and right transverse profile variance, units of mm^2.

Evaluating the left and right half transverse profile variances for each profile

3.9.3 The cleaned profile $\tilde{y}$ contains N re-sampled profile points $\{\tilde{y}_0, \tilde{y}_1, \ldots, \tilde{y}_{(n-1)}\}$.

3.9.4 The position of the road edge expressed as the re-sampled profile position index is given as $\mathbf{d_{max}}$. Data from points to the left of $\mathbf{d_{max}}$, $\{\tilde{y}_0, \tilde{y}_1, \ldots, \tilde{y}_{(d\max-1)}\}$, are set to 0 (zero).

3.9.5 The procedure 'Slope and offset suppression', defined in Section 3.5.4 is applied to the cleaned profile data, $\tilde{y}$, before proceeding with the transverse profile variance calculations.

3.9.6 The variances of the profile heights within each half are calculated, and reported as the left and right half variance values $\mathbf{T_L}$ and $\mathbf{T_R}$. This involves the calculation of the average of the cleaned profile heights for each half, $\overline{L}$ and $\overline{R}$. The sample position where the split between the left and right halves occur is calculated as **H**.

3.9.7 These values are all calculated for each profile as follows:

$$T_L = \left(\frac{1}{H-d_{\max}}\right)\left[\sum_{i=d_{\max}}^{H}\left(\tilde{y}_i - \overline{L}\right)^2 - \frac{\left(\sum_{i=d_{\max}}^{H}\left(\tilde{y}_i - \overline{L}\right)\right)^2}{H-d_{\max}+1}\right]$$

$$T_R = \left(\frac{1}{N-H-2}\right)\left[\sum_{i=H+1}^{N-1}\left(\tilde{y}_i - \overline{R}\right)^2 - \frac{\left(\sum_{i=H+1}^{N-1}\left(\tilde{y}_i - \overline{R}\right)\right)^2}{N-H-1}\right]$$

where

$$\overline{L} = \left(\frac{1}{H-d_{\max}+1}\right)\sum_{i=d_{\max}}^{H}\tilde{y}_i$$

$$\overline{R} = \left(\frac{1}{N-H-1}\right)\sum_{i=H+1}^{N-1}\tilde{y}_i$$

and

$$H = \operatorname{int}\left(\frac{(N-1)+d_{\max}}{2}\right)$$

3.9.8 With the cleaned profile values contained within $\tilde{y}$ in units of mm, the output profile variance values will be in the units of mm^2.

Calculating the transverse variance difference measure for the reporting length

3.9.9 Calculate the mean average of the (up to $\mathbf{T_c}$) values of $\mathbf{T_L}$ for valid transverse profiles within the reporting length **L**:

$$T_{Lave} = \left(\frac{1}{T_{Cval}}\right)\sum_{n=0}^{n=T_C-1}T_L(n)$$

where any invalid profile is excluded from the summation, and $\mathbf{T_{Cval}}$ is the number of (summed) valid profiles.

3.9.10 Calculate the mean average of the (up to $\mathbf{T_c}$) values of $\mathbf{T_R}$ for valid transverse profiles within the reporting length **L**.

$$T_{Rave} = \left(\frac{1}{T_{Cval}}\right)\sum_{n=0}^{n=T_C-1} T_R(n)$$

where any invalid profile is excluded from the summation, and $\mathbf{T_{Cval}}$ is the number of (summed) valid profiles.

3.9.11 The average difference between the two halves of the profile for the reporting length can then be calculated as $\mathbf{T_{DIFFave}} = \mathbf{T_{Lave}} - \mathbf{T_{Rave}}$. This is the value reported from the method.

3.10 Coverage

3.10.1 The coverage value **U** is evaluated for each reporting length **L**. This value indicates the percentage of the length where the profiles have been measured over the edge of the road surface.

3.10.2 Profiles that do not measure past the edge of the road surface are indicated by a located road edge position value, $\mathbf{e_n}$, of zero. The value $\mathbf{e_n}$ is the road edge location found for each profile.

3.10.3 For each reporting length:

- Count the number of valid transverse profiles within the reporting length which have a road edge position $\mathbf{e_n} > 0$, the valid coverage, **u**.
- Calculate the value **U** as:

  $\underline{U} = 100*(\mathbf{u}/\mathbf{T_C})$

3.11 Typical Values (Checks and Limits)

3.11.1 Typical values (to be confirmed during acceptance tests) for the checks and limits to be placed on the transverse profile data are given in Table 3.3

	Typical Value
Rut depth kerb value (mm)	20
Rut depth slope value (%)	15
Max % of inadequate profiles within an averaging length	25
Length of notional straight edge for rut depth (m)	2
Minimum distance between peaks for rut depth (m)	0.6

Table 3.3: Typical values for the calculation of transverse profile parameters

4 Rut Parameters

4.1 General requirements

4.1.1 The following parameters will be derived from the rutting data and delivered in the HMDIF file:

- Average nearside rut depth over each reporting length.
- Average offside rut depth over each reporting length.

4.1.2 These parameters are calculated from the measured rutting data before any fitting is carried out on the Survey Data (e.g. fitting to the Employer's network).

4.1.3 Before the parameters are calculated checks must be carried out on the validity of the rutting, as described in Section 4.2.

4.2 Checking the rutting data

4.2.1 When calculating an average nearside rut depth for a reporting length, if any individual measured nearside rut depth is invalid (i.e. outside the permitted range), that rut depth is not used in the calculation. If more than a defined percentage (typically 5%) of the individual nearside rut depths within a reporting length are invalid, the average nearside rut depth for that reporting length is considered invalid (and therefore not reported in the HMDIF file).

4.2.2 When calculating an average offside rut depth for a reporting length, if any individual measured offside rut depth is invalid (i.e. outside the permitted range), that rut depth is not used in the calculation. If more than a defined percentage (typically 5%) of the individual offside rut depths within a reporting length are invalid, the average offside rut depth for that reporting length is considered invalid (and therefore not reported in the HMDIF file).

4.3 Definitions

4.3.1 The following definitions apply in the calculation of the average rut depths.

D = longitudinal spacing between successive measured rut depths, typically approximately 0.1m.
L = reporting length. This should be parameterised, the recommended default value is 10m.
$\mathbf{T_c}$ = total number of measured rut depths pairs (nearside and offside) in a reporting length $\mathbf{T_c}$ = (**L/D**) rounded down to the nearest integer.

n = index for the measured rut depth pair within the reporting length.
Rut_L = individual measured nearside (left wheel path) rut depth.
Rut_R = individual offside (right wheel path) nearside rut depth.

4.4 Average Rut Depths

4.4.1 Where the reporting length is not an exact multiple of longitudinal spacing between successive measured rut depths there will be more measured rut depths than required within some reporting lengths.

> e.g. With a reporting length of 10m and a longitudinal spacing between successive measured rut depths of 0.09925m
>
> **T_c** will be calculated as (10/0.09925) = 100.75567, rounded down to 100
>
> However the number of measured rut depth pairs lying within each 10m reporting length will be as shown in Table 4.1
>
> In such situations, the “extra” measured rut depths (at the end of the reporting lengths) are not used in calculating the averages.

Reporting Length	Number of Readings
0-10	100
10-20	101
20-30	101
30-40	101
40-50	100
Etc	

Table 4.1: Reporting lengths versus number of readings

4.4.2 When a pair of measured rut depths falls exactly on the boundary between two reporting lengths, it is deemed to lie within the former of those lengths.

> e.g. With a reporting length of 10m and a longitudinal spacing between successive measured rut depths of exactly 0.1m, the 100^{th} pair of measured rut depths (at chainage 10m) is deemed to lie within the 0-10m reporting length.

4.4.3 For each wheel path, the average rut depth for a reporting length is calculated by averaging the (up to $\mathbf{T_c}$) individual rut depths for that wheel path, including zero rut depths but excluding invalid rut depths:

$$\text{Average nearside rut depth} = \left(\frac{1}{T_{CvalL}}\right)\sum_{n=1}^{n=T_C} Rut_L(n)$$

where any invalid nearside rut depth is excluded from the summation, and $\mathbf{T_{CvalL}}$ is the number of (summed) valid nearside rut depths.

$$\text{Average offside rut depth} = \left(\frac{1}{T_{CvalR}}\right)\sum_{n=1}^{n=T_C} Rut_R(n)$$

where any invalid offside rut depth is excluded from the summation, and $\mathbf{T_{CvalR}}$ is the number of (summed) valid offside rut depths.

4.5 Typical Values (Checks and Limits)

4.5.1 Typical values (to be confirmed during acceptance tests) for the checks and limits to be placed on the rutting data are given in Table 4.2

	Typical Value
Maximum percentage of invalid measured ruts in an reporting length:	5

Table 4.2: Limits for the calculation of rutting parameters

5 Texture Profile Parameters

5.1 General requirements

5.1.1 The following parameters are derived from the texture profile and delivered in the RCD file or HMDIF file:

5.1.2 Delivered in the RCD file:

- Raw texture profile for the nearside wheel track
- Multiple Line Root Mean Square Texture Depth (RMST)

5.1.3 Delivered in the HMDIF file:

- Nearside Sensor Measured Texture Depth (SMTD)
- Nearside Mean Profile Depth (MPD)
- Mean RMST
  - (i) Nearside
  - (ii) Middle
  - (iii) Offside
- Variance in RMST
  - (i) Nearside
  - (ii) Middle
  - (iii) Offside
- Texture Variability
  - (i) 5th Percentile RMST
  - (ii) 95th Percentile RMST
  - (iii) Variance in RMST

5.1.4 These parameters are calculated before any fitting is carried out on the Survey Data (e.g. fitting to the Employer's network).

5.1.5 Before the parameters are calculated checks must be carried out on the validity of the data, as described in Section 5.2.

5.2 Checking the texture data

5.2.1 Any individual texture parameter calculated from the raw texture profile (e.g. SMTD, RMST) is considered invalid if more than a defined percentage (typically 5%) of the texture profile points used to calculate the texture profile parameter within the calculation length is invalid.

5.2.2 Any mean, percentile or variance parameter calculated over a reporting length for that parameter (e.g. 10m mean SMTD or 10m mean RMST) is considered invalid (and therefore not reported in the HMDIF file) if more than a defined percentage (typically 50%) of the individual parameters within the reporting length (e.g. of the 33 SMTDs within a 10m length) is invalid. Only valid individual parameters are included in the calculation of the mean, percentile or variance.

5.3 Nearside Sensor Measured Texture Depth (SMTD)

5.3.1 Nearside Sensor Measured Texture Depth is calculated from the texture profile recorded in the nearside wheel track as described in the following paragraphs.

5.3.2 The number of texture profile points corresponding to a standard deviation length of D (typically 0.3m) is calculated as:

$$n = \frac{D}{l}$$

rounded to the nearest odd integer (exact even numbers rounded up), where ***l*** = interval, in metres, between texture profile point readings (typically approximately 0.001m).

e.g. For a standard deviation length of 0.3m and a readings interval of exactly 0.001m, the number of points would be 301.

5.3.3 The number of standard deviation lengths corresponding to the reporting length L over which SMTD is to be averaged (typically 10m,) is calculated as:

$$J = \frac{L}{n \times l}$$

rounded down to the nearest integer.

e.g. For 10m average lengths, a standard deviation length of 0.3m and a readings interval of exactly 0.001m, the number of standard deviation lengths would be 33.

5.3.4 An individual SMTD value over a length D is calculated as:

$$SMTD_D = \sqrt{\frac{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2 - \dfrac{12\left(\sum_{i=1}^{n} x_i y_i\right)^2 + p}{(n^2-1)}}{n^2}}$$

$$p = \frac{5\left\{\left(n^2-1\right)\sum_{i=1}^{n} y_i - 12\sum_{i=1}^{n} x_i^2 y_i\right\}^2}{4\left(n^2-4\right)}$$

where:

x_i = nominal scaled distance at point **i** within the length **D**,

ranging from $-\frac{(n-1)}{2}$ at point 1, to $+\frac{(n-1)}{2}$ at point ***n***

y_i = sensor measurement at point **i**.

5.3.5 The SMTD value averaged over the reporting length L is given by:

$$SMTD_L = \frac{1}{Jval}\sum_{i=1}^{J} SMTD_D$$

where **$SMTD_D$** values are calculated for successive standard deviation lengths within the reporting length, any invalid **$SMTD_D$** value is excluded from the summation and **Jval** is the number of (valid) **$SMTD_D$** values summed.

e.g. With: Texture Profile points at exactly 0.001m interval, a standard deviation length of 0.3m and a reporting length of 10m
if the Texture Profile point at the start of the length L was numbered 1, the first $SMTD_D$ would be calculated using points 1 through 301, the second using points 302 through 602, and the last (33rd) using points 9633 through 9933.
The last 67 points (9934 through 10000) within the reporting length would not be used.

5.3.6 The method for calculating SMTD must include the following configurable parameters:

The standard deviation length (default 0.3m)
The reporting length (default 10m)

5.4 Nearside Mean Profile Depth (MPD)

5.4.1 Nearside Mean Profile Depth is calculated from the texture profile recorded in the nearside wheel track, as described in the following paragraphs.

5.4.2 The evaluation of Mean Profile Depth (MPD) is generally as defined in ISO 13473-1:1997(E) “Characterization of pavement texture by use of surface profiles - Part 1: Determination of Mean Profile Depth”.

5.4.3 The ISO standard states that the MPD for an individual profile is determined as the arithmetically averaged two peak levels minus the average (profile) level over a baseline of 100mm ± 10mm length of road, as illustrated in Figure 5.1

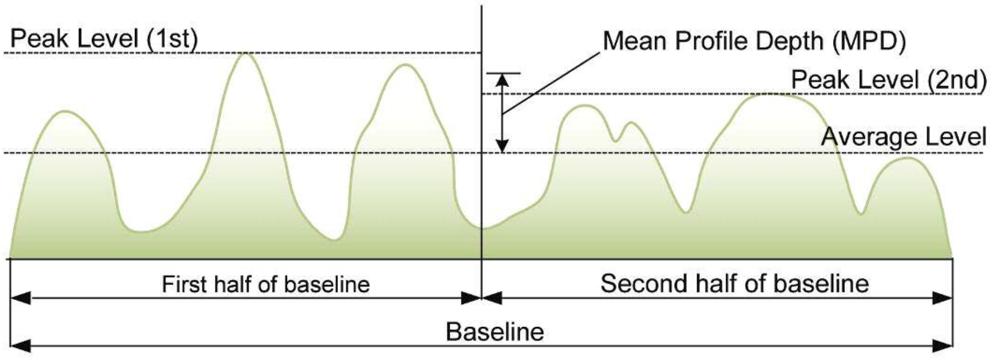


Figure 5.1: Illustration of the levels used for the calculation of the MPD

5.4.4 Before determining the peak and average levels from the texture profile points, short wavelengths are removed by calculating a 5mm moving average for each individual profile point. Slope suppression is then applied to the profile as a whole (within the 100mm baseline length) by calculating the regression line through all the (moving average) profile values and subtracting this line from the profile.

5.4.5 Valid MPD values obtained from successive 100mm lengths are finally averaged over a reporting length (typically 10m) to give the required average MPD.

> Note: The values of 0.005m (for the moving average)
>
> 0.1m (for the baseline)
>
> and 10m (for the averaging length), should be parameterised.

Calculation of MPD

5.4.6 The number of profile points corresponding to a moving average length M (typically 0.005m) is calculated as:

$m = \frac{M}{l}$ rounded to the nearest odd integer

(exact even numbers rounded up).

where $\boldsymbol{l}$ = interval, in metres, between texture profile point readings (typically approximately 0.001m).

e.g. For a moving average length of 0.005m and a readings interval of exactly 0.001m, the number of points would be 5.

5.4.7 The number of profile points corresponding to a baseline length of B (typically 0.1m) is calculated as:

$n = \frac{B}{l}$ rounded to the nearest even integer

(exact odd numbers rounded up).

where ***l*** = interval, in metres, between texture profile point readings (typically approximately 0.001m).

e.g. For a baseline length of 0.1m and a readings interval of exactly 0.001m, the number of points would be 100.

(Rounding to the nearest even number ensures that no point lies exactly at the mid point of the baseline.)

5.4.8 The number of baseline lengths corresponding to the reporting length **L** over which MPD is to be averaged (typically 10m,) is calculated as:

$J = \frac{L}{n \times l}$ rounded down to the nearest integer

e.g. For 10m average lengths, a baseline length of 0.1m and a readings interval of exactly 0.001m, the number of baseline lengths would be 100.

5.4.9 For each texture profile point ***k***, a moving average sensor measurement, $\bar{y}_k$, is calculated as follows:

For $k = 1$ to $k = \frac{m-1}{2}$:

$$\bar{y}_k = \frac{1}{i}\sum_{j=1}^{j=i} y_j$$

where $i = (k * 2) - 1$

and y_j = sensor measurement at point ***j***;

For $k = \frac{m+1}{2}$ to $k = T - \frac{m-1}{2}$

(where ***T*** = total number of readings in the survey)

$$\bar{y}_k = \frac{1}{m}\sum_{j=i}^{j=i+m-1} y_j$$

where $i = k - \frac{(m-1)}{2}$;

For $k = T - \frac{m-3}{2}$ to $k = T$:

$$\bar{y}_k = \frac{1}{i}\sum_{j=T-i+1}^{T} y_j$$

where $i = ((T-k)*2)+1$

5.4.10 For each successive baseline length, a regression line is calculated as:

$$y = ai + b$$

where ***i*** ranges from **1** to ***n*** over the baseline length,

$$D = \frac{1}{12}n^2\left(n^2-1\right)$$

$$a = \frac{1}{D}\left[n\sum_{i=1}^{n} i\bar{y}_i - \frac{n(n+1)}{2}\sum_{i=1}^{n}\bar{y}_i\right]$$

$$b = \frac{1}{D}\left[\frac{n(n+1)(2n+1)}{6}\sum_{i=1}^{n}\bar{y}_i - \frac{n(n+1)}{2}\sum_{i=1}^{n} i\bar{y}_i\right]$$

$\bar{y}_i =$ moving average sensor measurement at point ***i*** within the baseline length.

5.4.11 For each point ***i*** within the baseline length, an adjusted moving average sensor measurement is calculated as:

$$\bar{Y}_i = \bar{y}_i - (ai + b)$$

5.4.12 The maximum value of $\bar{Y}_i$ is determined within each half of the baseline, giving $\bar{Y}_{Bmax1}$ and $\bar{Y}_{Bmax2}$,

and the average value is calculated as: $\bar{\bar{Y}}_B = \frac{1}{n}\sum_{i=1}^{n}\bar{Y}_i$

5.4.13 The individual MPD value over the baseline is calculated as:

$$MPD_B = \frac{\bar{Y}_{Bmax1} + \bar{Y}_{Bmax2}}{2} - \bar{\bar{Y}}_B$$

5.4.14 The MPD value averaged over length ***L*** is given by:

$$MPD_L = \frac{1}{Jval}\sum_{i=1}^{J} MPD_B$$

where MPD_B values are calculated for successive baseline lengths within the reporting length, any invalid MPD_B values are excluded from the summation and ***Jval*** is the number of (valid) MPD_B values summed.

e.g. With texture profile points at exactly 0.001m interval, a baseline length of 0.1m and an averaging length of 10m;
if the texture profile point at the start of the length L was numbered 1, the first MPD_B would be calculated using moving average sensor measurements calculated for points 1 through 100, the second using points 101 through 200, and the last (100th) using points 9001 through 10000.

5.4.15 Where the baseline length is not an exact multiple of the interval between texture profile point readings, or the reporting length is not an exact multiple of the baseline length, there will be more moving average sensor measurements than required within some reporting lengths.

e.g. With a reporting length of 10m, a baseline length of 0.1m and an interval between texture profile point readings of 0.0009925m,
n will be calculated as (0.1/0.0009925) = 100.75567, rounded to 100, and ***J*** will be calculated as 10/(100*0.0009925) = 100.75567 rounded down to 100.
The number of moving average sensor measurements used for the calculations within a reporting length will therefore be 100*100 = 10,000.

5.4.16 However the number of measured texture profile points lying within each 10m reporting length will be as shown in Table 5.1

Reporting Length	Number of Readings
0 - 10	10,075
10 - 20	10,076
20 - 30	10,075
30 - 40	10,076
40 - 50	10,075
Etc	

Table 5.1: Reporting lengths versus number of readings

5.4.17 In such situations, the “extra” measured texture profile point readings (at the end of the reporting lengths) are used in calculating the moving average sensor measurements ($\bar{y}_k$), but moving average sensor measurements need not be calculated at those points and are not used in calculating the individual or average MPD values.

5.4.18 When a texture profile point reading falls exactly on the boundary between two reporting lengths, it is deemed to lie within the former of those lengths.

> e.g. With a reporting length of 10m,
>
> a baseline length of 0.1m
>
> and an interval between texture profile point readings of exactly 0.001m,
>
> the 10,000th texture profile point reading (at chainage 10m) is deemed to lie within the 0 10m reporting length.

5.5 Multiple Line Root Mean Square Texture Depth (RMST)

5.5.1 Multiple line Root Mean Square Texture Depth values are provided in the RCD and HMDIF files. RMST values are calculated from the measurement of the texture profile as described in the following paragraphs. Subsequent to obtaining RMST values, further derived parameters may be obtained. (e.g variance in RMST) for output in the HMDIF. The methodologies for obtaining these parameters, is also described below.

- For each texture profile line:
  - (i) Filter each texture profile measurement using a bandpass filter (paragraphs 5.5.2 through 5.5.10).
  - (ii) Calculate, over lengths of 0.1m, individual Root Mean Square Texture Depth (RMST) values (paragraph 5.5.11).

    > Individual RMST values are output in the RCD file.

- Obtain the Nearside, Middle and Offside Mean RMST values (paragraphs 5.5.12 through 5.5.14).
- Calculate further derived parameters from the dataset of individual RMST values (paragraphs 5.5.15 through 5.5.21).

  > Mean RMST values and the further derived parameters are output in the HMDIF file.

Filtering

5.5.2 The filter is a band pass filter that attenuates wavelengths shorter than 10mm and greater than 100mm, the frequency response is defined by:

$\mathbf{f_L}$= 1/100

$\mathbf{f_H}$=1/10

Note: These should be parameterised in software

5.5.3 The filter is defined by a set of (**m** plus one) coefficients.

$$m = \frac{R}{f_L * \Delta}$$ where:

Δ is the interval between profile points;
1/$\mathbf{f_L}$ is expressed in the same units as Δ;
R is the “Filter Order”, which should have a default value of 3 but which should be parameterised in the software.
The calculated value of **m** should be rounded up to the next, even integer.

5.5.4 There are (**m**+1) low-pass coefficients, $\mathbf{blp_i}$. These coefficients define a low-pass filter, which attenuates frequencies higher than the frequency limit, **f**. The values of $\mathbf{blp_i}$ are initially determined by:

$\mathbf{blp_i} = \mathbf{H_i} * \text{sinc}(2\pi * \mathbf{i} * \mathbf{f} * \Delta)$ for **i** = -**m**/2, -**m**/2+1, …., **m**/2

Where:

$\mathbf{H_i}$ are the coefficients of a Hamming window, given by: $\mathbf{H_i} = 0.54 – 0.46 * \cos(2\pi * (\mathbf{i} + \mathbf{m}/2) / \mathbf{m})$ sinc(x) = sin (x) / x if x ≠ 0 OR sinc(x) = 1 if x=0
π = 3.14159
f = $\mathbf{f_H}$ i.e. equal to the upper frequency limit of the filter, expressed in the same units as Δ
and the trigonometric functions are defined such that the arguments are in radians

5.5.5 The coefficients, $\mathbf{blp_i}$, are then normalised so that if the coefficients were plotted against **i**, the total area under the graph would equal one (i.e. the area under the filter window is equal to one). Hence:

$\mathbf{blp_i} = \mathbf{blp_i} / \mathbf{n}$ for **i** = -**m**/2, -**m**/2+1, …., **m**/2

Where $$n = \sum_{i=-m/2}^{m/2} blp_i$$

5.5.6 There are **m**+1 high-pass coefficients, $\mathbf{bhp_i}$. These coefficients define a high-pass filter, which attenuates frequencies below the frequency limit, **f**. To calculate the high-pass coefficients the method described above for calculating the low pass coefficients is applied, but where the frequency limit, **f**, is now equal to the lower frequency limit of the filter, $\mathbf{f_L}$. This generates a new set of coefficients termed **blp′**.

5.5.7 Following the normalisation of the coefficients (as described above), the following transformation is performed on the coefficients:

$\mathbf{bhp_i} = -\,\mathbf{blp'_i}$ for **i** = -**m**/2, -**m**/2+1, ….1 and for **i** = 1,…. +**m**/2 (i.e. for **i** ≠ 0)
$\mathbf{bhp_i} = 1 - \mathbf{blp'_I}$ for i = 0

5.5.8 The coefficients of the band pass filter are obtained by combining the low pass and high pass coefficients. The **m**+1 values of $\mathbf{bp_i}$ obtained through the convolution of $\mathbf{blp_i}$ and $\mathbf{bhp_i}$ are given by:

$$bp_i = \sum_{j=\max\left(-\frac{m}{2},\, i-\frac{m}{2}\right)}^{\min\left(\frac{m}{2},\, i+\frac{m}{2}\right)} bhp_j * blp_{j-i}$$ for **i** = -**m**/2, -**m**/2+1, …., **m**/2

Note: Only **m**+1 values are applied for the coefficients of the band pass filter to increase efficiency with negligible loss of accuracy.
Note: The convolution procedure can be visualised as the high-pass and low-pass coefficients being progressively overlapped. At each overlap position, the value of the convoluted coefficient is equal to the product of the corresponding high-pass and low-pass coefficients, summed over the overlap region. The convolution is applied to obtain **m**+1 values of $\mathbf{bp_i}$. It is assumed that extending the convolution to obtain 2**m**+1 values

would not significantly increase the performance of the filter for this application.

5.5.9 The value of the filtered longitudinal profile height, z_i', at each position, i, is obtained by multiplying the profile heights between $z_{(i-m/2)}$ and $z_{(i+m/2)}$ by the corresponding m+1 band pass filter coefficients and then summing the resulting products.

Hence: $$z_i' = \sum_{j=-m/2}^{m/2} z_{i+j} * bp_j$$

5.5.10 It can be inferred from the above definition, that the calculation of the filtered profile cannot be performed within a distance of **m**/2 points of the start of the survey or **m**/2 points of the end of the survey. Points falling in these lengths are defined as invalid for the purposes of calculating the texture parameters obtained from the filtered texture profile.

Individual Root Mean Square Texture Depth

5.5.11 Individual Root Mean Square Texture Depth (RMST) values are calculated over the individual RMST calculation length $\mathbf{L_{RMS}}$ for each filtered texture profile measurement line. The individual RMST values are calculated as:

$$RMST = \sqrt{\frac{1}{N}\sum_{1}^{N}(z_j)^2}$$ where:

$\mathbf{z_j}$ is the height of the filtered texture profile point **j** in mm.
N is the number of filtered profile points within each individual RMST calculation length $\mathbf{L_{RMS}}$.
$\mathbf{L_{RMS}}$ has a typical value of 0.1m, but should be parameterised.

Mean Nearside RMST

5.5.12 Mean nearside RMST values are obtained by averaging the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m of the nearside wheel path.

Note: The position (offset) of the nearside wheel path will be determined during the acceptance tests of the Equipment.

$$Mean_{RMST\ NS} = \frac{1}{m}\sum_{i=1}^{m} S_i$$

where, for each measurement line **i** lying within ±0.3m (inclusive) of the nearside wheel path,

$$S_i = \frac{1}{nval}\sum_{j=1}^{n} RMST_j$$ and where:

$RMST_j$ is the individual RMST value reported over interval **j** in a single measurement line;
n is the number of individual RMST values within a mean RMST reporting length **L** for a single measurement line;
S_i is the average of the valid individual RMST values from a single measurement line over the mean RMST reporting length **L**;
Invalid individual RMST values are not included in the summation and **n_{val}** is the number of valid (summed) individual RMST values;
m is the number of measurement lines lying within a distance of ±0.3m of the nearside wheel path;
L has a typical value of 10m (giving a typical value of n = 100) but should be parameterised. **L** will always be an exact integer multiple of **L_{RMS}**.

Mean Middle RMST

5.5.13 Mean middle RMST values are calculated by averaging the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m (inclusive) of the nominal line mid way between the nearside and offside wheel paths, using the approach described above for the mean nearside RMST.

Mean Offside RMST

5.5.14 Mean offside RMST values are calculated by averaging the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m (inclusive) of the offside wheel path, using the approach described above for the mean nearside RMST.

Note: The position (offset) of the offside wheel path will be determined during the acceptance tests of the Equipment.

Nearside RMST Variance

5.5.15 Nearside RMST Variance values are obtained from the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m (inclusive) of the nearside wheel path.

$$Variance = \frac{1}{Nval - 1} \sum_{j=1}^{N} (RMST_j - \overline{RMST})^2$$

where:

$\overline{RMST}$ is the mean RMST value, calculated by averaging the valid individual RMST values from all texture measurement lines over the nearside wheel path, using the approach described for the mean nearside RMST (paragraph 5.5.12).
N is the number of valid individual RMST values (from all measurement lines in the nearside wheel path) in the texture variability reporting length (**L**).
$RMST_j$ is the **j**th valid individual RMST value (from all measurement lines in the nearside wheel path) in the texture variability reporting length (**L**).
Invalid individual RMST values are not included in the summation and ***Nval*** is the number of valid (summed) individual RMST values in the nearside wheel path.
L has a typical value of 10m but should be parameterised. **L** will always be an exact integer multiple of **L_{RMS}**

Middle RMST Variance

5.5.16 Middle RMST Variance values are calculated from the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m (inclusive) of the nominal line mid way between the nearside and offside wheel paths, using the approach described above for the nearside RMST Variance.

Offside RMST Variance

5.5.17 Offside RMST Variance values are calculated from the valid individual RMST values from texture measurement lines lying within a distance of ±0.3m (inclusive) of the offside wheel path, using the approach described above for the nearside RMST Variance.

Texture variability

5.5.18 The texture variability measure assesses the evenness of the texture across the width of pavement. The measurement can be summarised as follows:

- Obtain the dataset of individual RMST values for each measurement line, as described in paragraphs 5.5.2 through 5.5.10.

- Calculate the 5th and 95th percentiles and variance of the valid individual RMST values within this dataset over texture variability reporting lengths of 10m (paragraphs 5.5.19 through 5.5.21).

Percentile

5.5.19 The percentile value is defined as:

5.5.20 The ***i***th valid individual RMST value after the valid individual RMST values from all measurement lines in the texture variability reporting length **L** have been sorted into increasing order, where:

i is equal to **N**.**x**/100 rounded to the nearest integer (exact 0.5 values rounded up),
N is the number of valid individual RMST values (from all measurement lines) in the texture variability reporting length (**L**),
x is the percentile value required.

For example, for a system recording texture profiles in 10 measurement lines, an individual RMST calculation length (LRMS) of 0.1m and a texture variability reporting length (L) of 10m, **N** will have a maximum value of (10*10/0.1) = 1000.
If there are 996 valid individual RMST values within a particular texture variability reporting length, the 5th percentile will result in a value of **i** = (996*5/100) = 49.8, rounded to 50; i.e. the 5th percentile will be the 50th lowest of the 996 values. Similarly the 95th percentile will result in a value of i = (996*95)/100 = 946.2, rounded to 946; i.e. the 95th percentile will be the 946th lowest of the 996 values.

Variance

5.5.21 The variance is defined as:

$$Variance = \frac{1}{Nval - 1} \sum_{j=1}^{N} (RMST_j - \overline{RMST})^2$$ where:

$\overline{RMST}$ is the mean RMST value, calculated by averaging the valid individual RMST values from all texture measurement lines over the texture variability reporting length, using the approach described for the mean nearside RMST (paragraph 5.5.12).
N is the number of valid individual RMST values (from all measurement lines) in the texture variability reporting length (**L**),
$\mathbf{RMST_j}$ is the **j**th valid individual RMST value (from all measurement lines) in the texture variability reporting length (**L**).
Invalid individual RMST values are not included in the summation and **Nval** is the number of valid (summed) individual RMST values.

Typical Values (Checks and Limits)

5.6.1 Typical values (to be confirmed during acceptance tests) for the checks and limits to be placed on the texture profile parameters are given in Table 5.2.

Parameter	**Typical Value**
SMTD standard deviation length (m)	0.3
MPD moving average length (m)	0.005
MPD baseline length (m)	0.1
Individual RMST calculation length (m)	0.1
Maximum invalid points within a calculation length (%)	5
Maximum invalid parameters within a reporting length (%)	50
RMST lower filter (mm^{-1})	0.01
RMST upper filter (mm^{-1})	0.1

Table 5.2: Limits for the calculation of texture profile parameters

6 Cracking Parameters

6.1 General requirements

6.1.1 The following parameters will be derived from the cracking data and delivered in the HMDIF file:

- Carriageway cracking intensity
- Transverse cracking intensity
- Surface deterioration intensity
- Left and right wheel track cracking intensity

6.1.2 These parameters are calculated from the measured cracking data before any fitting is carried out on the Survey Data (e.g. fitting to the Employer's network).

6.1.3 Before the parameters are calculated checks must be carried out on the validity of the cracking data, as described in Section 6.2.

6.2 Checking cracking data

6.2.1 During the acceptance tests, the valid crack type codes will be established. It will also be established which of those crack types are to be included in calculation of the parameters (e.g. cracks identified as joints will normally not be included in calculation of cracking intensities).

6.2.2 Any parameter derived from the cracking data over any reporting length (**L**) shall be considered invalid (and therefore not output in the HMDIF file) if any single crack used to calculate that parameter within that length was invalid (i.e. with an offset, length or angle outside the permitted ranges).

6.3 Cleaning the cracking data

6.3.1 Cleaning of the cracking data is the process of identifying grid cells that arise from the false positive identification of cracks. Survey contractors are required to demonstrate that their systems remove false positive measurements of cracking effectively. Illustrative methods to remove false positive cracked grid cells arising from the edges of survey width and arising from traffic sensors are described in Annex 1. Note that the methods given in Annex 1 apply cleaning to crack grids and therefore do not assist in the cleaning of crack data for the calculation of wheeltrack cracking given in section 6.8.

6.3.2 Following removal of the false grid cells the carriageway cracking intensity, transverse cracking intensity and surface deterioration intensity can be calculated, noting that:.

There may be a need to provide multiple values of whole carriageway cracking intensity. For example
(a) For the full measurement width
(b) For a reduced measurement width (e.g. 2.4m)
(c) With and without removal of false positives using the cleaning algorithms
Therefore processes for checking, cleaning and reporting cracking data should be developed with variable parameters, wherever possible, rather than simply with fixed parameters

6.4 Obtaining the carriageway cracking grid

6.4.1 The carriageway cracking grid is obtained from the crack map provided in the survey data by overlaying the crack map with a 2-dimensional rectangular grid. This is illustrated in figure 6.1 for a typical Scanner survey vehicle within a 3.2m survey width.

6.4.2 The carriageway cracking grid is obtained using the following configurable parameters:

- Width of each grid cell (typically 200mm).
- Number of cells across the grid (to be agreed during the acceptance tests).
- Offset of the centre of the grid from the centre of the vehicle / survey (typically zero).
- Length of each grid cell (typically 200mm).

Note that:
The grid may not cover the full width of the crack detection system, i.e. cracks may start and/or end outside the grid.
Alternatively, the grid may extend beyond the full width of the crack detection system.

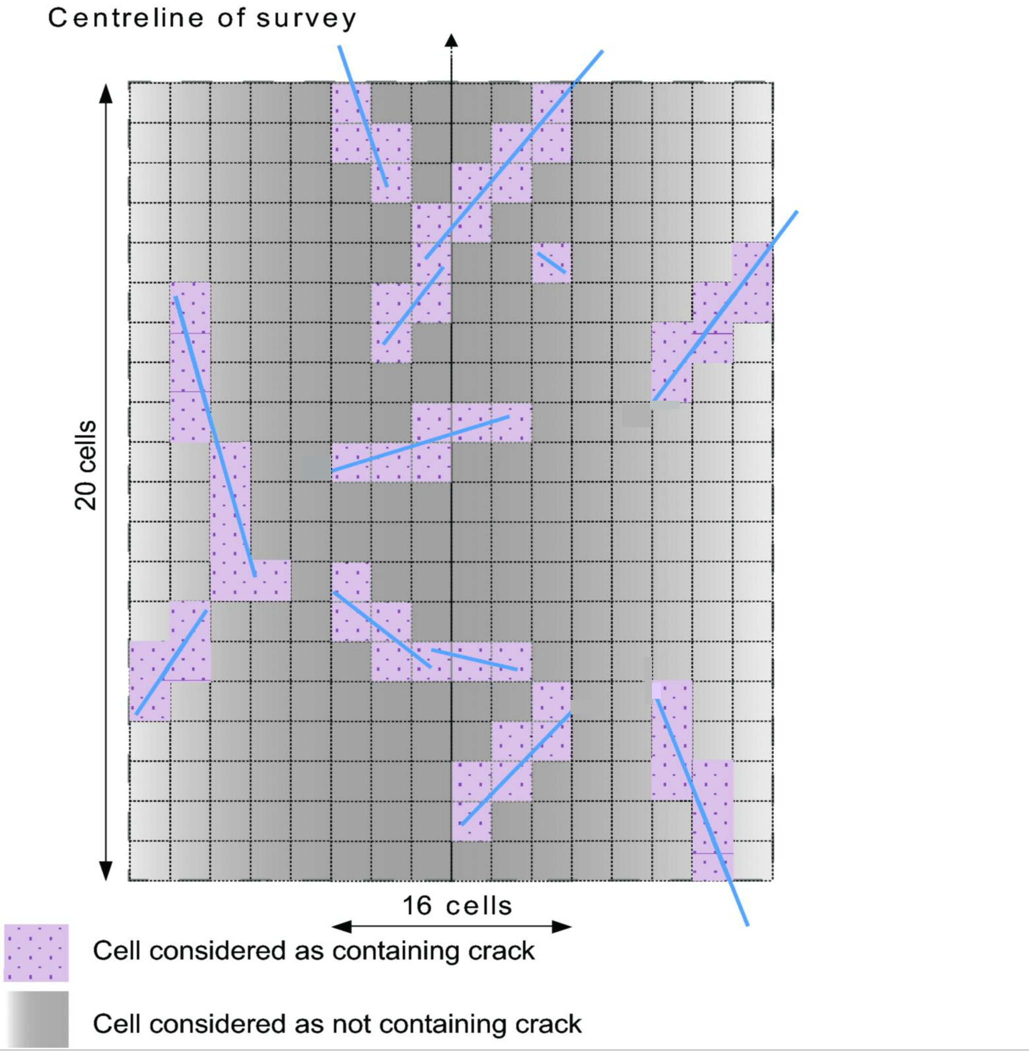


Figure 6.1: Crack map overlaid with grid to obtain the carriageway cracking intensity

6.4.3 The carriageway cracking grid is obtained using the following rules:

- Where a crack starts or ends exactly on a line or corner point between grid cells, or passes through a corner point, the principles shown in Figure 6.2 are applied. The crack is only considered to be within the cell(s) from which it approaches the line or corner.
- Where a crack runs exactly alone a line between grid cells or along the edge of the grid the principles shown in Figure 6.3 are applied. A crack is only considered to be within the cell(s) immediately above or to the right of the line, except where it runs exactly along the right hand side of the grid or at the end of the survey, in which case it is considered to be within the cell(s) immediately to the left or below respectively.

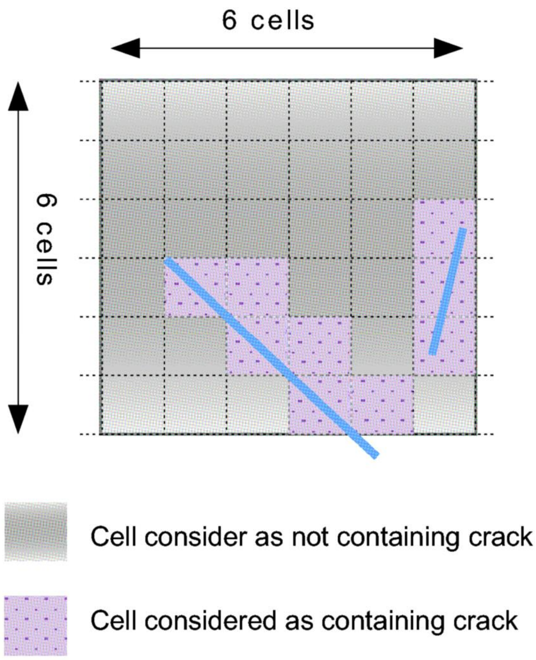


Figure 6.2: Classification of grid cells containing cracks (1)

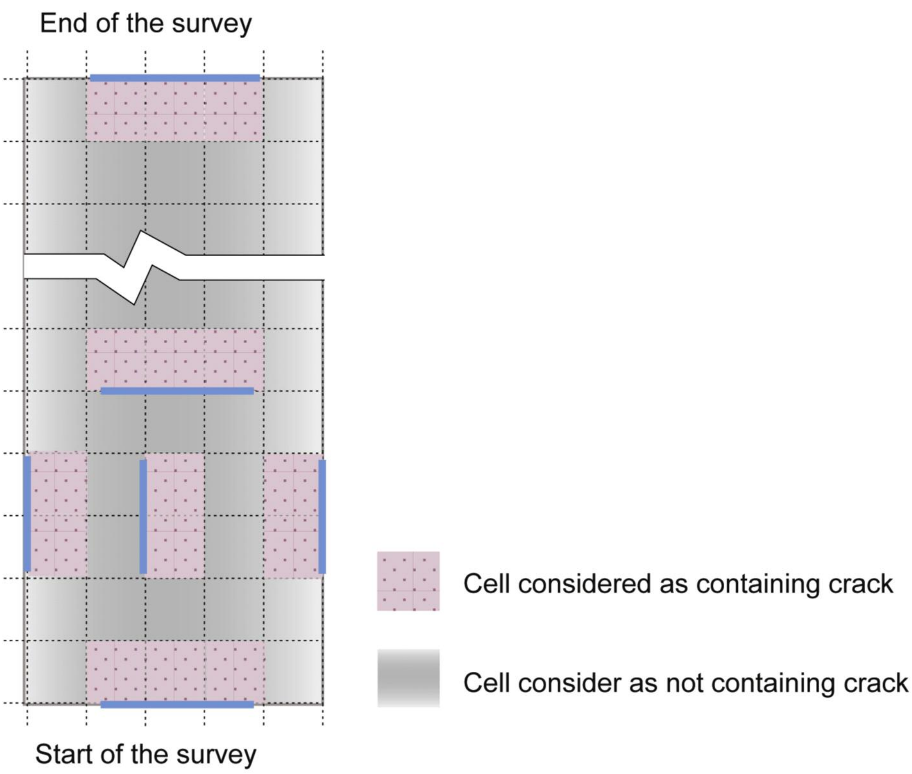


Figure 6.3: Classification of grid cells containing cracks (2)

6.5 Carriageway Cracking Intensity

6.5.1 The carriageway cracking intensity is expressed as the percentage of the cracked grid cells.

6.5.2 The calculation of carriageway cracking intensity is carried out using the following configurable parameters:

> Length over which the cracking intensities are to be calculated and reported (typically 10m), which shall be an integer multiple of the length of each grid cell.

6.5.3 The carriageway cracking intensity is expressed as a percentage to one decimal place.

6.6 Transverse Cracking Intensity

6.6.1 To calculate transverse cracking intensity the percentage of cracking within defined lengths of the survey data is evaluated using a moving window. If the percentage area of cracking within this window exceeds a defined cut off value, then all grid cells within the window are considered to have arisen from the presence of transverse cracks.

6.6.2 The calculation of transverse cracking intensity is carried out using the following configurable parameters:

- The number of grid cells (longitudinally) used for the calculation of transverse cracks (default 2). This defines the longitudinal length of the moving window used to identify transverse cracks;
- The percentage of the area within the moving window considered for the identification of transverse cracking required to classify all grid cells within the window as transverse (default 20%);
- The length over which the transverse cracking intensities are to be calculated and reported (typically 10m), which shall be an integer multiple of the length of each grid cell.

6.6.3 The calculation of transverse cracking intensity is carried out using the following definitions:

> The width of the window used for the identification of transverse cracking is the width of the survey, as shown in figure 6.4

6.6.4 The calculation of transverse cracking intensity is carried out using the following rules:

- Commencing at the start of the survey evaluate the percentage area of cracking within the window.
- If the percentage of cracked grid cells within the window exceeds the defined percentage, all grid cells within this window are considered to have arisen from the presence of transverse cracks, as shown in Figure 6.4;

- Move the window down the survey by one grid cell and repeat the assessment;
- If a cracked grid cell is classified as transverse in one window, but not classified in an adjacent window, the crack should be recorded as transverse;
- The transverse cracking intensity should be expressed as the percentage of grid cells within the surveyed area for each (configurable) length that have been classified as arising from transverse cracking;

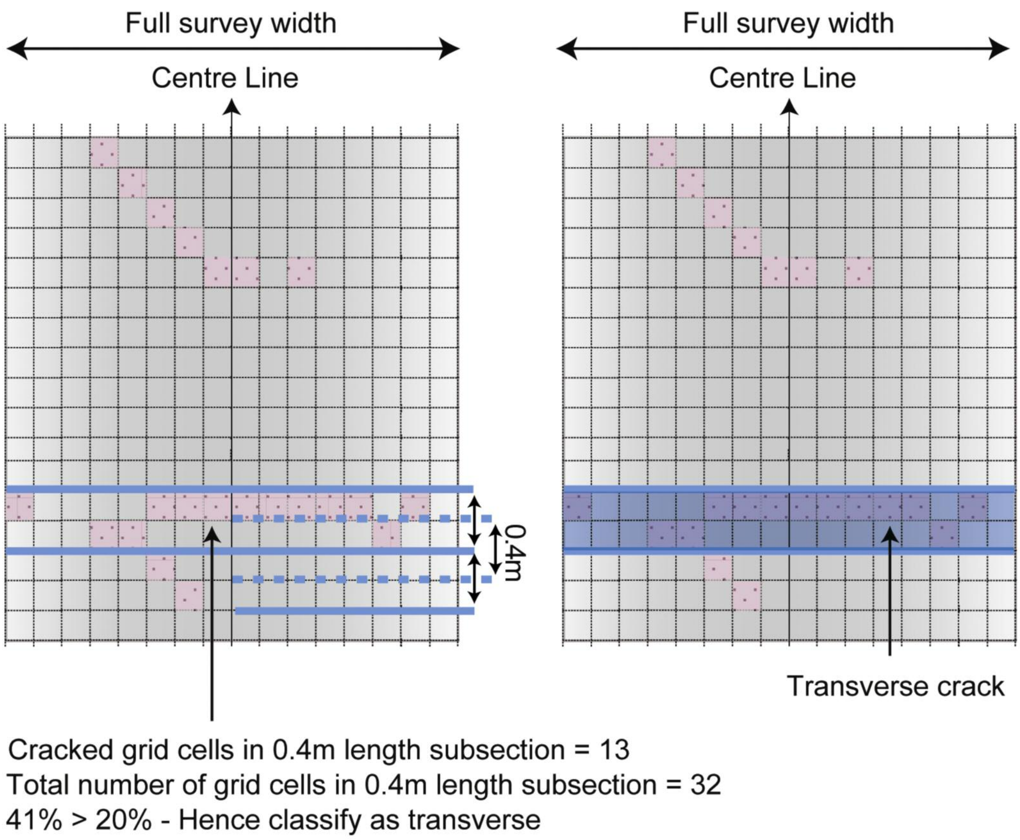


Figure 6.4: Classification of transverse cracking within the crack grid

6.7 Surface Deterioration Intensity

6.7.1 To calculate the surface deterioration intensity each cracked grid cell within the crack grid is examined and the position, size and the number of cells in the surrounding area reviewed.

6.7.2 The calculation of surface deterioration features intensity is carried out using the following configurable parameters:

- The length over which the surface deterioration feature intensities are to be calculated and reported (typically 10m), which shall be an integer multiple of the length of each grid cell.

- Size of Area A (cells) – Figure 6.5.
- Size of Area B (cells) – Figure 6.5.

6.7.3 The calculation of surface deterioration features intensity is carried out using the following definitions:

Area A: All grid cells within the surrounding circumference of the selected cracked grid cell
Area B: All grid cells between the surrounding circumference and 0.4m circumference of the selected cracked grid cell.

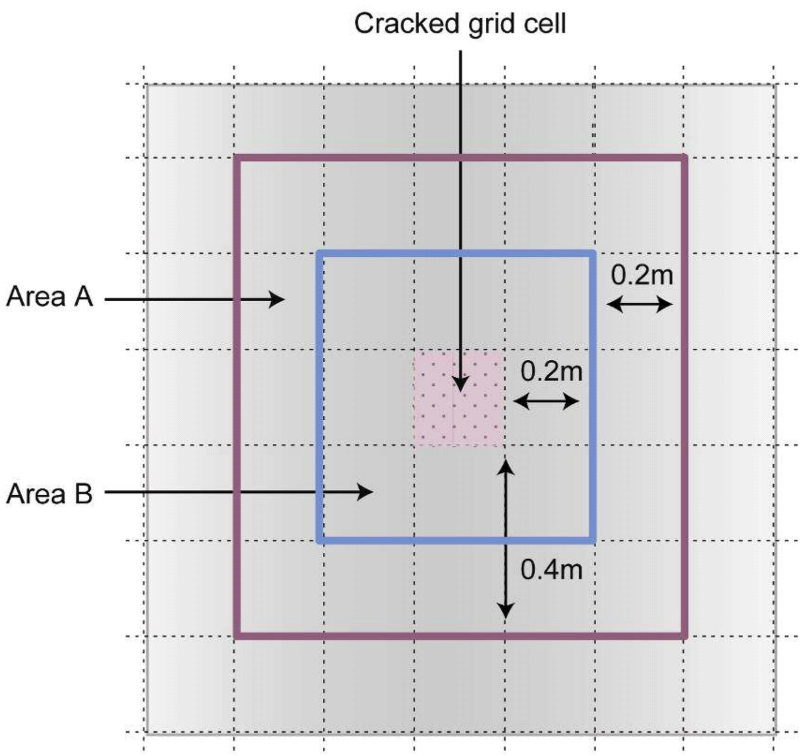


Figure 6.5: Classification of surface deterioration features

6.7.4 The calculation of surface deterioration features intensity is carried out using the following approach:

- Starting at the start of the survey data, assess each grid cell containing a crack.
- If, for this cracked grid cell, no cracked grid cell exists in area A, and no greater than one cracked grid cell exists in area B, then classify the assessed cracked cell as containing surface deterioration.

6.7.5 The surface deterioration features intensity is expressed as the total percentage area of grid cells defined as containing surface deterioration features for each reporting length.

6.8 Wheel track Cracking Intensity

6.8.1 The wheel track cracking intensity is obtained by first examining the position and length of each crack to determine whether the crack is a “wheel track crack”, as demonstrated in Figure 6.6.

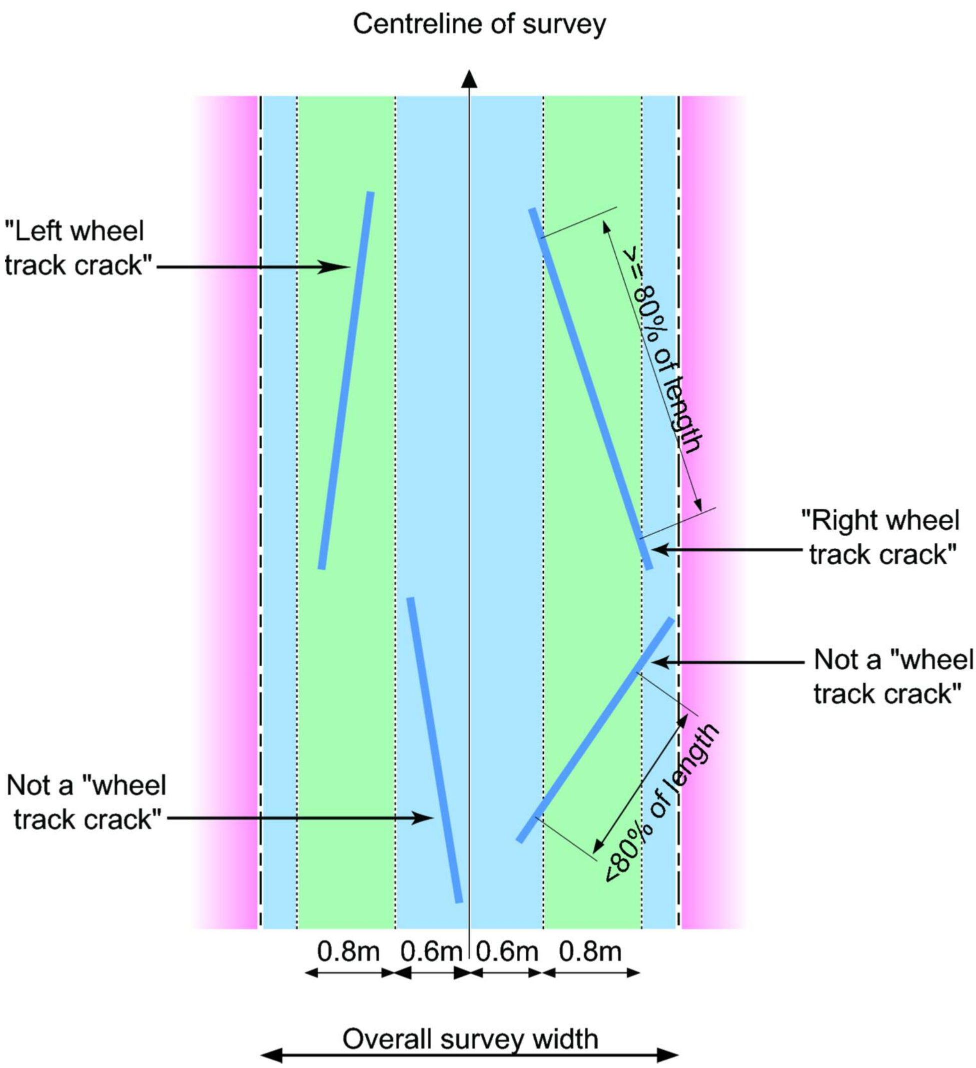


Figure 6.6: Classification of wheel track cracks

6.8.2 The determination of wheel track cracks is carried out using the following configurable parameters:

- Offset to the right edge of the left wheel track (typically -0.6m);
- The width of the left wheel track (typically 0.8m);

- The offset to the left edge of the right wheel track (typically 0.6m);
- The width of the right wheel track (typically 0.8m)
- The width of the grid cells for the left wheel track grid (typically 0.8m);
- The width of grid cells for the right wheel track grid (typically 0.8m);
- The length of the grid cells for the left wheel track grid (typically 0.2m);
- The length of the grid cells for the right wheel track grid (typically 0.2m);
- The percentage of the length of the crack required to be within the wheel track for the crack to be classified as a wheel track crack (typically 80%).
- Maximum absolute angle of a crack for it to be classified as a wheel track crack (typically 90 degrees, i.e. effectively no limit, but may be reduced as a result of the acceptance tests).
- The length over which the cracking intensities are to be calculated and reported (typically 10m), which shall be an integer multiple of the length of each grid cell.

6.8.3 The left wheel track cracking intensity and right wheel track cracking intensity are calculated and reported individually. The principle applied in the calculation of left wheel track cracking intensity is shown in Figure 6.7. (Calculation of the right wheel track cracking intensity is simply a mirror image)

> Note: The offsets and grid widths used in the calculation of wheel track cracking intensity may differ from the dimensions used in the calculation of carriageway cracking intensity and may even differ from the dimensions used in determining whether cracks are wheel track cracks.

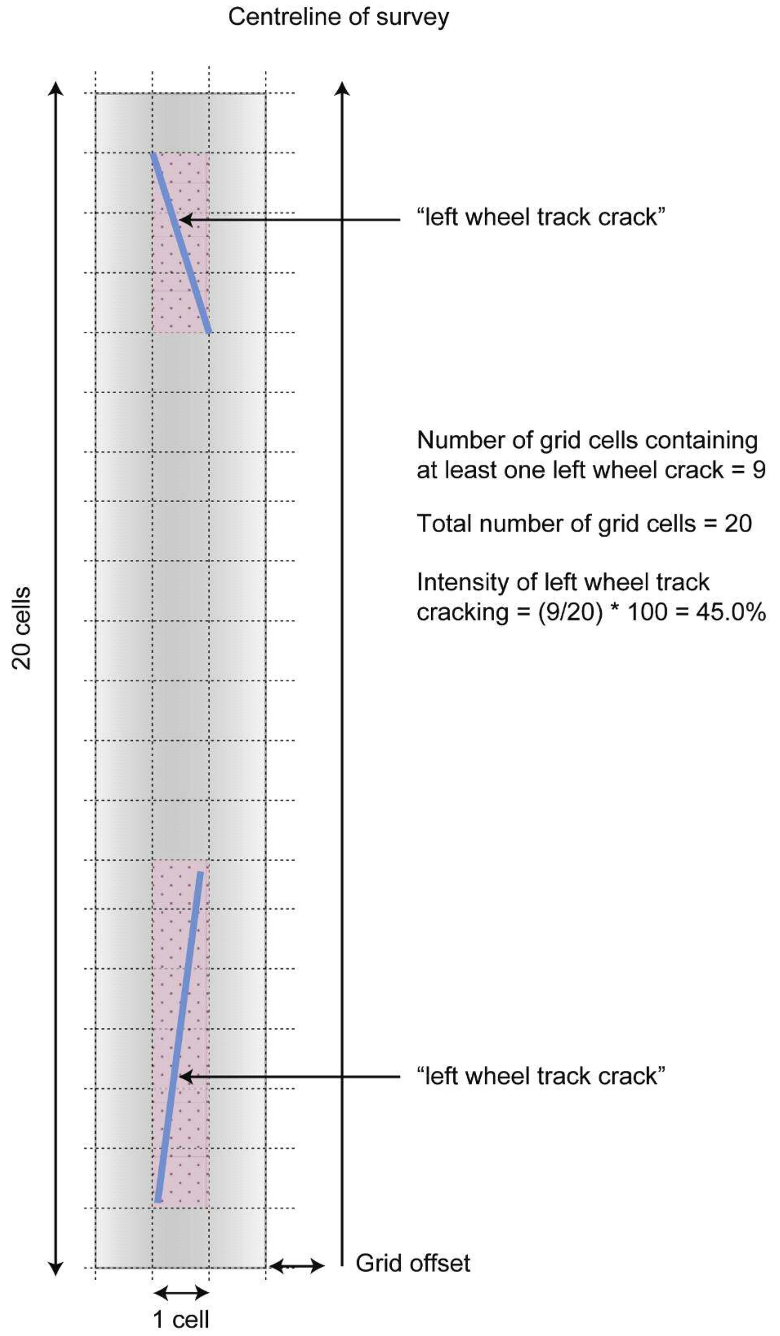


Figure 6.7: Obtaining left wheel track cracking intensity

6.8.4 The wheel track cracking intensities are expressed as a percentage to one decimal place.

6.9 Typical Values (Checks and Limits)

6.9.1 Typical values for the checks limits and to be placed on the cracking parameters data are given in Table 6.1.

Cracking parameter	**Typical value**
Width of cells - whole carriageway cracking (m)	0.2
Cells across grid – whole carriageway cracking	16
Offset to centre of whole carriageway grid (m)	0
Length of cells – whole carriageway cracking (m)	0.2
Offset to right edge of left wheel track (m)	-0.6
Width of left wheel track (m)	0.8
Offset to left edge of right wheel track (m)	0.6
Width of right wheel track (m)	0.8
Required percentage of crack in wheel track (%)	80
Maximum absolute angle for wheel track crack (degrees)	90
Offset to right edge of left wheel track grid (m)	-0.6
Width of cells - left wheel track grid (m)	0.8
Cells across grid – left wheel track grid	1
Length of cells – left wheel track grid (m)	0.2
Offset to left edge of right wheel track grid (m)	0.6
Width of cells – right wheel track grid (m)	0.8
Cells across grid – right wheel track cracking	1
Length of cells – right wheel track cracking (m)	0.2
Columns in each edge region	2
Length of edge region (in cells)	20
Required percentage for definition as false edge cracking (by column)	50
Required percentage for definition as false edge cracking (by region)	50
Minimum length to be a diagonal crack (m)	1.4

Cracking parameter	Typical value
Minimum angle of diagonal feature (degrees)	17
Maximum angle of diagonal feature (degrees)	70
Number of steps for definition as a diagonal crack	3
Transverse cracking window length (cells)	2
Required percentage for definition as transverse crack	20
Surface features – A (cells)	1
Surface features – B (cells)	2

Table 6.1: Limits for the calculation of cracking parameters

7 Data File Formats

7.1 The Route File Format

7.1.1 The definition of a survey route is provided in a single file, logically divided into three sections:

- Route “header” data;
- Survey lanes comprising the route;
- “End of Route” Reference.

7.1.2 The file consists of sequential records, each containing printable ASCII characters terminated by ASCII “Carriage Return” and “Line Feed” characters (See Section 7.5).

7.1.3 The file contains:

- One record of type R1.1 (Table 7.1) followed by
- One or more of type R2.1 (Table 7.2) followed by
- One record of type R3.1. (Table 7.3)

7.1.4 The following generic conventions are used within the “Format” column:

“**A**n” indicates a text field of n characters, left justified and padded with spaces;
“**I**n” indicates an integer numeric field of up to n characters, including an optional leading sign (+ or -), right justified and padded with spaces;
“**F**n.d” indicates a real number field of up to n characters, including the decimal point and an optional leading sign (+ or -), with d digits after the decimal point, right justified and padded with spaces.

Route “header” data

7.1.5 Record R1.1 (Single record), as defined in Table 7.1.

Characters	Description	Format	Value range
1 - 8	‘SCNROUTE’	A8	
9 - 58	Route identifier	A50	
59 - 63	Number of survey lanes within the route	I5	1-99999

Table 7.1: Record R1.1 (Route Header File)

Survey Lanes

7.1.6 Record R2.1 (Repeated for each survey lane as defined in record R1.1, sorted in sequence through the route), as defined in Table 7.2.

Characters	Description	Format	Value range
1 - 30	Section label (blank for a “dummy” survey lane – see Note 1 below)	A30	
31 - 41	Section length, measured in metres	F11.3	0.000 to 9999999.999
42 - 61	Start Node label (i.e. node at the end of the section from which the survey starts)	A20	
62 - 64	Cross-section position (XSP) code of the lane (see Note 2 below)	A3	See UKPMS documentation
65 - 75	Start Node x co-ordinate (if known)	F11.3	0.000 to 9999999.999
76 - 86	Start Node y co-ordinate (if known)	F11.3	0.000 to 9999999.999
87 - 186	Section description (see Note 3 below)	A100	

Table 7.2: Record R2.1 (Survey lanes)

Note 1: A “dummy” survey lane requires only a Start Node label (normally set to the label of the node at the end of the previous section) and co-ordinates (if known). Other data items may be provided (if known) or may be blank / zero as appropriate.
Note 2: The XSP code should be that appropriate to the **direction of survey, not the direction of section referencing.** Thus, when surveying Lane 1 in either direction on two-way section, the XSP Code should be “CL1”.

Note 3: The section description is for information only and would normally include the road number and descriptions of the start and end of the section in the direction of survey. Whilst this is good practice, and is strongly recommended, it is not something that can be taken for granted, as there is considerable variation in the standard of description and definition of local road networks.

"End of Route" Reference

7.1.7 Record R3.1 (Single record), as defined in Table 7.3.

Characters	Description	Format	Value range
1 - 20	End Node label (i.e. node at the end of the last section within the route)	A20	
21 - 31	End Node x co-ordinate (if known)	F11.3	0.000 to 9999999.999
32 - 42	End Node y co-ordinate (if known)	F11.3	0.000 to 9999999.999

Table 7.3: Record R3.1 (End of Route Reference)

7.2 The Fitted Route File

7.2.1 The Contractor provides the Fitted Route File in the same format as the Route File

7.3 SCANNER RCD File Format

Overview

7.3.1 Survey "header" data. The Contractor provides the following "header" data for a survey:

- Machine identifier;
- Date at the start of the survey;
- Time at the start of the survey;
- Date at the end of the survey;
- Time at the end of the survey;
- Survey identifier (descriptive text);
- Co-ordinates (x, y and z) at the start of the survey data;
- Status for co-ordinates at the start of the survey

- Chainage at the end of the survey data;
- Co-ordinates (x, y and z) at the end of the survey data;
- Status for co-ordinates at the start of the survey
- Number of nodes identified and recorded;
- Chainage interval between geometric measurements;
- Chainage interval between nearside and offside longitudinal profile points (and associated speed);
- Offset of longitudinal profile measurement relative to the centre of the vehicle;
- Chainage interval between transverse profiles;
- Number of points within each transverse profile;
- Offset of each transverse profile point relative to the centre of the vehicle;
- Chainage interval between wheel path rutting values;
- Chainage interval between texture profile points;
- Offset of texture profile measurement relative to the centre of the vehicle;
- Chainage interval between multiple line RMST values;
- Number of points within each multiple line texture measurement;
- Number of cracks identified and recorded;
- Offset of each multiple line RMST value relative to the centre of the vehicle.

> Note: Longitudinal profile data is filtered to remove wavelengths above a certain value (initially 100m).
>
> All survey data must start at a distance of at least half that wavelength before the start of the first survey lane within the route against which the survey is to be fitted, and will end at a distance of at least half that wavelength beyond the end of the last survey lane within the route.
>
> If the data collection method requires a longer run-in and/or run-out (e.g. using the HRM principal for measuring longitudinal profile), the additional data is included within the data file.

7.3.2 Location data. For each node identified during the survey run, the following data are provided:

- Node label;
- Chainage;

7.3.3 Geometric data. For each interval as defined in the survey “header” data, the following data are provided:

- Co-ordinates (x, y and z);
- Status for co-ordinates;
- Gradient;
- Crossfall;
- Radius of curvature;
- Deviation flag;

7.3.4 Longitudinal profile and speed data. For each interval as defined in the survey "header" data, the following data are provided:

- Single profile point;
- Average speed of the survey vehicle.

7.3.5 Transverse profile data. For each interval as defined in the survey header data the following data are provided:

7.3.5

- Set of **n** transverse profile points (**n** is the number of points within each transverse profile, as defined in the survey "header" data).

7.3.6 Wheelpath rutting data. For each interval as defined in the survey "header" data, the following data are provided:

- Rut depth in nearside wheelpath
- Rut depth in offside wheelpath

7.3.7 Texture data. For each interval as defined in the survey "header" data, the following data are provided:

- Single texture profile point.

7.3.8 Multiple Line Texture data. For each interval as defined in the survey "header" data, the following data are provided:

- Set of **n** multiple line texture (RMST) values (**n** is the number of points within each multiple line texture measurement, as defined in the survey "header" data).

7.3.9 Crack data. For each crack identified during the survey run, the following data are provided:

- Chainage;
- Offset;
- Length;
- Angle;
- Type code.

7.3.10 Invalid data: There may be instances where it is not possible to produce a valid value for a parameter due to, for example, limitations of the equipment. For each parameter where this may occur a specific "invalid" value is reserved and must be output in such circumstances. The "invalid" value for each parameter is defined in Section 7.4.

> Note there is no "invalid" value for cracking.
>
> Invalid crack measurements should not be reported in the SCANNER RCD

7.4 Data Format

7.4.1 Data is provided in a single file, logically divided into eight sections – one for each of the data types described in the previous section of this document:

- Survey "header" data;
- Location data;
- Geometric data;
- Longitudinal profile and speed data;
- Transverse profile data;
- Wheelpath rutting data;
- Texture data;
- Multiple Line Texture Data;
- Crack data.

7.4.2 The file consists of sequential records, each containing printable ASCII characters terminated by ASCII "Carriage Return" and "Line Feed" characters. As defined in the following sections, the file contains:

- One record of type S1.1, followed by
- One record of type S1.2, followed by
- One record of type S1.3, followed by
- One record of type S1.4, followed by
- None, one or more records of type S1.5, followed by
- None, one or more records of type S2.1, followed by
- None, one or more records of type S3.1, followed by
- None, one or more records of type S4.1, followed by
- None, one or more records of type S5.1, followed by
- None, one or more records of type S6.1, followed by
- None, one or more records of type S7.1 , followed by
- None, one or more records of type S8.1 , followed by
- None, one or more records of type S9.1.

7.4.3 Where a record type has the capacity for more than one value / set of values, all records except the last are utilised, and unused values within the last record should be set to blank or zero, as appropriate.

> e.g. If the length of survey and spacing of texture data define there to be 50,000,004 texture profile point values recorded,
>
> there should be 2,500,001 texture data records (type S7.1)
>
> with the first 2,500,000 records having 20 values in each
>
> and the last record having 4 actual values and 16 values of zero.

7.4.4 Within each record type, data is output in order of increasing survey chainage.

7.4.5 The following convention is used within the "Format" column:

- "**A**n" indicates a text field of n characters, left justified and padded with spaces;
- "**I**n" indicates an integer numeric field of up to n characters, including an optional leading sign, right justified and padded with spaces;
- "m**In**" indicates m consecutive fields of format "In";
- "**F**n.d" indicates a real number field of up to n characters, including the decimal point and an optional leading sign, with d digits after the decimal point, right justified and padded with spaces;
- "m**F**n.d" indicates m consecutive fields of format "**F**n.d".

7.4.6 The Contractor agrees the machine (Equipment) identifier with the Auditor

Survey "header" data

7.4.7 Record S1.1 (Single Record)

Characters	Description	Format	Value range
1 - 6	'SCN071'	A6	
7 - 14	Machine identifier	A8	
15 - 25	Date at the start of survey (dd-mmm-yyyy, e.g. "31-dec-2006")	A11	Valid date
26 - 30	Time at the start of the survey (hh:mm, 24-hour clock, e.g. "09:35")	A5	00:00 to 23:59

Characters	Description	Format	Value range
31 - 41	Date at the end of survey (dd-mmm-yyyy, e.g. "31-dec-2006")	A11	Valid date
42 - 46	Time at the end of the survey (hh:mm, 24-hour clock, e.g. "13:43")	A5	00:00 to 23:59

Table 7.4: Record S1.1 (Single Record – Survey Header Data)

7.4.8 Record S1.2 (Single Record)

Characters	Description	Format	Value range
1 - 80	Survey identifier	A80	

Table 7.5: Record S1.2 (Single Record – Survey Header Data)

7.4.9 Record S1.3 (Single Record).

Characters	Description	Format	Value range
1 - 11	x co-ordinate at the start of the survey data, measured in metres	F11.3	0.000 to 9999999.999
12 - 22	y co-ordinate at the start of the survey data, measured in metres	F11.3	0.000 to 9999999.999
23 - 31	z co-ordinate at the start of the survey data, measured in metres	F9.3	-9999.999 to +9999.999
32 - 32	Start of survey co-ordinate status	I1	0 to 2
33 - 43	Chainage at the end of the survey data, measured in metres	F11.3	0.000 to 9999999.999
44 - 54	x co-ordinate at the end of the survey data, measured in metres	F11.3	0.000 to 9999999.999
55 - 65	y co-ordinate at the end of the survey data, measured in metres	F11.3	0.000 to 9999999.999
66 - 74	z co-ordinate at the end of the survey data, measured in metres	F9.3	-9999.999 to +9999.999
75 - 75	End of survey co-ordinate status	I1	0 to 2

Table 7.6: Record S1.3 (Single Record – Survey Header Data)

Note. Each set of co-ordinates is accompanied by a Status. Status values have the following meanings:
0 = GPS signal available, values meet accuracy requirements
1 = GPS signal unavailable, values meet accuracy requirements
2 = Values do not meet accuracy requirements.

7.4.10 Record S1.4 (Single Record).

Characters	Description	Format	Value range
1 - 5	Number of nodes identified during the survey run	I5	0 to 99999
6 - 17	Chainage interval between geometric measurements, measured in metres. (see note 1 below)	F12.9	0.000000000 to 99.999999999
18 - 29	Chainage interval between nearside and offside longitudinal profile points (and associated speeds), measured in metres (see note 1 below)	F12.9	0.000000000 to 99.999999999
30 - 35	Offset of nearside longitudinal profile points, measured in metres from the centre of the survey vehicle, negative to the left.	F6.3	-9.999 to +9.999
36 - 41	Offset of offside longitudinal profile points, measured in metres from the centre of the survey vehicle, negative to the left.	F6.3	-9.999 to +9.999
42 - 53	Chainage interval between transverse profiles, measured in metres (see note 1 below)	F12.9	0.000000000 to 99.999999999
54 - 55	Number of points within each transverse profile (see note 2 below)	I2	0 to 99
56 - 67	Chainage interval between wheelpath rutting values,	F12.9	0.000000000 to

	measured in metres (see note 1 below)		99.999999999
68 - 73	Offset of texture profile points, measured in metres from the centre of the survey vehicle, negative to the left.	F6.3	-9.999 to +9.999
74 - 85	Chainage interval between texture profile points, measured in metres (see note 1 below)	F12.9	0.000000000 to 99.999999999
86 - 97	Chainage interval between multiple line texture profile values, measured in metres (see note 1 below)	F12.9	0.000000000 to 99.999999999
98 - 99	Number of points within each multiple line texture measurement	I2	0 to 99
100 - 104	Number of cracks identified and recorded during the survey run. [3](see note 3 below)	I5	0 to 99999

Table 7.7: Record S1.4 (Single record – Survey Header Data)

Note 1: A value of zero for a chainage interval implies that that particular item of data will not be included in the data file.
Note 2 Where the measurement system collects more that 99 points per transverse profile the profile may need to be re-sampled prior to delivery as RCD. This shall be agreed with the Auditor.
Note 2 A value of -1 for the number of cracks identified and recorded during the survey run implies that the crack detection system was not operational during the survey. A value of zero implies that the system was operational but that no cracks were found.

7.4.11 Record S1.5 (Repeated as necessary to define the number of transverse profile points specified in record S1.4)

Characters	Description	Format	Value range
1 - 60	Offsets of up to 10 transverse profile points, measured in metres from the centre of the survey vehicle, negative to the left. Offsets to be in order of increasing value.	10F6.3	9.999 to +9.999

Table 7.8: Record S1.5 (Survey Header Data, repeated as necessary to define the number of transverse profile points specified in record S1.4)

Note 1: Where re-sampling has been applied, the offsets relate to the offsets of the re-sampled points.

7.4.12 Record S1.6 (Repeated as necessary to define the number of multiple line texture measurements points specified in record S1.4)

Characters	Description	Format	Value range
1 - 5	Offsets of up to 10 multiple line texture values (RMST), measured in metres from the centre of the survey vehicle, negative to the left. Offsets to be in order of increasing value.	10F6.3	9.999 to +9.999

Table 7.9: Record S1.5 (Survey Header Data, repeated as necessary to define the number of multiple line texture values specified in record S1.4)

Location data

7.4.13 Record S2.1 (Repeated for each node as defined in record S1.4)

Characters	Description	Format	Value range
1 - 20	Node label	A20	
21 - 31	Chainage, measured in metres	F11.3	0.000 to 9999999.999

Table 7.10: Record S2.1 (repeated for each node as defined in record S1.4)

Geometric data

7.4.14 Record S3.1 (Repeated as necessary to provide number of measurements as defined by length of survey and spacing of values)

Characters	Description	Format	Value range
1 - 11	x co-ordinate	F11.3	0.000 to 9999999.999
12 - 22	y co-ordinate	F11.3	0.000 to 9999999.999
23 - 31	z co-ordinate	F9.3	-9999.999 to +9999.999
32 - 32	Co-ordinate status (Rec.S1.3 Note 1)	I1	0 to 2
33 - 37	Gradient, measured as a percentage relative to horizontal, positive implying upwards travelling in the direction of the survey (see Note 1)	F5.1	-99.9 to +99.9
38 - 42	Crossfall, as a percentage relative to horizontal, positive implying right higher than left in the direction of the survey (see Note 2 below)	F5.1	-99.9 to +99.9
43 - 50	Radius of curvature, measured in metres, positive implying a left hand curve travelling in the direction of the survey (see Note 3 below)	F8.2	-9999.99 to +9999.99
51	Deviation flag. “D” indicates that the survey deviated from the defined route over all or part of the length ending at the chainage of this record	A1	“D” or “ ”
52	Spare	A1	“ “

Table 7.11: Record S3.1 (Repeated as necessary to provide number of measurements as defined by length of survey and spacing of values)

Note 1:	An invalid gradient must be output as 999.9
Note 2:	An invalid crossfall must be output as 999.9
Note 3:	An invalid radius of curvature must be output as 99999.99

Longitudinal profile and speed data.

7.4.15 Record S4.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of points/speeds (7 points/speeds per record))

Characters	Description	Format	Value range
1 - 7	Nearside profile point value, measured in 1/10mm (see Note 1 below)	I7	-999999 to +999999
8 - 14	Offside profile point value, measured in 1/10mm (see Note 1 below)	I7	-999999 to +999999
15 - 18	Speed value, measured in cm/sec (see Note 2 below)	I4	0-9998
19 - 36	As Cols 1-18 for next profile points and speed		
37 - 55	As Cols 1-18 for next profile points and speed		
56 - 72	As Cols 1-18 for next profile points and speed		

Table 7.12: Record S4.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of points/speeds (4 points/speeds per record))

Note 1:	An invalid profile point value must be output as 9999999
Note 2:	An invalid speed value must be output as 9999

Transverse profile data

7.4.16 Record S5.1 (Repeated as necessary to provide number of values as defined by length of survey, number of transverse profile points and spacing of profiles)

Characters	Description	Format	Value range
1 - 80	Up to 16 profile point values, measured in 1/10mm (see Note 1 below)	16I5	-9999 to +9999

Table 7.13: Record S5.1 (Repeated as necessary to provide number of values as defined by length of survey, number of transverse profile points and spacing of profiles)

Note 1:	An invalid transverse profile value must be output as 99999

Wheel path rutting data

7.4.17 Record S6.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of values (10 pairs of rut depths per record)).

Characters	Description	Format	Value range
1 - 4	Rut depth in nearside wheelpath, measured in 1/10mm (See Note 1 below)	I4	0 to 9998
5 - 8	Rut depth in offside wheelpath, measured in 1/10mm (See Note 1 below)	I4	0 to 9998
9 - 16	As Cols 1-8 for next pair of rut depths		
17 - 24	As Cols 1-8 for next pair of rut depths		
25 - 32	As Cols 1-8 for next pair of rut depths		
33 - 40	As Cols 1-8 for next pair of rut depths		
41 - 48	As Cols 1-8 for next pair of rut depths		
49 - 56	As Cols 1-8 for next pair of rut depths		
57 - 64	As Cols 1-8 for next pair of rut depths		
65 - 72	As Cols 1-8 for next pair of rut depths		
73 - 80	As Cols 1-8 for next pair of rut depths		

Table 7.14: Record S6.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of values (10 pairs of rut depths per record))

Note 1: An invalid rut depth value must be output as 9999

Texture data

7.4.18 Record S7.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of points)

Characters	Description	Format	Value range
1 - 80	Up to 20 texture profile point values, measured in 1/10mm (see Note 1 below)	20I4	-999 to +999

Table 7.15: Record S7.1 (Repeated as necessary to provide number of values as defined by length of survey and spacing of points)

Note 1: An invalid texture profile point value must be output as 9999

Multiple Line Texture Values

7.4.19 Record S8.1 (Repeated as necessary to provide number of values as defined by length of survey, number of multiple line texture values and spacing of values)

Characters	Description	Format	Value range
1 - 80	Up to 16 multiple line texture values (RMST), measured in 1/10mm. (see Note 1 below)	16I5	-9999 to +9999

Table 7.16: Record S8.1 (Repeated as necessary to provide number of values as defined by length of survey, number of multiple line texture values and spacing of values)

Note 1: An invalid RMST value must be output as 99999

Crack data

7.4.20 Record S9.1 (Repeated as necessary to provide data for the number of cracks defined in record S1.4 (three cracks per record)).

Characters	Description	Format	Value range
1 - 11	Chainage, measured in metres	**F**11.3	0.000 to 9999999.999
12 - 17	Offset, measured in metres from the centre of the survey vehicle, negative to the left.	**F**6.3	-9.999 to +9.999
18 - 22	Length, measured in metres	**F**5.3	0.000 to 9.999
23 - 25	Angle, measured in degrees from the direction of travel, negative anticlockwise	**I**3	-90 to +90
26 - 27	Type code	**A**2	1 to 99
28 - 54	As Cols 1-27 for next crack		
55 - 81	As Cols 1-27 for next crack		

Table 7.17: Record S9.1 (Repeated as necessary to provide data for the number of cracks defined in record S1.4 (three cracks per record))

7.5 SCANNER RCD Character Set

7.5.1 The ASCII printable characters given in Table 7.18 may be included within SCANNER data.

Char	Dec Code	Char	Dec Code	Char	Dec Code	Char	Dec Code	Char	Dec Code	Char	Dec Code
Space	**32**	0	**48**	@	**64**	P	**80**	`	**96**	p	**112**
!	**33**	1	**49**	A	**65**	Q	**81**	a	**97**	q	**113**
”	**34**	2	**50**	B	**66**	R	**82**	b	**98**	r	**114**
#	**35**	3	**51**	C	**67**	S	**83**	c	**99**	s	**115**
$	**36**	4	**52**	D	**68**	T	**84**	d	**100**	t	**116**
%	**37**	5	**53**	E	**69**	U	**85**	e	**101**	u	**117**
&	**38**	6	**54**	F	**70**	V	**86**	f	**102**	v	**118**
’	**39**	7	**55**	G	**71**	W	**87**	g	**103**	w	**119**
(	**40**	8	**56**	H	**72**	X	**88**	h	**104**	x	**120**
)	**41**	9	**57**	I	**73**	Y	**89**	i	**105**	y	**121**
*	**42**	:	**58**	J	**74**	Z	**90**	j	**106**	z	**122**
+	**43**	;	**59**	K	**75**	[	**91**	k	**107**	{	**123**
,	**44**	<	**60**	L	**76**	\	**92**	l	**108**	|	**124**
-	**45**	=	**61**	M	**77**	]	**93**	m	**109**	}	**125**
.	**46**	>	**62**	N	**78**	^	**94**	n	**110**	~	**126**
/	**47**	?	**63**	O	**79**	_	**95**	o	**111**		

Table 7.18: SCANNER RCD Character Set

7.5.2 Each record is terminated by ASCII “carriage return” and “line feed” characters which have decimal codes 13 and 10, respectively.

7.6 SCANNER Format Definitions

7.6.1 In the formal definitions, the following notation and terminology are used:

<table>
<tr><td>|</td><td>means ‘or’</td></tr>
<tr><td>space</td><td>means ASCII character code 32</td></tr>
<tr><td>letter</td><td>means any alphabetic character (A-Z, a-z)</td></tr>
<tr><td>digit</td><td>means 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9</td></tr>
<tr><td>others</td><td>means any printable character as defined in Table 7.18 with the exception of space, letters and digits</td></tr>
<tr><td>$\{a\}^{n,m}$</td><td>means a may appear n to m times</td></tr>
<tr><td>$\{a\}^{n}$</td><td>means a will appear n times</td></tr>
</table>

7.6.2 “An” - means a string of n characters without leading spaces, or a string of n spaces. More formally:

$$(\{ \text{letter} \mid \text{digit} \mid \text{others} \}^{1} \{\text{letter} \mid \text{digit} \mid \text{others} \mid \text{space}\}^{n-1}) \mid \{\text{space}\}^{n}$$

7.6.3 “In” -means an integer numeric field of up to n characters, including an optional leading sign, right justified and padded with leading spaces. More formally:

$$\{ \text{space} \}^{0,n-1} \{ - \mid + \}^{0,1} \{ \text{digit} \}^{1,n} \quad \text{with a total of n characters}$$

Note: In some instances, where only positive values are permitted, the width of a field may preclude the inclusion of a sign character. This is intentional.

7.6.4 “m**I**n” means "m" consecutive fields of format “**I**n”. More formally:

$$\{ \text{In} \}^{m}$$

7.6.5 “**F**n.d” means a real number field of up to n characters, including the decimal point and an optional leading sign, with d digits after the decimal point, right justified and padded with spaces. More formally:

$$\{ \text{space} \}^{0,n-d-2} \{ - \mid + \}^{0,1} \{ \text{digit} \}^{1,n-d-1} \{.\}^{1} \{ \text{digit} \}^{d} \quad \text{with a total of n characters.}$$

Note: In some instances, where only positive values are permitted, the width of a field may preclude the inclusion of a sign character. This is intentional.

7.6.6 “m**F**n.d” means m consecutive fields of format “**F**n.d”. More formally:

{ Fn.d }^{m}

7.7 SCANNER HMDIF Data Format

7.7.1 The SCANNER HMDIF file takes the format of a Highways Maintenance Data Interchange Format (HMDIF) file.

7.7.2 The SCANNER HMDIF file should be produced in accordance with the latest released version of UKPMS Document 71 'SCANNER HMDIF Specification', available on the UKPMS Web Site (www.ukpms.com)

7.7.3 The HMDIF format does not have the ability to accommodate invalid data and therefore lengths containing invalid values should not be reported in the HMDIF.

8 Accreditation Testing

8.1 Accreditation

8.1.1 Before carrying out any SCANNER accredited surveys the Survey Equipment must have a currently valid Accreditation Certificate, awarded following successful Accreditation Testing or subsequent re-testing.

8.1.2 The Employer and/or the Auditor may require the Contractor to produce a currently valid Accreditation Certificate for the Survey Equipment at any time.

8.1.3 The Accreditation Tests may be carried out on any machine and at any time. Following the successful completion of the tests, the tester issues an Accreditation Certificate for the survey machine to carry out SCANNER accredited surveys for a period of up to 14 months from the first date on which fully acceptable survey data was collected.

8.1.4 The Auditor may revoke an Accreditation Certificate at any time and require the Contractor to undertake retesting if the Equipment fails to meet the accuracy requirements during SCANNER surveys, including Contractor's repeat surveys and Auditor's repeat surveys.

8.1.5 If a Contractor makes any significant change to the Equipment after the issue of an Accreditation Certificate the Auditor may require the Equipment to be submitted for an additional Accreditation re-test.

8.1.6 If the Equipment is required to undergo an additional Accreditation re-test, the Auditor may also require the Equipment to be submitted for an additional Consistency re-test.

8.1.7 The Accreditation Tester may also assess the competence of drivers and operatives as part of the Accreditation Testing and the annual re-testing.

8.2 General requirements

8.2.1 The Accreditation Tests assess the capability of the Equipment in the measurement and reporting of the parameters specified in the following sections. The accuracy of the equipment in the measurement of each parameter is assessed separately so that the equipment may be judged as acceptable or not (as applicable) in the measurement of each parameter individually.

8.2.2 The machine developer or Contractor attends the Accreditation Tests, and carries out any surveys or data processing required by the Accreditation Tester, at its own cost.

8.2.3 The Equipment is driven and operated by drivers and operators named in the Contractor's quality system. The Accreditation Tester supervises and controls the tests.

8.2.4 The Accreditation Testing is carried out as site tests, network tests and survey data acceptance tests:

- In the site tests the parameters measured by the survey equipment are compared with those measured by the Reference Methods on test sections located on sites selected by the Accreditation Tester.
- The network tests assess the operational capabilities of the survey equipment when carrying out surveys under normal operating conditions on one or more routes selected by the Accreditation Tester and located on the public road network.
- In the survey data Accreditation tests the data output from the Equipment is checked to ensure that it complies with all the requirements for loading into a UKPMS accredited system.

8.2.5 If the Equipment fails to achieve the required levels of accuracy in the measurement of individual parameters, the machine developer or Contractor may seek to resolve this issue by enhancing the performance of the Equipment. The Accreditation Test for that measurement may then be repeated, at the Contractor's expense, at a time convenient to both the Accreditation Tester and the machine developer or Contractor. Any SCANNER surveys that may have been completed (in the Accreditation Approval Period) may also be invalidated and need to be repeated, at the Contractor's expense.

8.2.6 On successful completion of the Accreditation Tests, including the survey data Accreditation testing, the Accreditation Tester issues an Accreditation Certificate (similar to the example in Figure 8.1), which summarises the results of the Accreditation Tests in the measurement of each defined survey parameter.

8.2.7 The initial accreditation certificate is valid up to 14 months from the date of issue. At intervals of no more than one year following the commencement date of the Accreditation Certificate the Contractor submits the survey equipment for Accreditation re-testing.

8.2.8 The Accreditation timetable is outlined below and an example accreditation timetable for a new SCANNER survey vehicle is given in Figure 8.2:

- Testing Period (no set timescale): ALL accreditation test sites to be surveyed during this phase. NO SCANNER surveys are permitted.
- Accreditation Approval Period (maximum length seven weeks): The test data from (at least) the site level tests must be delivered to the Accreditation Tester before this stage can commence. SCANNER surveys are then permitted but these MUST be agreed with the Accreditation Tester. There then follows a three week period where the Accreditation Tester processes the site level test data and the Survey Contractor must deliver all remaining test data (network routes and crack sites). There then follows a four week period where the Accreditation Tester completes all data analysis.

- Accreditation: SCANNER Certificate awarded for 14 months from the date the site level tests commenced. To ensure continuous accreditation the Vehicle may commence re-accreditation testing 12 months after certificate started.

8.2.9 Following the successful completion of an annual re-test, the tester issues a SCANNER Accreditation Certificate for a further period of up to 12 months.

Figure 8.1: Illustrative example of a SCANNER Accreditation Certificate

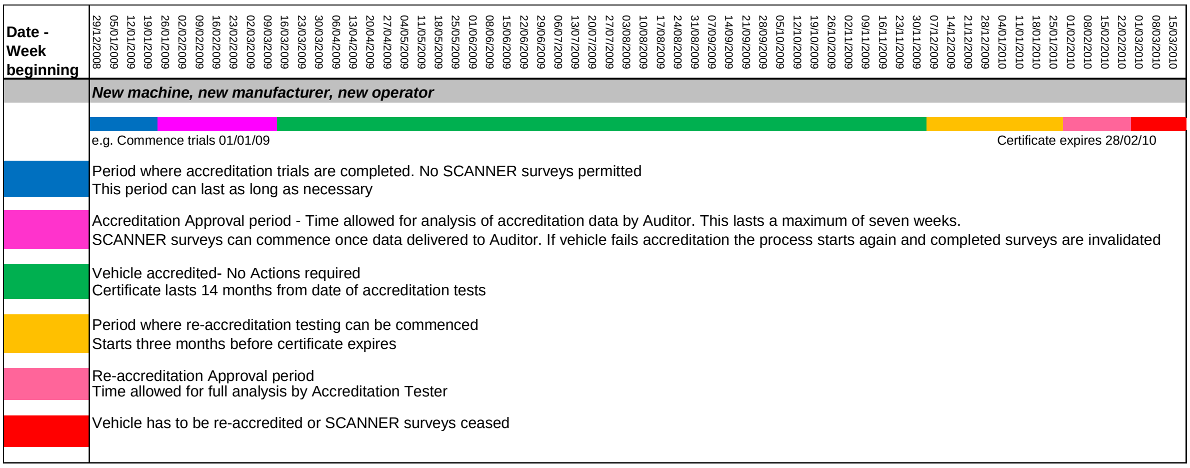


Figure 8.2: Summary accreditation timetable for new SCANNER vehicle

8.3 Site tests

8.3.1 For several of the Site Tests it is necessary for the survey equipment to record the location of the start of each test section to an accuracy better than ±1m so that the data provided by the machine developer or Contractor can be accurately aligned with the Reference Data.

- To enable this level of accuracy to be achieved the Accreditation Tester places markers at the test section start and end points adjacent to the nearside of the traffic lane being surveyed.
- These markers take the form of posts approximately 0.75m tall. The face of the posts (aligned longitudinally with the traffic lane) are covered with a retro-reflective material of dimensions approximately 0.65m by 0.1m.
- The survey equipment must record the location of these posts placed at the test Section start and end points to an accuracy of better than ±1m over the range of speeds under which the survey equipment would normally be operated.

8.3.2 The Accreditation Tester provides the Contractor with a plan describing the test sites and the survey procedures to be applied (e.g. survey speeds) on those sites at least 5 working days before the commencement of the tests.

8.3.3 For the Site Tests the Contractor:

- Surveys the test sites as instructed by the Accreditation Tester in the plan provided before the tests.
- Where reflective posts are placed at the Section Start and End Points, records the location of the posts marking the Section Start and End Points to an accuracy of better than ±1m using suitable equipment installed on the survey equipment

- Processes the Survey Data from the test site to generate SCANNER RCD and SCANNER HMDIF files.

Note: Where reflective posts are placed at the Section Start and End Points and are recorded by the survey equipment, it should not normally be necessary to align the Survey Data with the planned survey route before generating the SCANNER RCD and SCANNER HMDIF files. However, where it is found necessary to carry out alignment of the Survey Data with the planned survey route the Contractor ensures that the elapsed distances of the section change points recorded in the location records of BOTH the SCANNER RCD and SCANNER HMDIF files are the aligned (post-fitted) distances.

8.3.4 The Accreditation Tester uses a number of Reference Methods to assess the accuracy of the Equipment in the Site Tests, these are summarised in Table 8.1

Parameter type	Parameter measure	Values to be compared with Reference	Reference Method for Site Tests
Location Referencing	Distance Travelled	Measured lengths of Sections	Calibrated Measuring wheel and Steel Tape
	National Grid Co-ordinates of Section start points	National Grid Co-ordinates of Section start points	Static GPS combined with an Optical Survey
	National Grid Co-ordinates of positions of moving vehicle	National Grid Co-ordinates of positions of moving vehicle	Static GPS combined with an Optical Survey
Geometry	Gradient	Gradient	Rod and level
	Crossfall	Crossfall	Rod and level
	Radius of Curvature	Radius of Curvature	Calibrated Measuring wheel / Steel Tape
Longitudinal Profile	Longitudinal Profile	Measured Longitudinal Profile in both wheelpaths	ARRB Walking Profiler and/or Artificial Profile (characterised using micrometer and/or rod and level)
	Variance	3m, 10m Variance (both wheelpaths)	ARRB Walking Profiler
Transverse profile	Transverse Profile	Measured Transverse Profile	Artificial Profile, transverse profile measured over the road edge
		Cleaned Rut Depth	HARRIS (1), with manual assessment of the measured transverse profiles
Rutting	Rut Depth	Rut depth	Straight-edge and wedge and/or HARRIS (1), with manual assessment of the measured transverse profiles
Texture Profile	Texture Profile	Measured Texture Profile	Characterised Artificial Profile
	Sensor Measured Texture Depth (SMTD)	Sensor Measured Texture Depth (SMTD) and Mean Profile Depth (MPD)	HARRIS (1)
	Multiple Line Texture	RMST	HARRIS (1)
Cracking	Crack Intensity	Crack Intensity	Primary Reference Data: Manual Assessment of Digital Images
	Crack Intensity	Crack Intensity	Secondary Reference Data: Mean Crack Intensity Recorded by each item of Equipment (2)
	Crack map	Individual Cracked Grid tiles	Manual Assessment of Digital Images
(1) Highways Agency Road Research Information System (HARRIS1/HARRIS2)			
(2) Where more than one piece of Equipment from different Contractors participate in the Tests			

Table 8.1: Reference Methods to be used in the Accreditation Tests

8.4 Site tests of location referencing

8.4.1 The Accreditation Tester selects a test site and divides it into a number of Sections, marking the start and end of each section with a reflective post.

- The site may contain both straight and curved Sections.
- The site may contain Sections having levels of GPS signal availability (in terms of the length of the Section over which the GPS signal is available) ranging from less than 10% availability of GPS signal to greater than 90% availability.

8.4.2 The Contractor defines a survey route appropriate for the survey of the test site, surveys the test site at a range of speeds (as required by the Accreditation Tester) and delivers the SCANNER RCD and the SCANNER HMDIF file from the test site to the Accreditation Tester.

8.4.3 The Accreditation Tester compares the lengths of the Sections recorded in the SCANNER RCD and SCANNER HMDIF files provided by the Contractor with the lengths of the Sections measured by the Reference Method.

8.4.4 The Accreditation Tester compares the National Grid Co-ordinates and the Altitudes recorded in the SCANNER RCD and SCANNER HMDIF files provided by the Contractor with National Grid Co-ordinates and the Altitude recorded for these Sections using the Reference Method.

8.4.5 The test is passed if all the following criteria are met:

- 95% of the measured Section lengths fall within ±1m (or ±0.1%, whichever is larger) of the Section lengths measured using the Reference Method.
- 95% of the measured National Grid Co-ordinates are within ±2m of the National Grid Co-ordinates measured using the Reference Method for those Sections having better than 70% availability of the signal used by the equipment for the calculation of National Grid Co-ordinates
- 95% of the measured National Grid Co-ordinates are within ±10m of the National Grid Co-ordinates measured using the Reference Method for those Sections having less than 70% availability of the signal used by the equipment for the calculation of National Grid Co-ordinates.
- All of the measured National Grid Co-ordinates are within ±50m of the National Grid Co-ordinates measured using the Reference Method.
- 95% of the measured Altitudes are within ±5m of the Altitudes measured using the Reference Method for those Sections having better than 70% availability of the signal used by the equipment for the calculation of National Grid Co-ordinates.

- 95% of the measured Altitudes are within ±10m of the Altitudes measured using the Reference Method for those Sections having less than 70% availability of the signal used by the equipment for the calculation of National Grid Co-ordinates
- All of the measured Altitudes are within ±50m of the Altitudes measured using the Reference Method.

8.5 Site tests of road geometry

8.5.1 The Accreditation Tester selects a test site and divides it into a number of Sections, marking the start and end of each section with a reflective post.

8.5.2 The Accreditation Tester surveys the test site for Gradient, Cross-fall and Radius of Curvature using the Reference Method(s) given in Table 8.1.

> The geometry of the site may vary, with cross-fall, gradient and curvature lying in the full range specified in Volume 4.

8.5.3 The Contractor defines a survey route appropriate for the survey of the test site, surveys the test site at a range of speeds (as required by the Accreditation Tester) and delivers the SCANNER RCD and the SCANNER HMDIF files from the test site to the Accreditation Tester.

8.5.4 The Accreditation Tester subtracts the gradient and cross-fall recorded in the SCANNER RCD files provided by the Contractor from the gradient and cross-fall measured with the Reference Method, expressed over 5m lengths.

8.5.5 For the radius of curvature measurements, the Accreditation Tester will assess the accuracy of the equipment in terms of the curvature (defined as 1/radius of curvature), and therefore will subtract the curvature obtained from the Scanner RCD and Scanner HMDIF from the reference curvature.

8.5.6 The test is passed if all the following criteria are met:

- 95% of the differences between the measured Gradient and the Reference Gradient fall within ±1.5% (gradient), or ±10% of the Reference Gradient, whichever is greater.
- The difference between the measured gradient and the Reference Gradient shall never exceed ±6.0% (gradient)
- 95% of the differences between the measured Cross-fall and the Reference Cross-fall fall within ±1.5% (crossfall), or ±10% of the Reference Cross-fall, whichever is greater.
- The difference between the measured cross-fall and the Reference Cross-fall shall never exceed ±6.0% (crossfall)
- 65% of the differences between the measured Curvature and the Reference Curvature fall within $\pm 0.0015 m^{-1}$.

- 95% of the differences between the measured Curvature and the Reference curvature fall within ±0.003m^{-1}.

8.6 Site tests of longitudinal profile

8.6.1 The site tests of longitudinal profile described in the following sections will be carried out on the longitudinal profile recorded in both wheelpaths. The tests will be passed if the measurements provided in both wheelpaths satisfy the specified requirements.

8.6.2 The Accreditation Tester selects a test site and divides it into a number of Sections, marking the start and end of each section with a reflective post.

> The site may contain both straight and curved Sections, but will not contain any extremes of geometry

8.6.3 The Accreditation Tester measures the longitudinal profile of the site using the Reference Method given in Table 8.1.

8.6.4 The Contractor defines a survey route appropriate for the survey of the test site.

8.6.5 The Accreditation Tester provides the Contractor with a breakdown of the range of speeds for which longitudinal profile measurements of the site will be required.

- A number of test surveys are carried out at constant survey speed and a number of test surveys are carried out under conditions of deceleration.
- To achieve even decelerations the Accreditation Tester marks out the test site to indicate the locations at which survey vehicle braking should start and end.

8.6.6 The Contractor uses the survey equipment to collect measurements of Longitudinal Profile on the test site under the range of conditions defined by the Accreditation Tester and delivers the SCANNER RCD and the SCANNER HMDIF files from the test site to the Accreditation Tester.

8.6.7 The measurement of Longitudinal Profile measured by the survey equipment over the test site and provided in the SCANNER RCD is assessed as follows:

- A moving average filter is applied to both the Reference Profile and the measured profile to obtain two filtered profiles for which wavelengths in excess of 3m and 10m have been attenuated.
- If required, the Accreditation Tester normalises the measured profile, for example to remove any constant, or linear, offset between the Reference and measured profiles. The Accreditation Tester calculates the differences between the filtered Reference Profile and the filtered measured profile by subtracting the filtered Reference Profile from the filtered measured profile.

- If required, the Accreditation Tester normalises the measured profiles and calculates the cross-correlation coefficient between the filtered Reference Profile and the filtered measured profile.

8.6.8 The measurement of Longitudinal Profile Variance measured by the survey equipment over the test site and provided in the SCANNER RCD is assessed as follows:

- The Accreditation Tester calculates both the 3m and 10m Enhanced and Moving Average Longitudinal Profile Variances from the Longitudinal Profiles measured by the survey equipment over 10m lengths. The Accreditation Tester subtracts these values from the 3m and 10m Enhanced and Moving Average Longitudinal Profile Variances calculated from measurements of Longitudinal Profile previously made on the selected lengths using the Reference Method(s), to obtain the differences between the measured and the Reference Enhanced and Moving Average Longitudinal Profile Variances.
- The Accreditation Tester calculates fractional errors by dividing the differences by the 3m and 10m Enhanced and Moving Average Longitudinal Profile Variances calculated from the Reference Profile.

8.6.9 The tests for longitudinal profile are passed, for the surveys carried out at constant speed, if:

- 95% of the differences between the measured Longitudinal Profile and the Reference Profile fall within the ranges given in column A of Table 8.2.
- 95% of the cross-correlation coefficients equal or exceed the values given in column B of Table 8.2.
- 65% of the errors between Enhanced and Moving average Longitudinal Profile Variances calculated from the measured profile and the Enhanced and Moving average Longitudinal Profile Variances calculated from Reference Profile (respectively) fall within the ranges given in column C of Table 8.2.
- 95% of the errors between the Enhanced and Moving average Longitudinal Profile Variances calculated from the measured profile and the Enhanced and Moving average Longitudinal Profile Variances calculated from Reference Profile (respectively) fall within the ranges given in column D of Table 8.2.

8.6.10 The Accreditation Tester assesses accuracy separately for surveys carried out at constant speed and surveys carried out under conditions of deceleration.

8.6.11 The Accreditation Tester compares the performance of the Equipment at each level of deceleration with the accuracy requirements given in Table 8.2 for the surveys carried out under conditions of deceleration.

- The Accreditation Tester records the level of deceleration at which, in its opinion, the Equipment fails to provide measurements to an acceptable level of accuracy when compared with the accuracy requirements given in Table 8.2. This defines the limit of deceleration under which the Equipment provides acceptable data.

	A	B	C	D
Wavelength (m)	Profile differences (95%)	Profile Cross Correlation Coefficient	Variance Error (65%)	Variance Error (95%)
3m	±2.00	0.75	±0.30	±0.60
10m	±4.00	0.85	±0.35	±0.70
Note: For 3m and 10m Longitudinal Profile Variance the tolerances are in terms of the either differences or the fractional errors between the Longitudinal Profile Variances calculated from the measured profile and the Longitudinal Profile Variances calculated from the Reference Profile, as defined in Volume 4.				

Table 8.2: Accuracy requirements for the Site Tests of longitudinal profile

8.7 Site tests of transverse profile

8.7.1 The Accreditation Tester provides one or more lengths laid out with features of a known Transverse Profile. The shapes of these features will be characterised using the Reference Methods given in Table 8.1. These measurements will be referred to as the Reference Profiles for the assessment of Transverse Profile measurement.

8.7.2 The contractor measures the Transverse Profile of these features at a range of speeds.

8.7.3 The Accreditation Tester compares the measured Transverse Profiles with the Reference Profile as follows. The differences between the Reference Profile and the measured profile will be calculated by subtraction of the Reference Profile from the measured profile following any required normalisation of the measured profile. Normalisation may include, for example, the removal of the Crossfall from the Reference and measured profiles.

8.7.4 The test will be passed if

- 95% of the differences between the measured Transverse Profile points and the Reference Profile points fall within ±1.5mm.

8.7.5 The Accreditation Tester also selects a number of test sites on the local road network and divides them into a number of Sections. The Accreditation Tester provides the Contractor with a map showing the location of the sites and the description of each Section start and end point on each site.

The sites may cover a broad range of rut depths and other transverse features

8.7.6 The Accreditation Tester measures the transverse profile present on the test sites using the Reference Method given in Table 8.1.

8.7.7 The Contractor defines a survey route appropriate for the survey of each of the test sites, carries out one or more surveys of the test sites as required by the Accreditation Tester and delivers the SCANNER RCD to the Accreditation Tester.

8.7.8 The Accreditation Tester visually examines the transverse profiles recorded in the SCANNER RCD, in particular over lengths where the Contractor is expected to have surveyed over the road edge.

8.7.9 The Accreditation Tester calculates the Cleaned Rut depths from the transverse profile provided within the SCANNER RCD, and reports these over 10m lengths. The Accreditation Tester subtracts the calculated Cleaned Rut Depths from the Cleaned Rut Depths measured with the Reference Method.

8.7.10 The test is passed if all the following criteria are met:

- The visual examination of the transverse profile confirms that the Equipment is not adversely affected by the measurement of transverse profile over the road edge.
- 65% of the differences between the measured Cleaned Rut Depths in each Wheelpath, and the Reference Cleaned Rut Depth in each Wheelpath fall within ±1.5mm.
- 95% of the differences between the measured Cleaned Rut Depths in each Wheelpath, and the Reference Cleaned Rut Depth in each Wheelpath fall within ±3.0mm.
- All of the differences between the measured Cleaned Rut Depths in each Wheelpath, and the Reference Cleaned Rut Depth in each Wheelpath are less than ±10.0mm, or 50% of the magnitude of the Reference Cleaned Rut Depth, whichever is the greater.
- 65% of the differences between the measured Transverse Unevenness in each wheel path and the Reference Transverse Unevenness fall within ±0.003.
- 95% of the differences between the measured Transverse Unevenness in each wheel path and the Reference Transverse Unevenness fall within ±0.006.
- 65% of the differences between the edge roughness calculated from the measured Transverse Profile (over 10m lengths) and

the edge roughness calculated from the Reference Transverse Profile fall within ±0.025.

- 95% of the differences between the edge roughness calculated from the measured Transverse Profile (over 10m lengths) and the edge roughness calculated from the Reference Transverse Profile fall within ±0.05.

8.8 Wheel path ruts

8.8.1 The Accreditation Tester selects a test site and divides it into a number of Sections, marking the start and end of each section with a reflective post.

8.8.2 The Accreditation Tester provides the Contractor with a map showing the location of the sites and the description of each Section start and end point on each site.

> The sites may cover a broad range of rut depths and other transverse features

8.8.3 The Accreditation Tester measures the rutting present on the test sites using the Reference Method given in Table 8.1.

8.8.4 The Contractor defines a survey route appropriate for the survey of each of the test sites, carries out one or more surveys of the test sites as required by the Accreditation Tester and delivers the SCANNER RCD and the SCANNER HMDIF files to the Accreditation Tester.

8.8.5 The Accreditation Tester averages the rut depths recorded in the SCANNER HMDIF over 10m lengths and subtracts them from the rut depths measured with the Reference Method over 10m lengths.

8.8.6 The test is passed if all the following criteria are met:

- 65% of the differences between the measured maximum Rut Depths in each Wheelpath, and the Reference maximum Rut Depth in each Wheelpath fall within ±1.5mm.
- 95% of the differences between the measured maximum Rut Depths in each Wheelpath, and the Reference maximum Rut Depth in each Wheelpath fall within ±3.0mm.
- All of the differences between the measured maximum Rut Depths in each Wheelpath, and the Reference maximum Rut Depth in each Wheelpath are less than ±10.0mm, or 50% of the magnitude of the Reference Rut Depth, whichever is the greater.

8.9 Site tests of texture profile

8.9.1 The Accreditation Tester selects a test site consisting of a single Section for the assessment of the measurement of “raw” texture profile, marking the start and end of the Section with a reflective post.

- The Section contains features of a known Texture Profile, characterised using conventional measurement methods.
- These measured shapes are referred to as the Reference Profile for the assessment of Texture Profile measurement.

8.9.2 The Accreditation Tester selects a further test site and divides it into a number of Sections for the assessment of the measurement of Sensor Measured Texture Depth (SMTD) and Mean Profile Depth (MPD), marking the start and end of each section with a reflective post.

> The site may contain both straight and curved Sections, but will not contain any extremes of geometry.

8.9.3 The Accreditation Tester measures the texture profile of the site using the Reference Method given in Table 8.1 for the measurement of SMTD and MPD.

8.9.4 The Contractor defines a survey route appropriate for the survey of the test site, carries out one or more surveys of the test site as required by the Accreditation Tester and delivers the SCANNER RCD and the SCANNER HMDIF files to the Accreditation Tester.

8.9.5 The Accreditation Tester assesses the measurement of texture Profile by the Equipment, over the test site, and provided in the SCANNER RCD as follows:

- The texture profile recorded in the SCANNER RCD provided from the test site for the assessment of the measurement of “raw” texture profile is subtracted from the Reference Profile to obtain the differences between the texture profile and the reference profile.
- The SMTD and MPD are calculated (over 10m lengths) from the texture profiles recorded in the SCANNER RCD provided from the test site for the assessment of the measurement of SMTD and MPD. These values will then be subtracted from the SMTD and MPD calculated from measurements of texture Profile previously made on the selected lengths using the Reference Method(s) to obtain the differences between the measured SMTD (MPD) and the Reference SMTD (MPD).

8.9.6 The tests for texture profile measurement will be passed if:

- 95% of the differences between the measured Texture Profile and the Reference Profile (from the test site for the assessment of the measurement of “raw” texture profile) fall within ±0.5mm.
- 65% of the differences between the SMTD calculated from the measured Texture Profile and the SMTD calculated from the Reference Profile (from the test site for the assessment of the measurement of SMTD) fall within the range ±0.13mm.

- 95% of the differences between the SMTD calculated from the measured Texture Profile and the SMTD calculated from the Reference Profile (from the test site for the assessment of the measurement of SMTD) fall within the range ±0.25mm.
- All of the differences between the SMTD calculated from the measured Texture Profile and the SMTD calculated from the Reference Profile (from the test site for the assessment of the measurement of SMTD) fall within the range ±0.75mm.
- 65% of the differences between the MPD calculated from the measured Texture Profile and the MPD calculated from the Reference Profile (from the test site for the assessment of the measurement of MPD) fall within the range ±0.13mm.
- 95% of the differences between the MPD calculated from the measured Texture Profile and the MPD calculated from the Reference Profile (from the test site for the assessment of the measurement of MPD) fall within the range ±0.25mm.
- All of the differences between the MPD calculated from the measured Texture Profile and the MPD calculated from the Reference Profile (from the test site for the assessment of the measurement of MPD) fall within the range ±0.75mm.

8.10 Site tests of Multiple Line Texture

8.10.1 The Accreditation Tester selects one or more test sites for the assessment of the measurement of Multiple Line Texture measurements (RMST), marking the start and end of each section with a reflective post.

The site may contain both straight and curved Sections, but will not contain any extremes of geometry.
The site may contain lengths with even texture across the width of the pavement and lengths where the texture depth present in the wheel tracks differs with that present in the centre of the pavement.

8.10.2 The Accreditation Tester measures the texture profile of the site using the Reference Method given in Table 8.1 for the measurement of Multiple Line Texture (RMST). The reference measurement will provide up to 25 measurements of RMST spaced evenly across a survey width of 3.6m. The reference data will be reported as Mean Nearside RMST, Mean Middle RMST and Mean Offside RMST over 10m lengths. Each of these values will be obtained as the mean of at least 3 multiple line texture measurements obtained in the Nearside, Middle and Offside of the survey width.

8.10.3 The Contractor defines a survey route appropriate for the survey of the test site, carries out one or more surveys of the test site as required by the Accreditation Tester and delivers the SCANNER RCD and the SCANNER HMDIF files to the Accreditation Tester.

8.10.4 The Accreditation Tester assesses the measurement of Multiple Line Texture (RMST) by the Equipment over the test site by assessing the Nearside, Middle and Offside Mean RMST provided in the SCANNER HMDIF file as follows:

- The measured Nearside, Middle and Offside Mean RMST measurements will be subtracted from reference Nearside, Middle and Offside Mean RMST measurements.

8.10.5 The tests for texture profile measurement will be passed if:

- 95% of the differences between the measured and the Reference Nearside, Middle and Offside Mean RMST (respectively) fall within ±0.25mm.
- All of the differences between the measured and the Reference Nearside, Middle and Offside Mean RMST (respectively) fall within the range ±0.75mm.

8.11 Site tests of cracking intensity measurement

8.11.1 The Accreditation Tester selects a number of test sites and divides them into one or more Sections, marking the start and end of each Section with a reflective post.

> The sites may cover a broad range of crack intensities; pavement constructions (including fully flexible, rigid and composite); surface types; surface texture; crack widths and crack orientations; as may be found on UK local road networks.

8.11.2 There are two sources of reference data for the Accreditation Tests of the measurement of cracking, shown in Table 8.1, termed the Primary and Secondary Reference Data.

8.11.3 The Primary Reference Data forms the basis for initial assessment of the performance of the Equipment as described in the following paragraphs 8.11.4 to 8.11.14.

8.11.4 The Accreditation Tester derives the Primary Reference Data by visual inspection of digital images. The Highways Agency Road Research Information System (HARRIS) survey vehicle provides the images from which the Primary Reference Data are derived, as follows:

- The HARRIS survey vehicle provides greyscale images (256 levels) of the test sites over a survey width of approximately 2.9m at an image resolution of approximately 2mm longitudinally and 2mm transversely.
- The HARRIS images are displayed in a strip map format on a computer screen for visual inspection. The images are marked with a 200mm square grid. (Note the outermost grid square will therefore be only partially occupied.).
- The grid-marked images are inspected by eye to identify cracking. Any grid tile containing a crack is counted. The total number of grid tiles with a crack is counted over each 50m length of survey data.
- The Accreditation Tester calculates the Cracking Intensity as the percentage of 200 mm square grid tiles with a crack over each 50m sub-section length, which is the Primary Reference Data.

8.11.5 The Accreditation Tester interprets the Primary Reference Data to obtain the Relative Normalised Cracking Intensity for each sub-section.

- The Accreditation Tester calculates the average Cracking Intensity and the standard deviation of the Cracking Intensity recorded over all of the sub-sections surveyed in the Primary Reference Dataset.
- The Accreditation Tester subtracts the average Cracking Intensity from the Cracking Intensity and divides this by the standard deviation of the Cracking Intensity for each sub-section

to obtain the Normalised Cracking Intensity for each of the 50m sub-sections.

> Note, the data will now have an average value of 0 and a standard deviation of 1.

- The Accreditation Tester calculates the 75th and 88th percentile values of the Normalised cracking data for each sub-section.
- Sub-sections with a Normalised Cracking Intensity greater than the 88th percentile value are defined as sub-sections containing high levels of cracking.
- Sub-sections with a Normalised Cracking Intensity less than the 88th percentile value but greater than the 75th percentile value are defined as sub-sections containing moderate levels of cracking.
- Sub-sections with a Normalised Cracking Intensity less than the 75th percentile value will be defined as sub-sections containing low levels of cracking.

8.11.6 The Accreditation Tester provides the Contractor with a map showing the location of the test sites and the description of each Section start and end point on each test site.

8.11.7 The Contractor defines survey routes appropriate for the surveys of these test sites and carries out at least two surveys over each site, or more if requested by the Accreditation Tester.

8.11.8 The methods of identifying and measuring cracking intensity differ for different systems and the Contractor may need to calibrate the Survey Equipment to be able to measure cracking intensity on UK local road networks. Therefore the Accreditation Tester provides the Contractor with a sample of the Reference Data for a length not exceeding 5km of the Reference Sites. The Contractor may use this data to calibrate the crack identification system fitted to the Equipment.

8.11.9 After any necessary calibration of the crack identification system, the Contractor carries out the surveys of the test sites, and delivers the SCANNER RCD and the SCANNER HMDIF files from the test sites to the Accreditation Tester.

8.11.10 The Accreditation Tester processes the crack data provided by the Contractor in the SCANNER RCD to obtain the Cracking Intensity over each 50m long sub-section.

- The Accreditation Tester calculates the average Cracking Intensity and the Standard deviation of the Cracking Intensity recorded over all of the sub-sections surveyed from the SCANNER RCD provided by the Contractor.

- The Accreditation Tester subtracts the average Cracking Intensity from the Cracking Intensity and divides this by the standard deviation of the Cracking Intensity for each sub-section.
- The Accreditation Tester classifies the sub-sections in the same way as the Primary Reference Data to obtain the Relative Normalised Cracking Intensities for the survey data provided by the Contractor.

8.11.11 The Accreditation Tester compares the Primary Reference Data with the results of the surveys carried out by the Contractor. Each survey run is treated separately, so that if there are two survey runs two sets of Relative Cracking Intensities will be compared with the Primary Reference Data.

8.11.12 The Accreditation Tester assesses the accuracy of the measurement of cracking using the Primary Reference Data:

- The Accreditation Tester identifies the 50m sub-sections containing a high level of cracking in the Primary Reference Data. The Accreditation Tester compares the results of the survey carried out by the Contractor using the Equipment over the same sub-sections with the Primary Reference Data.
- The Accreditation Tester identifies the 50m sub-sections containing a moderate level of cracking in the Primary Reference Data. The Accreditation Tester compares the results of the survey carried out by the Contractor using the Equipment over the same sub-sections with the Primary Reference Data.
- The Accreditation Tester identifies the 50m sub-sections containing a low level of cracking in the Primary Reference Data. The Accreditation Tester compares the results of the survey carried out by the Contractor using the Equipment over the same sub-sections with the Primary Reference Data.

8.11.13 The tests for measuring Cracking Intensity will be passed only if all of the following requirements are met for each survey run

- The Equipment shows a high level of cracking over at least 65% of the 50m sub-sections that the Primary Reference Data shows to have high level of cracking.
- The Equipment shows a low level of cracking over at least 85% of the 50m sub-sections that the Primary Reference Data shows to have a low level of cracking.
- The overall level of agreement between the level of cracking recorded by the Equipment and the Primary Reference Data for each 50m sub-section, for low, moderate and high levels of cracking combined, is 75%

8.11.14 As a test of repeatability, the Accreditation Tester applies the above requirements separately to the Cracking Intensity recorded in each of the survey runs carried by the Contractor.

8.11.15 If the Equipment is able to meet all of the above requirements (section 8.11.13) the Accreditation Tester accredits the Equipment to carry out SCANNER accredited surveys.

8.11.16 If the Survey Equipment is unable to meet all of the above requirements (section 8.11.13), the Accreditation Tester assists the Contractor to investigate the performance of the Equipment in the measurement of Cracking Intensity to ascertain the reasons for the failure to meet the required standards. This investigation may include, for example:

- Allowing the Contractor to re-process the Survey Data in view of the performance achieved during the first tests of the survey data
- Reviewing performance in terms of surface type.
- Reviewing performance in terms of surface texture.
- Reviewing performance in terms of surface features (such as road furniture, joints etc).

8.11.17 The Contractor and the Accreditation Tester may repeat the assessment of the Equipment, taking into account the results of the further investigations, to determine whether the Equipment is suitable for carrying out surveys on parts of the local road network, with limitations or restrictions.

8.11.18 If the Equipment is acceptable, but with restrictions on the areas of the local road network for which it is acceptable, then:

- The Accreditation Tester endorses any Accreditation Certificate to identify the limitations of the Survey Equipment and the restrictions on its use to provide SCANNER accredited surveys.
- The Contractor removes all cracks identified on such areas from the Survey Data before delivering either the SCANNER RCD or the SCANNER HMDIF files to any Employer.
- The lengths for which the Contractor is unable to provide acceptable measurements of Cracking Intensity do not contribute to the coverage requirements for the measurement of Cracking Intensity.
- If required, the Contractor agrees a procedure with any Employer for providing alternative measurements on these areas.

> Note: Options for this might include, for example, the commissioning of alternative surveys by the Employer to provide this data, or the provision of this data by the Contractor using alternative survey methods. These options may have cost

> implications which the Employer and Contractor should clarify before letting any contract.

8.11.19 The Accreditation Tester uses Secondary Reference Data to assess the sensitivity and accuracy of the Equipment in relation to other Equipment (operated by others) that provides measurements of cracking. These comparison tests can, therefore, only be carried out when data from the test sites is provided by more than one set of Equipment

8.11.20 The Accreditation Tester assembles data provided from surveys of the test sites by each piece of Equipment to form the Secondary Reference Data:

- The Accreditation Tester obtains the Cracking Intensities from the SCANNER RCD or SCANNER HMDIF files provided by each set of Equipment participating in the Site Tests of cracking, expressed over 50m sub-section lengths.
- The Accreditation Tester examines all the data from each set of Equipment and removes any measurements of Cracking Intensity that are not representative of the overall levels reported by that set of survey equipment (outlying data values).
- The Accreditation Tester calculates a single average Cracking Intensity for each 50 m sub-section from the Cracking Intensities provided by each set of survey equipment.

> These average Cracking Intensities are the Secondary Reference Data.

8.11.21 The Accreditation Tester compares the Cracking Intensities obtained from the SCANNER RCD provided by each Contractor with the Secondary Reference Data.

- The Accreditation Tester identifies any significant local differences between the Cracking Intensities obtained from the SCANNER RCD provided by each Contractor and the Secondary Reference Data.
- The Accreditation Tester may require the Contractor to investigate and explain the reasons for these differences. If the difference arises from an apparent deficiency in the Contractor's Equipment the Accreditation Tester may require the Contractor to make improvements or may impose restrictions such as those described in section 8.11.18.
- The Accreditation Tester evaluates the differences between the general sensitivity of the Equipment and the Secondary Reference Data.

8.11.22 The comparison with the Secondary Reference Data may enable the Accreditation Tester to estimate a sensitivity factor for the Equipment so that the Cracking Intensities reported by the Equipment can be correlated with the Cracking Intensities reported by Equipment provided by other Contractors. Where this is possible the Accreditation Tester endorses the Accreditation Certificate with the results of the comparison

8.11.23 The comparison with the Secondary Reference Data may show significant differences between the Cracking Intensities reported by the Equipment, or show deficiencies in the capability of the Equipment. In these cases, the Accreditation Tester will require the Contractor to explain the reasons for these differences, and will give the Contractor an opportunity to make improvements to the Equipment. Differences or deficiencies that remain at the conclusion of the Accreditation Tests may result in the Accreditation Tester specifying restrictions on the use of the Equipment or the refusal to issue an Accreditation Certificate.

8.12 Site tests of Other Visible Defects

8.12.1 Currently there is no requirement to measure or to report other visible defects as part of the SCANNER specification.

8.13 Network tests

8.13.1 Providing that the Accreditation Tester accepts the performance of the Survey Equipment in the Site Tests, the performance of the Contractor and the Survey Equipment is further examined in the Network Tests.

8.13

8.13.2 The Network Tests assess the overall operational capability of the Contractor and the Survey Equipment in carrying out surveys under conditions typical of those to be encountered on the local road network. They test:

- Route planning.
- Survey procedures.
- Efficiency of operation of the Survey Equipment.
- Alignment of the surveyed route with the planned route and accuracy of locating Section start points.
- Accuracy of the SCANNER RCD and SCANNER HMDIF files.
- Coverage obtained by the Survey Equipment.

8.13.3 The Accreditation Tester selects one or more test sites consisting of several Sections. The sites include road types that are typical of the local road network in terms of construction, condition and traffic levels. The test sites may include:

- Flexible and rigid constructions;
- Urban and rural roads;
- Single and dual carriageway roads;
- Traffic light controlled junctions;

- Slip roads;
- Roundabouts and
- A wide range of typical road geometries.

8.13.4 The Accreditation Tester obtains Reference Data on the test sites using the Highways Agency Road Research Information System (HARRIS). The Accreditation Tester processes Survey Data provided by the HARRIS survey vehicle to provide the following Reference Data for the Network Tests for each Section within the test site (reported relative to elapsed chainage within Section, as appropriate):

- The OSGR co-ordinates of the Section Start Points.
- Reported at 10m intervals
  - (i) The OSGR co-ordinates.
- reported as averages over 50m sub-section lengths
  - (i) The road geometry
  - (ii) The 3m and 10m moving average longitudinal profile variance in each wheelpath
  - (iii) The 3 m and 10 m enhanced longitudinal profile variance in each wheelpath
  - (iv) The rut depths and cleaned rut depths in each wheelpath
  - (v) The transverse unevenness
  - (vi) The edge roughness
  - (vii) The Nearside SMTD
  - (viii) The Nearside, Middle and Offside Mean RMST
  - (ix) The Texture Variability
- Reported as a percentage over 50m lengths
  - (i) The cracking intensity

8.13.5 The Accreditation Tester also produces a forward facing video record of the test route surveyed by HARRIS for reference purposes.

8.13.6 The Accreditation Tester provides the Contractor with a map showing the location of the test sites, the description of each Section start and end point and the Section Labels. The Accreditation Tester provides the Contractor with OSGR co-ordinates of some, but not all, of the Section start points.

8.13.7 The Contractor:

- Defines survey routes appropriate for the surveys of these sites and delivers the planned route to the Accreditation Tester as required for Network surveys in accordance with the requirements of the SCANNER survey specification for survey routes.

- Carries out at least one survey of each route, or more if required by the Accreditation Tester. Wherever possible, the Contractor takes measurements in the left most traffic lane except where otherwise instructed by the Accreditation Tester.
- Uses an appropriate method to record the location of the Section start points for which OSGR co-ordinates are provided, and applies the rules defined in the SCANNER user guide for survey routes (Volume 4) for recording the location of the remaining Section start points (unless otherwise instructed by the Accreditation Tester).
- Processes the survey data to obtain the SCANNER RCD and SCANNER HMDIF files, noting the requirements of the SCANNER user guide (Volume 4) concerning the delivery of the route information in the SCANNER HMDIF and SCANNER RCD files.
- Following the completion of the survey, carries out any necessary route alignment. This includes obtaining the elapsed chainage of those Section start points for which OSGR co-ordinates were provided by the Accreditation Tester.
- Delivers the SCANNER RCD and SCANNER HMDIF files to the Accreditation tester for analysis and comparison with the Reference Data.
- Delivers the coverage records as defined in the SCANNER user guide (Volume 4).

8.13.8 The Accreditation Tester evaluates the Network Level performance by comparing frequency distributions of the data from the whole of the test routes and by comparing detailed data from a sample of individual Sections with the Reference Data.

8.13.9 The tolerances allowed for the comparison of the measurements provided by the Contractor and the Reference Data are given in Table 8.3.

8.13.10 The Network Test will be passed if all the following criteria are met:

- The survey equipment is, in the opinion of the Accreditation Tester, able to operate safely whilst causing minimum disruption to other road users
- In the opinion of the Accreditation Tester, satisfactory procedures have been implemented by the Contractor for route planning and carrying out the survey
- The data provided by the Contractor meet the tolerances given in Table 8.3
- The data provided by the Contractor comply with the requirements for coverage for each measured parameter given in the specification for SCANNER accredited surveys

Parameter Measured	Tolerance (90% Limits	Tolerance (Maximum Error)
Section Lengths	±5m or ±0.1% (6)	±50m or ±10% (7)
National Grid Co-ordinates of Section Start Point (1)	±5m	±50m
Altitude of Section start point (1)	10m	±50m
National Grid Co-ordinates (2) where GPS > 70%	±7m	±50m
National Grid Co-ordinates (3) where GPS < 70%	±15m	±50m
Altitude (2) where GPS > 70%	±10m	±50m
Altitude (3) where GPS < 70%	±15m	±50m
Road Geometry – Gradient	±1.5 or ±10% (6)	±6
Road Geometry – Crossfall	±1.5 or ±10% (6)	±6
Road Geometry - Curvature	$\pm 0.003 m^{-1}$	$\pm 0.005 m^{-1}$
3m Moving Average and Enhanced Longitudinal Profile Variance in each wheelpath (4)	±0.6	N/A
10m Moving Average and Enhanced Longitudinal Profile Variance (4)	±0.7	N/A
Transverse Unevenness	0.006	0.05
Edge Roughness	0.05	0.3
Rut Depth and Cleaned Rut Depth	±3.0mm	50% of True Rut Depth or 10mm (7)
Nearside SMTD	±0.25mm	±0.75mm
Nearside, Middle and Offside RMST	±0.25mm	±0.75mm
Cracking Intensity (5)	75%	N/A
Other Visual Defects	[*No requirement*]	[*No requirement*]

Table 8.3: Tolerances for network level evaluation

Notes for Table 8.3	
(1)	The Accreditation Tester calculates National Grid Co-ordinates (and altitude) of Section Start Point from the SCANNER RCD and/or HMDIF and compares them with the Reference co-ordinates. 90% of the positions obtained from the SCANNER RCD and/or HMDIF must fall within the required tolerance of the reference position. For those Sections start points for which National Grid Co-ordinates (and altitude) were provided by the Accreditation Tester the reference position is the National Grid Co-ordinates (and altitude) provided by the Accreditation Tester. For the remaining Section start points the reference position is the National Grid Co-ordinates (and altitude) of the Section start point recorded in the Reference Survey.
(2)	National Grid Co-ordinates and altitude where signal availability > 70% over each 100m length.
(3)	National Grid Co-ordinates and altitude where signal availability < 70% over each 100m length.
(4)	The tolerance for 3m and 10m Moving Average and Enhanced Longitudinal Profile are in terms of the differences or fractional errors between the Moving Average or Enhanced Longitudinal Profile Variances calculated from the measured profile and the Moving Average or Enhanced Longitudinal Profile Variances calculated from the Reference Profile, as described in Volume 4.
(5)	The tolerance for the detection of Cracking Intensity is the minimum percentage of sub-sections that the survey data show to contain high or low levels of Cracking Intensity that are also shown to contain high or low levels of Cracking Intensity in the Reference Data. Cracking Intensity is assessed over selected test Sections using a similar method to that described for the Site Tests
(6)	Whichever is greater.
(7)	Whichever is smaller.

Table 8.4: Notes for Table 8.3

9 Survey Data Accreditation Testing

9.1 General requirements

9.1.1 In addition to checking that the survey data successfully meets the requirements of both the Site Tests and the Network Tests, the data output from the Survey Equipment is checked to ensure that

- All specified checks have been carried out on the survey data as defined in Sections 1 to 7.
- The data complies with all the requirements for loading into a UKPMS accredited system.

9.1.2 The Accreditation Tester provides the Contractor with test datasets, as RCD and Route Files, for the purpose of testing the data processing systems employed by the Contractor for the generation of HMDIF files.

9.1.3 The Contractor processes the RCD files and provides the resulting HMDIF files to the Accreditation Tester.

9.1.4 The Accreditation Tester

- Checks that the values of the parameters (e.g. variance) provided in the HMDIF files by the Contractor are the same as the reference parameters obtained by the Accreditation Tester using their own systems.
- Tests the SCANNER HMDIF file to ensure that it complies with the requirements of the UKPMS specification in all respects.
- Checks a sample of SCANNER HMDIF files to ensure that the format is consistent with the current version of the HMDIF specification, and the current version of the UKPMS Rules and Parameters.
- May ask any or all of the organisations that supply UKPMS accredited Pavement Management Systems to check the Contractors SCANNER HMDIF files to ensure that the files can be loaded into their Pavement Management Systems.
- Notifies the Contractor if the SCANNER HMDIF files cannot be loaded or if any differences are found between the format of the SCANNER HMDIF file and the current version of the HMDIF.

9.1.5 If required by the Accreditation Tester, the Contractor explains any differences, and amends the systems until the parameters match the reference parameters.

9.1.6 On completion of these tests the Accreditation Tester approves the system for the delivery of SCANNER HMDIF files.

9.1.7 The Contractor ensures that

- All processing of SCANNER survey data is carried out using the approved HMDIF generation software.
- No changes are made to the HMDIF generation software without approval from the Accreditation Tester.

10 Consistency Tests

10.1 General requirements

10.1.1 The Consistency Tests measure the repeatability of the Equipment in the measurement and reporting of the parameters, and the reproducibility between different survey equipment. The overall consistency of the Equipment is reported in terms of the bias and random error present in the reported SCANNER Road Condition Indicator.

10.1.2 The Consistency Tests will be carried out on all survey equipment at, as near as possible, the same time of year. This will normally be as part of the annual Accreditation re-testing. When new survey equipment is accredited at a different time of the year, the Tester will award a provisional consistency score, based on the predefined sample road network, and re-tested at the next annual re-accreditation tests.

10.1.3 The machine developer or Contractor attends the Consistency Tests, and carries out any surveys or data processing required by the Tester, at its own cost.

10.1.4 The Equipment is driven and operated by drivers and operators named in the Contractor's quality system. The Tester supervises and controls the tests.

10.1.5 The Consistency Testing is carried out on a predefined road network which includes representative samples of the road networks for which the Equipment is required

10.2 Consistency Tests

10.2.1 The Accreditation Tester selects a road network consisting of many Sections. The network will include road types that are typical of the overall local road network in terms of construction, condition and traffic levels, and in proportions that broadly reflect the proportions to be found on typical local authority road networks.

10.2.2 Where possible, the Accreditation Tester will select test routes for the Consistency Tests that coincide with the routes used for the Network Tests component of the Accreditation tests.

10.2.3 The process for the consistency testing shall follow the requirements for network route surveys described in Section 8.13 (sub sections 8.13.1 to 8.13.9). However:

- The Accreditation Tester analyses all data collected for the sample networks at a 10m sub-section level
- The Accreditation Tester also calculates the SCANNER RCI for each 10m sub-section.
- The Accreditation Tester compares the values of the SCANNER Road Condition Indicator with the reference measurements to

obtain an estimate of the bias in the SCANNER Road Condition Indicator.

- The Accreditation Tester compares the values of the SCANNER Road Condition Indicator obtained from repeat runs from accredited SCANNER equipment, to obtain an estimate of the random error in the SCANNER Road Condition Indicator.

10.3 Reporting consistency measurements

10.3.1 The Accreditation Tester determines the bias and standard deviation of measurement error for each survey machine individually. The Tester reports the individual results to the relevant Contractor, and to the relevant national government responsible for statistical monitoring and performance indicators.

10.3.2 The Accreditation Tester determines the overall single industry-wide measurement of bias determined from the consistency tests. The Accreditation Tester reports the overall performance of all SCANNER accredited survey machines as the basis for calculating the confidence limits for an individual authority’s BVPI results.

11 Accreditation Re-testing

11.1 General requirements

11.1.1 At intervals of one year the Contractor submits the Survey Equipment for retesting to demonstrate that it still meets the SCANNER specification requirements under rigorously controlled test conditions.

11.1.2 In the event of a failure to achieve the survey requirements set out in the quality assurance and audit regime, Survey Equipment may be required to undergo additional Accreditation re-testing. The requirements for Quality Assurance and Audit for SCANNER accredited surveys are set out in Volume 4 of the SCANNER User Guide. In the event of additional accreditation re-testing, the standards defined in this volume 5 for accreditation testing (and re-testing) apply.

11.1.3 The Accreditation Tester supervises and controls the tests.

11.1.4 The Contractor attends the accreditation retests, and carries out any surveys or data processing required by the Accreditation Tester, at its own cost.

11.1.5 During the re-testing the Survey Equipment is driven and operated by drivers and operators named in the Contractor's quality system.

11.1.6 The Accreditation re-testing assesses the accuracy of the Survey Equipment in the measurement of each survey parameter and is carried out on a site or sites selected by the Accreditation Tester.

11.1.7 The accreditation retesting follows the same general procedure as the Accreditation Tests described in Section 8. However, it is unlikely that tests of acceleration and deceleration described in section 8.6 will be carried out during re-testing of the measurement of longitudinal profile unless the Accreditation Tester specifically requires these tests.

11.1.8 The tests will normally take same form as the Accreditation Tests, but reduced in extent and duration, including site tests, as described in Sections 8.3 to 8.11, a short network test, as described in Section 8.13, on a route located conveniently near the site tests, and survey data acceptance tests as described in Section 9.

11.1.9 The Contractor delivers the survey data obtained in the re-testing to the accreditation tester as SCANNER RCD and SCANNER HMDIF files for all test sites used in the re-testing within 8 working days following the date when the surveys for the re-tests were carried out.

11.1.10 The Accreditation Tester assesses the SCANNER RCD and SCANNER HMDIF files from the Contractor's re-testing surveys against the reference methods described in Table 8.1 for site tests, Section 8.13 for network tests and Section 9 for the survey data acceptance tests. On completion of these tests the Accreditation Tester approves the system for the delivery of SCANNER HMDIF files.

11.1.11 If the survey equipment meets the requirements for accuracy in the re-test then the Auditor will issue an accreditation certificate for a further 12 months. An example re-testing timetable is given in Figure 11.1.

11.1.12 If the survey equipment fails to meet the requirements for accuracy in the re-test then any current Accreditation Certificate becomes invalid, any data collected by the Equipment since the last successful weekly check on a Reference Test Site (see requirements for Quality Assurance and Audit in the SCANNER User Guide volume 4) are invalid and any results reported from that data are not acceptable as SCANNER accredited surveys.

11.1.13 If a Contractor makes any significant change to the Survey Equipment after the issue of an Accreditation Certificate the Auditor may require the Survey Equipment to be submitted for an additional Accreditation re-test.

11.1.14 During the retesting the Contractor uses the same survey equipment and settings that are employed by for routine SCANNER accredited surveys.

11.1.15 The timescales involved in Accreditation Re-testing are outlined below and an example accreditation timetable for a SCANNER survey vehicle is given in Figure 11.1:

- Testing Period (starts three months before certificate expires): ALL accreditation test sites to be surveyed during this phase. SCANNER surveys are permitted.
- Re-Testing Accreditation Approval Period (maximum length four weeks): The test data from ALL the test sites must be delivered to the Accreditation Tester four weeks before certificate expires.
- Accreditation: If successful SCANNER Certificate awarded.

11.1.16 Following the successful completion of an annual re-test, the tester issues a SCANNER Accreditation Certificate for a further period of up to 12 months.

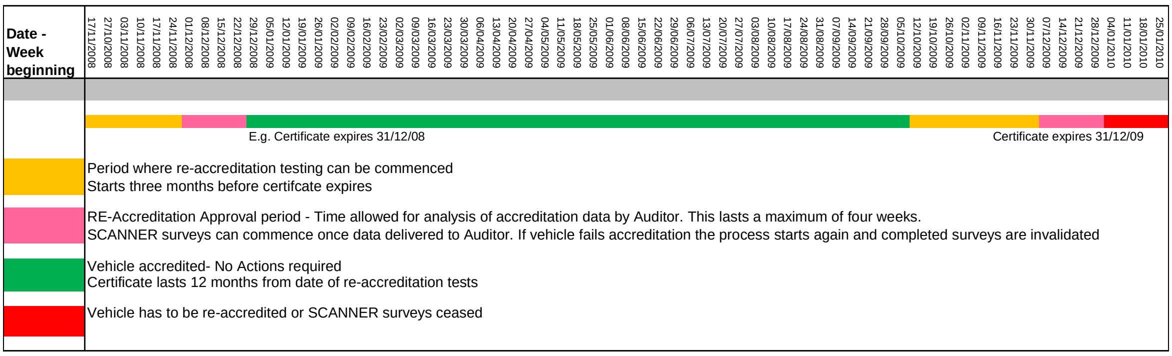


Figure 11.1: Example re-accreditation testing timetable

12 Annex 1 – Identifying False Cracks

12.1 Removal of false positives from the edge of survey data

12.1.1 The following procedures may be applied to identify and remove false positive cracked grid cells at the edge of the survey width. The method requires that a crack grid has already been obtained as described in section 6.4.

12.1.2 To define edge cracking the nearside and offside outer edges of the survey width are defined as edge regions. Each edge region is made up of 1 or more columns of grid cells. The identification of excessive cracking at the road edge is undertaken by evaluating the percentage cracking within each column over a defined length. If the cracking exceeds a defined threshold all the cracked cells within that column are removed from the crack grid. A further test evaluates the percentage cracking over the whole of each edge region over a defined length. If the cracking exceeds a defined threshold all the cracked cells within that region are removed from the crack grid.

12.1.3 The classification of false positives within the edges should be carried out using the following configurable parameters:

- The number of columns of cells in each edge region (default 2). The first column of the nearside region is the outermost column in the nearside, the first column of the offside region is the outermost column in the offside. For example, for a 3.3m survey width and 0.2m grid cells there are 17 columns. For 2 column regions the nearside region would be columns 1 and 2, the offside region would be columns 16 and 17;
- The number of grid cells defining the length of each edge region (default 20);
- The percentage area of each column required to reclassify all cracks within the column as false positive (default 50%);
- The percentage of the total edge region area required to reclassify all cracks within edge region area as false positive (default 50%);

12.1.4 The identification of false positives within the edges should be determined using the following rules (note that the method is applied to the nearside and offside edges separately);

- Commencing at the start of the survey data, evaluate the total area of cracking within each edge column over the defined length. For each column, if the percentage of cracked grid cells exceeds the specified percentage all cracks within the column are reclassified as false positive.

- Evaluate the total area of cracking in each edge region. If the percentage of cracked grid cells in the region exceeds the specified percentage all cracks within this region are reclassified as false positive, and can be removed during the calculation of carriageway cracking intensity.
- The process is repeated, starting from the next grid cell (e.g. 0.2m after the previous step).

12.1.5 This approach to removal of false positives may also be applied to the removal of cracks over other predefined regions (e.g. the centre of the survey width).

12.2 Removal of traffic sensors and other similar non crack features

12.2.1 To identify false positive cracks arising from traffic sensors or other similar non crack features a process may be applied that examines the average angle of cracks, directional continuity and the number of cracked grid cells within a continuous/semi continuous crack.

12.2.2 The classification of false positive cracking considered to be the result of traffic sensor like features uses the following definitions:

- A diagonal crack is a crack containing a number of continuous/ semi continuous cracked grid cells joined in a similar diagonal direction across the carriageway.
- The starting grid cell of a diagonal crack is the first cracked cell identified in the diagonal crack.
- The end grid cell of a diagonal crack is the final cracked cell identified in the diagonal crack.
- The length of a diagonal crack, L (m), is the sum of the cracked grid cells identified between and including the starting grid cell and the end grid cell, multiplied by the grid size (default 0.2m). For example a diagonal crack containing 7 cracked grid cells would have a length L = 7 × 0.2m = 1.4m.
- The height, H (m), is the distance in the direction of travel between the starting grid cell and the end grid cell of each diagonal crack.
- The width, W (m), is the distance in the direction transverse to the direction of travel between the starting grid cell and the end grid cell of each diagonal crack. NOTE: THIS SHOULD ALWAYS BE POSITIVE.
- The average angle, A (degrees), between the start and end cell of each diagonal crack is determined by $A=(\tan^{-1}(H/W))$
- The number of steps for each diagonal crack, S (unitless), is defined as the number of occurrences within a full scan (detailed

in the classification rules, below) where there is an increase in the direction of travel from one cracked grid cell to the next. For example in Figure 12.2 there are 6 occurrences in the diagonal where there is an increase in the direction of travel between neighbouring cracks.

12.2.3 The classification of false positive cracking considered to be the result of traffic sensor like features should be carried out using the following configurable parameters:

- The length required to reclassify all cracks within the diagonal crack as false positive (default 1.4m);
- The angle required to reclassify all cracks within the diagonal crack as false positive (default between 17° and 70°);
- The step required to reclassify all cracks within the diagonal crack as false positive (default 3);

12.2.4 The identification of false positive cracking considered to be the result of traffic sensor like features uses the following approach:

- Commencing at the start of the survey, examine each grid cell containing cracking. For the first grid cell containing cracking, record the location of the grid cell, and search surrounding cells in a NE or NW direction, where North is the direction of travel. For grid cells located in the nearside of the carriageway (on or to the left of the centre line) commence a full diagonal search in the NE direction, and for grid cells located in the offside of the carriageway (to the right of the centre line) commence a full diagonal search in a NW direction. The search pattern is shown in Figure 12.1.
- If a further cracked grid cell is identified in the search then store the position of the grid cell with the position previously recorded for the starting grid cell. Commence a new search (in the same direction) from this grid cell, to identify the next cracked grid cell. Continue until searching fails to identify further cracked grid cells.
- The stored data now describes the location of grid cells forming part of a traffic sensor or diagonal feature. For this feature determine: the starting grid cell, the end grid cell, the length L, the Height H, the Width W, the Angle A and the number of steps S.
- If the length L, angle A and step criteria S are satisfied then the grid cells have been positively identified to belong to a traffic sensor or diagonal feature.
- All grid cells within the diagonal crack should be reclassified as false positive as illustrated in Figure 12.2.
- The search then recommences from the cell to the right of the cell identified in step (a). If step (a) commenced from a cell at the

right hand side of the crack grid then proceed to the first cell in the left hand side of the next row in the crack grid.

- Optional additional search: An additional search of all cells within a 1m circumference of the starting point of each feature could improve the identification, but is subject to further investigation.

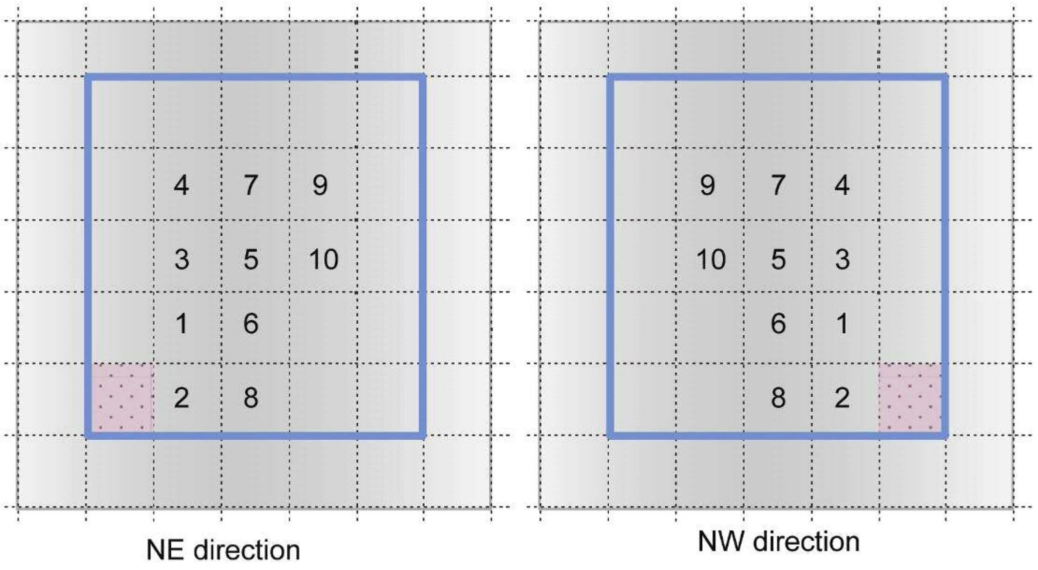
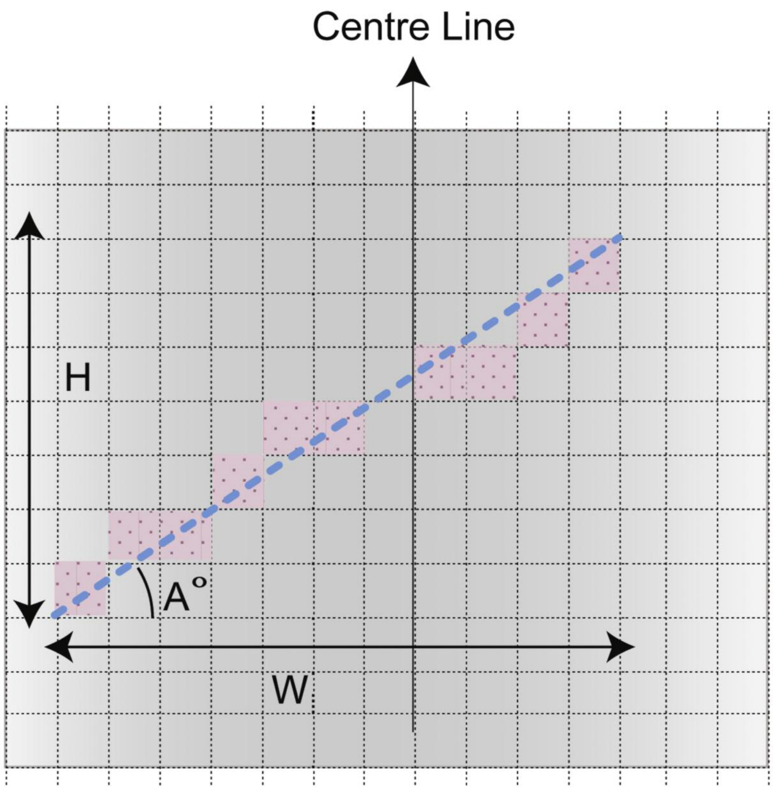


Figure 12.1: The sequence of grid cells to be searched, starting at a crack identified in the shaded square.



H = 1.4m L = 10 cracked grid squares = 2.0
W = 2.2m S = number of steps = 6
A° = 32 ° All criteria are satisfied, hence reclassify as false positive

Figure 12.2: Example of the reclassification of a traffic sensor or other diagonal feature

13 Annex 2 - Other Visible Defects

13.1 General requirements

13.1.1 Research by Scott Wilson and the University of Nottingham identified the potential of combining high quality images of the road surface with sophisticated image recognition software to identify visible defects that might indicate road surface wear or deterioration. (Scott Wilson Pavement Engineering Ltd. "Department for Transport SCANNER research – Other Visible Defects" available on the UK Roads Board website).

13.1.2 This measure is not part of the SCANNER specification. However the approach described in the research might be developed to detect and report other visible defects.

13.1.3 The approach would be applied to deliver a parameter describing the intensity of the other defects within the Scanner RCD or BCD.