Notes to specification for state highway skid resistance management

1 Scope

1.1 Preamble

These notes are to be read in conjunction with the *Specification for state highway skid resistance management* (T10 Specification). The notes provide guidance for using the T10 Specification. See also section 2: Status of notes.

1.2 Numbering

Base numbering in these notes (i.e. this is section 1) generally follows that of the T10 Specification.

1.3 Skid resistance and the NZTA process in general

Numerous studies internationally have shown that a skid resistance policy, which implements appropriate skid resistance at various locations on the network, reduces crash rates and is a very economic crash reduction tool when used both proactively and reactively.

A review of outcomes from the NZTA state highway skid resistance policy has shown, through matched pair analysis, that increasing the SCRIM coefficient (SC) by 0.1 reduces crash rates on average by 30% on wet roads and 20% on dry roads. The New Zealand state highway skid resistance policy is an important part of the total NZTA safety management of the state highway.

Analysis of changes in crash rates since the implementation of the T10 Specification in 1998 has enabled an economic evaluation of the policy. This found the policy has a benefit cost (B/C) ratio of at least 13 and may be up to 35. The recent update of the curve risk analysis policy also has a very high B/C. It should be noted these results occur despite the costs of treating sections of network where crashes may not occur.

A Dashboard Report is available from the Data Analyst, Asset Management, Highways and Network Operations (HNO), National Office for each network area. Currently Bernadette Banez Bernadette.Banez@nzta.govt.nz. The 2002-11 crash data shows that 27% of all fatal and serious crashes occur on wet roads, average for the New Zealand state highway network.

When considering crash clusters, if the wet road crash rate is higher than the regional average then increasing skid resistance is likely to be effective in reducing crash rates. While increasing skid resistance (within bounds) reduces the probability of a crash, no level of skid resistance will eliminate all crashes.

1.4 Microtexture, macrotexture and water (the basics of skid resistance)

Microtexture is defined as the texture less than 0.5mm on the surface of individual aggregate particles (chips). Macrotexture is defined as the texture greater than 0.5mm formed by the gaps between aggregate particles. The T10 Specification, appendix A, gives a more detailed definition of these terms. Skid resistance is primarily a function of the surfacing aggregate microtexture and macrotexture. It is lower when the road surface is wet. For wet road surfaces skid resistance is a maximum at low speed (around 20kph) and reduces from this base value progressively with increasing speed. This mechanism is modelled generally by the International Friction Index and associated equations. A limit state of aquaplaning may occur at higher speeds and thicker water films.

1.4.1 Other factors influencing skid resistance

Other factors that influence skid resistance include surface contamination, vehicle tyres (in particular the polishing action of heavy vehicle tyres), vehicle suspension and hysteresis of vehicle tyre rubber. The surface contaminants with the greatest effect on skid resistance are bitumen, oil, grease, tyre rubber, mud, clay and organic (plant) matter.

1.5 Overview of the NZTA skid resistance process

The objective of the skid resistance policy is to provide a cost-effective surface that has an appropriate skid resistance for road vehicles in wet and dry conditions. Appropriate skid resistance is determined by reference to investigatory and threshold levels (IL and TL) of skid resistance for a range of site categories. Skid resistance is measured with the SCRIM methodology – refer to the T10 Specification, appendix A, for a more detailed definition. The loss of skid resistance with increasing speed is managed by ensuring there is adequate macrotexture on the road surface and tread depth in vehicle tyres.

An annual survey is undertaken in most lanes; this measures the SC in both wheelpaths, together with the macrotexture. As skid resistance varies with time (primarily due to rainfall and traffic numbers) the data is seasonally corrected for both within-year and between-year variations to produce the equilibrium SCRIM coefficient (ESC). This is then used as a factor for prioritising surface maintenance for skid resistance via the IL and TL appropriate to the site category or according to the risk of a skidding crash at the site.

As the seasonal correction cannot be completed until the end of summer, a skid resistance exception report (referred to as an 'exception report') is produced following the survey to enable prompt programming of treatment to address the most important skid resistance issues. The exception report details those sections of the network with a lower SC or macrotexture.

Initial assessment and programming of treatment is undertaken at the exception report stage. Further assessment should be carried out when the NZTA road assessment and maintenance management (RAMM) database has been populated with seasonally corrected data.

1.6 Outline of responsibilities

The following is an outline of responsibilities for the implementation of the skid resistance policy:

a The National Pavements Manager, HNO, National Office, is responsible for the skid resistance T10 Specification and review of the regions.

b The Skid Technical Advisory Group (STAG) is responsible for providing technical advice on skid resistance policies and initiatives.

c The National Assets Manager, HNO, National Office, is responsible for the high-speed data collection (HSDC) contract and management of the RAMM database.

d The NZTA Regional Operations Manager or their nominee within NZTA in each region is responsible for authorising changes to ILs.

e The National Assets Manager, HNO, National Office, will administer changes to location data and ILs.

f Regional offices are responsible, through the NZTA Regional Operations Manager or their nominee within the NZTA, for proactively maintaining adequate skid resistance in accordance with the T10 Specification throughout their network. Contractors and consultants may prepare work programmes for approval by the relevant NZTA officer.

The regional responsibilities include:

- Provision of adequate skid resistance macrotexture and associated actions
- Action following release of the exception report
- Maintenance of existing surfacings
- Review of the full RAMM database for skid resistance
- Aggregate selection and monitoring
- Construction of new surfacings
- Regional review of ILs
- Authorising changes to ILs
- Ensuring appropriate levels of skid resistance are obtained on projects.

The NZTA Regional Operations Manager or their nominee within the NZTA is responsible for the management of skid resistance. However, they should also ensure that regional safety staff are consulted on major actions for skid resistance. Project staff must consult with the NZTA Regional Operations Manager or their nominee within the NZTA to ensure the surfacings constructed provide adequate long-term skid resistance.

1.7 Relevant features outside the specification scope

The following is comment on some relevant features outside the scope of the T10 Specification:

- Increased water depth causes a loss of skid resistance by reducing the contact pressure between the vehicle’s tyres and the road surface
- Poor surface drainage will lead to increased water depths on the road surface. Attention should be given to crossfall, grades, moving crowns and similar surface features
- Crossfall tends to shed water from the surface
- Roughness may reduce crossfall locally and increase water depths. High roughness may also affect vehicle stability in both wet and dry conditions
- Rutting may reduce crossfall within the rut or cause water to pond and lead to deeper water depths

- On grades, water may flow down the slope and within ruts rather than off the pavement and increase the water depth. Large increases in water depth may occur at the bottom of sag curves
- Aquaplaning (or hydroplaning). When a vehicle tyre runs on a wet road some of the normal force is resisted by hydrostatic water pressure. With increasing speed and depth of water there is a progressive loss of skid resistance. At the limit state there is no contact with the surfacing aggregate and the vehicle is said to be aquaplaning. While aquaplaning lateral resistance is minimal but vehicle deceleration may be significant due to hydrostatic forces, generation of spray etc. The progressive loss of skid resistance is minimised by macrotexture on the road surface and tread in the tyre. Macrotexture on the road surface and tread in the tyre also increase the speed at which aquaplaning occurs.
- Spray may reduce visibility for following or overtaking vehicles. Generally the spray generation is more significant for larger vehicles and during heavier rain. Free-draining open-graded porous asphalt (OGPA) and specialised highly porous asphalt mixes reduce spray generation but this benefit may be short lived with clogging of the internal drainage
- Snow and ice may dramatically reduce the skid resistance available to vehicles
- High hysteresis tyres (known as snow tyres) may be used to give additional grip in snow and ice. They have disadvantages for general use on New Zealand roads.

2 Status of notes

These notes contain guidance for the implementation of the T10 Specification. The notes are a reference document in terms of the *Register process manual for network standards* & *guidelines*

3 Investigatory and threshold levels

Plots of crash rates versus skid resistance show increasing skid resistance reduces crash rates. While the general shape of the curve is the same for all sites, the actual crash risk may vary significantly between different types of sites. This differential risk is addressed through the default value allocated to each of the site categories in table 1 of the T10 Specification.

The investigatory level (IL) is a skid resistance maintenance priority level that has been set with the objective of equalising the personal risk (crash rate rather than crash numbers) of a wet road skidding crash across the state highway network, while maintaining an economic balance between the cost of achieving the skid resistance and the crash savings.

The threshold level (TL) is a skid resistance level generally set at 0.1 below the IL.

ILs and TLs apply to skid resistance and macrotexture separately to ensure appropriate levels of safety are maintained across a wide range of conditions normally found on the state highway network.

4 Investigatory levels: skid resistance

Microtexture is defined as the sub 0.5mm texture on the surface of individual aggregate particles (chips).

The microtexture affects the wet road skid resistance at all speeds. Direct measurement of friction is very difficult and correlates poorly with skid resistance. In practice, all measurements of skid resistance are made by sliding rubber across the road surface, normally with a prior application of water. On the state highway network skid resistance is measured with a sideway-force coefficient routine investigation machine (SCRIM+). The basic output is a SCRIM reading which is adjusted by a sideway-force coefficient (SFC) factor and corrected for speed and temperature to provide the SC. This is normalised for within-year and between-year seasonal variations in the SC to produce an equilibrium SCRIM coefficient (ESC). The macrotexture is measured with high-speed lasers on the survey vehicle. An appropriate default value for the IL is given to each site category to reflect the relative risk of a wet road or skidding crash at each of Site Description (table 1 in the T10 Specification).

Skid assessment length (SAL): The SAL is used to prioritise sections of lanes to be investigated for treatment or maintenance using seasonally corrected data.

4.1 Rural curves (radius less than 400m)

Rural curves with a radius less than 400m (site categories 2b and 2c) undergo a curve risk analysis, which ranks them according to the personal crash risk they present to vehicles entering the curve. The level of risk is derived from a crash prediction model. The key predictors of crash risk on a curve are the curve speed, the difference between approach speed and curve speed, the curve length, traffic volume, the skid resistance on the curve and the average approach gradient over 100m prior to the curve.

The curve speed is calculated from the design speed for a rolling 30m around the curve. The lowest of these rolling values is then compared with the average speed for the approach 500m in both directions to determine the amount the curve is out of context. It should be noted that the approach speed may be different for the two directions; in this case the risk and therefore the IL used for the curve is based on the higher value. All rural curves with a radius less than 400m have been included in the assessment of ILs for the network. The curve with its associated IL is defined to exist from the point on the transition where the radius becomes sharper than 800m and continues until the radius exceeds 800m on the exit transition.

The curves were initially assigned a risk rating and an associated IL based on a crash prediction model. High-risk curves were assigned a default IL of 0.55, medium risk 0.5, low risk <250m radius 0.45, and low risk ≥250m radius 0.4 (as detailed in T10 Specification, table 1). Approximately 25% of the curves were rated as high risk, 25% low risk with the remaining 50% medium risk. This has subsequently been reviewed and the ILs amended based on actual crash data over a 10 year period.

The introduction of the curve risk analysis policy has increased the IL on a number of curves and reduced it on some under a 250m radius. Where an increase in the IL is required, it will take time to obtain the resources to upgrade the network. Nationally, following the latest review, the sites managed at an IL of 0.55 are around 2.5% of the state highway network compared with 0.2% previously.

Urban curves are not affected by this initiative and retain a default IL of 0.5 where the radius is less than 250m.

Some background information on the policy is contained in the 3rd International Road Surface Friction Conference May 2011 paper: *A Prioritisation Scheme for the Safety Management of Curves*; Cenek et al. which can be downloaded using the following link: www.nzta.govt.nz/resources/safety-management-of-curves/

4.2 Skid assessment length on curves

The skid assessment length on curves is 50m. Most curves are much longer than this and it may be found that only part of a curve has low skid resistance. It is acceptable to treat only part of a curve (eg by watercutting or resurfacing) provided that:

- the remainder of the curve is no more than 0.05 ESC below the IL
- the full costs of maintaining the remainder continuously above the TL, and re-treating parts of the curve when the first treatment reaches the end of its life, are included in any assessment of total costs.

Note: The sections of curves with lowest life may be in the approach braking zone, at the tightest radius of the curve or in an acceleration zone at the exit.

4.3 Short skid assessment lengths

Where the length of a site category is less than the SAL, the IL is averaged over the shorter length. The same process is applied to short lengths at the end of a site category.

5 Investigatory levels: macrotexture

Generally the influence of macrotexture is secondary to microtexture. However, the influence may be substantial in specific situations. Macrotexture is required for two main reasons:

1. To minimise the progressive loss of skid resistance with increasing speed on wet roads. This loss of skid resistance with increasing speed applies to all surfacings.
2. To prevent or minimise the loss of skid resistance due to contact between vehicle tyres and bitumen. This applies primarily to chipseal surfacings.

5.1 Macrotexture to minimise loss of skid resistance with increasing speed

Once a road surface is wet, even a very thin film of water reduces the skid resistance significantly. Research with the Pavement Friction Tester has shown reductions of up to 50% in skid resistance between 20 and 100km/h where the road is wet and there is low macrotexture and smooth tyres. This loss of skid resistance is further reduced by thicker films of water and increasing travel speed. The main mechanism for the loss of skid resistance is a film of water remaining under the vehicle tyre and reducing the normal contact (normal force) between the tyre and the road aggregate. In the limit state, all of the vehicle weight is supported on water and aquaplaning occurs (see sections 1.4 and 1.7). With increasing speed Skid resistance on wet roads reduces continuously from the base low speed value. At a speed of 50km/h the reduction in skid resistance is small but at speeds >70km/h the loss of skid resistance is larger when the macrotexture is low and tyre tread depth is at the legal minimum. This is the reason behind the macrotexture requirements in the asphaltic concrete columns in table 3 of the T10 Specification. See also the comments in section 1.7 on rutting, roughness, crossfall, grades, rainfall intensity and the effect of water depth.

5.2 Macrotexture to minimise loss of skid resistance due to contact between tyres and bitumen

This section primarily relates to chipseals. Vehicle tyres deflect around individual chips in the surfacing and some of the normal force is taken on the bitumen rather than on the aggregate. As the bitumen rises towards the top of the aggregate this effect may dominate the skid resistance, leading to low or very low SC in wet conditions. The SCRIM methodology models this well. Hence, if the surfacing has an adequate ESC (or SC) it is assumed the macrotexture is adequate to minimise contact of vehicle tyres with bitumen. The lowered skid resistance may become a significant problem at a mean profile depth of 1.5mm for larger grade chipseals, but for grade 5 chipseals and asphaltic mixes adequate ESC may be obtained at lower macrotexture levels. Note: most skid resistance measuring equipment has a low contact pressure and will not model this feature as well as SCRIM.

5.3 Bleeding

If vehicle tyres make contact with the bitumen and this is sufficiently active to wet the tyres, bitumen is picked up and then deposited on top of the surfacing aggregate along the lane in the wheelpaths. This may extend the low skid resistance (low SC) up to a kilometre or more along the lane.

5.4 Visual assessment of flushing and bleeding

Flushing of chipseals generally proceeds at a more rapid rate during summer. A very short length of flushing, less than 1.0m, may bleed and blacken the surface. This will increase the surface temperature and accelerate bleeding on further sections. The outcome may be low skid resistance over very long lengths (possibly a kilometre or more).

Flushing may be assessed visually by experienced practitioners. Where the surface is clearly flushed or bleeding has occurred it is important that surfacing maintenance is programmed as it occurs, rather than waiting for the high-speed data survey. The following actions should be undertaken where the surfacing is clearly flushed or bleeding has occurred:

- Make a note of the flushed sections during any driveover and programme remedial action. Give greater priority to flushed sections on curves and sections that may bleed in hotter weather.
- Record bleeding on the network and programme it for prompt maintenance.

Bleeding must be stopped promptly because any delay will further extend the length of tracking with associated low skid resistance (see the T10 Specification, appendix A, for a definition of tracking), Once the bleeding is stopped it is a matter of judgement whether to treat the length where tracking has occurred. Having stopped the bleeding the detrimental effect on the SC (or ESC) caused by tracking will always reduce reasonably quickly through the wearing action of the vehicle tyres.

short lengths of flushing (or low SC) may be masked by higher values over the rest of the 10m length. Short lengths of network that are obviously flushed should be maintained as part of the monthly maintenance programme.

5.5 Hysteresis

Macrotexture also contributes to skid resistance through hysteresis. It is very difficult to separate this from microtexture effects. It is measured as part of the side force on the SCRIM tyre and is not considered further in the T10 Specification. Tyres designed to maximise hysteresis skid resistance are used in snow and ice (snow tyres).

6 Survey of existing surfacings

6.1 Segmentation of the network

For each lane, the network is divided into 10m lengths with the beginning and end of each length accurately defined by GPS coordinates and given a linear label. Historically, the HSDC contractor has allocated a site category (see T10 Specification, table 1) from site descriptions, an event code and hence a default IL and an investigatory level for macrotexture (ILM) for each 10m section of lane surveyed. The site categories are calculated from a combination of manually entered data and other measurements made during the survey.

Since 2011, the event codes and ILs from the existing RAMM database are provided annually on 1 September by the National Office to the survey contractor, prior to the start of each survey.

It is the responsibility of the NZTA Regional Operations Manager or their nominee within the NZTA to ensure the information in the database is accurate.

To assist in identifying new features, a crosscheck will be performed by comparing fixed RAMM data with data entered by the survey contractor. For further details on this ‘Skid event discrepancy report’ refer to section 7.1 of these notes.

A continuous length with a single site description is referred to as a skid site. These sites are normally not less than 50m long but can be several kilometres or more.

Network changes and new alignments, which are being surveyed for the first time and have no associated skid site information, will be assigned event codes and ILs by the survey contractor for verification by the region.

Where changes are required it is the responsibility of the NZTA Regional Operations Manager or their nominee within the NZTA, to approve the change and authorise the data to be entered in the RAMM database.

The annual survey will not cover all sections of the network. Generally only the outer lane (highest RAMM lane number,) excluding slow vehicle bays, is surveyed. This strategy is based on the assumption that the outer lane will carry most heavy traffic and so receive most wear.

For most motorways all lanes and ramps are surveyed. For the remainder of the network the lanes to be surveyed may be amended on request; however, for economic reasons the whole network cannot be surveyed. Any request for amendment to the survey (including any additional lanes) should be forwarded to the National Office prior to 1 August.

See also the comment within section 6.4

6.2 SCRIM background

Skid resistance, primarily influenced by microtexture, is measured with SCRIM methodology. This measures the side force on a freely rotating tyre with a 200kg load, and inclined at 20 degrees to the direction of travel. The following corrections are applied to ensure the value used for prioritising maintenance of the surfacing is influenced by the condition of the surfacing only:

- the SC is the raw SCRIM reading adjusted by the SFC factor and corrected for survey speed, test wheel load and road temperature.
- as the SC is not constant, but generally lower in the middle of summer, it is further normalised to a mean summer value (MSSC).

- as the summer climate may vary between years, the MSSC is further normalised for the average value over the preceding three summers. Data that has been normalised for within and between summer variations is referred to as the ESC.

At the completion of each annual survey, these seasonal and annual correction factors are calculated and all the information is entered into the RAMM database for regions to access and use.

The uncorrected skid resistance data and other high-speed data for each individual area is normally available in RAMM approximately two weeks after the exception report has been issued, or four weeks after the survey has been carried out.

6.3 Other survey data

In addition to skid resistance, the annual survey also measures macrotexture and other high-speed road condition statistics such as rutting and roughness as well as road geometry such as gradient, crossfall and horizontal curvature.

6.4 Assessment of sections of network not surveyed

Where non-motorway multiple lanes occur and maintenance of only one lane is contemplated, the assessment of the economics of this strategy will include the cost of obtaining skid resistance data in all lanes in the same direction.

6.5 Other skid resistance measuring equipment

The skid resistance policy improves safety by allocating an appropriate level of skid resistance to each section of the network. Vehicles differ in their ability to use the skid resistance or microtexture provided and react differently to various road surfaces geometry etc. In a similar manner skid resistance testers react differently and any correlation of data from testers is an approximation for the conditions of the correlation exercise.

It has been found that the SCRIM methodology correlates well with the performance of road vehicles. In addition, the IL research has been carried out using SCRIM data. For these reasons the survey of the state highway network is carried out with SCRIM equipment. Should additional data be required over short sections, other equipment may be used subject to the methodology defined later (see section 11).

Other equipment that may be used includes:

- GripTester
- Norsemeter Road Analyser Recorder (ROAR)
- British Pendulum
- Pavement Friction Tester
- Vericom and similar accelerometers in vehicles
- Dynamic Friction Tester.

7 Exception report

This section covers the action to be taken by a region on receipt of the exception report (ie selected non-seasonally corrected SCRIM data).

The exception report process is:

a Following the survey of each network the data is checked and an exception report forwarded to the relevant region by HNO, National Office, through the HSDC contractor and consultant.

b The exception report details the SC and macrotexture for each 10m section, where either the SC and/or macrotexture is below the TL or TLM together with the location and survey time.

c On receipt of the exception report, regions should promptly investigate priority A sites, determine if treatment is required and prioritise them for treatment. Where priority B sites are within or immediately adjacent to priority A sites they should be considered for treatment at the same time. The remaining priority B sites do not require any further action.

d Records should be kept of all inspections and treatment programmed. Progress for both inspections and treatment should be reviewed monthly.

e Resurfacing or pavement rehabilitation treatment should only be carried out in appropriate weather conditions. Therefore, if the time of year precludes treatment being carried out within the annual maintenance programme, temporary action such as signage etc should be considered followed by treatment at the appropriate time.

Further to sections 7c and d above, the information detailed below should be recorded during a site inspection (alternatively, the site inspection sheet in appendix A may be used):

- Network management area, state highway, reference station, location (start/end), survey year
- Inspector, name and date, on site or desktop
- Site category and IL
- Skid resistance survey data
- Whether flushing or polishing was the cause of low skid resistance
- Confirm or recommend change to site Category or IL
- Crash data, wet/dry, period, length considered (within 250m either way)
- Type and condition of surfacing, including aggregate name and PSV
- Local defects, e.g. stripping, potholes, rutting, roughness, crossfall
- Debris or contaminants on the road surface
- Does survey data appear correct?
- Proposed treatment and programme

Further instructions on actions required on receipt of the exception report may be issued annually with the report.

7.1 Skid event discrepancy report

The HSDC contractor will collect skid site data during the high-speed survey and report annually on their calculation of the network ILs. This will enable a comparison to be made between the RAMM IL data given to the contractor and the surveyed values. By comparing these two sets of data, a skid event discrepancy report is produced recording sites where the two methodologies:

- **either** record the same event more than ±10m apart, (effectively 20m or more apart)
- **or** record different skid events at the same displacement, which may change the IL.

The contractor will produce an annual skid event discrepancy report for each location where a difference in IL or event code occurs and this will be issued alongside the exception report.

The locational tolerance (detailed above) has been applied to overcome reporting annual minor differences caused by operator entered features. Additionally, a small tolerance will be placed on reporting against machine-defined features, such as downhill gradients, to allow for the measuring variability of the survey vehicle.

It is the responsibility of the NZTA Regional Operations Manager or their nominee within the NZTA to assess the correct IL, authorise the National Office to enter the data in the RAMM database and take appropriate action for the SC or ESC recorded at the site.

The method for recording changes to ILs and location of events is detailed in section 14 of these notes.

8 Prioritising sites for investigation and treatment

It is expected that for the 2013 SCRIM+ survey (2012/13 summer), and possibly further ahead, more sites will be included in the exception report than can be investigated as a priority. To this end it is important to focus on priority A sites at the exception report stage. This investigation may include adjacent sites in the same treatment length to ensure the most appropriate treatment is selected. A further decision is then required on whether and when treatment or maintenance will be undertaken.

Due to the uncertainty in the location of crashes the Specification stipulates that crashes within 250m of a site for investigation are to be considered. This can lead to a crash being assigned to multiple sites (10m lengths for the exception report or multiple SALs when using seasonally corrected data). This could falsely increase the priority score for some sites. It is therefore important, when carrying out a site investigation, to attribute the location of the crashes appropriately (as far as possible from the crash report). This will change some priority A sites to priority B sites or reduce the score when using seasonally corrected data once the crashes are removed. On sites where resurfacing is the best option but seasonal constraints prevent this treatment, interim action to ensure the site is safe during winter must be considered. This may include removal of excess binder (e.g. waterblasting), rejuvenating the microtexture (e.g. scabbling) or signage.

Sites listed in the exception report that do not meet the criteria for priority A will be assigned to the priority B list and not considered any further.

The expectation is that as experience is gained and appropriate maintenance work is undertaken the size of the exception report and the number of sites requiring investigation will reduce significantly. To this end the priority criteria for sites that are flushed or have a low SC have not been defined in the Specification. They will be advised in the instructions issued each year with the exception report.

9 Skid resistance maintenance

Further to section 9.1 in the T10 Specification, any maintenance undertaken should cost effectively achieve the requirements of the T10 Specification and these notes. The estimated life should be recorded and compared with actual life. Over time, this information will provide greater certainty that the most economic long-term solution has been selected.

9.1 Unstable chip seals

Section 9.2 of the T10 Specification details action where waterblasting of chipseals is undertaken. It should be realised that water blasting on unstable seals will only be of temporary improvement to the texture and as such should only be carried out when a more permanent treatment cannot be applied. Since the treatment is of a temporary nature it is important to carry out regular inspections during the summer period to ensure the road has not re-flushed.

The objective is to ensure that road users are not exposed to unexpected low skid resistance due to flushing of unstable chipseals.

The background to the requirements are: Polishing of aggregate may be predicted with reasonably accuracy. Flushing leading to low skid resistance is very difficult predict accurately but may be assessed visually with reasonable accuracy by experienced practitioners. Criteria for chipseals that may be unstable have been added to the specification, with requirements for inspection, maintenance / signage and record keeping. Normally flushing occurs at the onset of summer heat and so the first inspection is required during November and monthly thereafter.

10 Waterblasting

When assessing macrotexture on site it is intended that most decisions are made based on a visual inspection and estimation of macrotexture by experienced practitioners. Records must be kept of all decisions.

In all cases the surfacing should be inspected around six months after the waterblasting, and further inspections or treatment programmed if required.

11 Skid resistance investigations: general

Site investigations should be led by experienced personnel who have knowledge of skid resistance and pavement surfacing characteristics. Experience is gained by involvement in previous skid resistance investigations. In addition, knowledge should be gained by attendance at a workshop run by, the New Zealand Institute of Highway Technology or other training organisation.

Site investigations should also be prompted at any time of the year when there is a high proportion of wet crashes, or when information from the Police or members of the public suggest a possible skid resistance problem.

11.1 Methodology for confirming the SC or ESC

If there is doubt about the SC or ESC indicated in the exception report or the RAMM report, it may be necessary to confirm the skid resistance by measuring it. In addition to SCRIM, skid resistance testers generally available in New Zealand are the GripTester, the British Pendulum Tester, the Norsemeter ROAR and the Dynamic Friction Tester.

Conversion of skid resistance from these other skid resistance testers to an SC is an approximate procedure depending on the actual aggregate, surface texture shape and presence of bitumen. The following are some approximate conversions:

11.1.1 GripTester

Findlay Irvine recommends the following conversion equation:

$$SC = 0.85 GripNumber$$

Earlier work on New Zealand surfaces produced the following conversion:

$$SC = 0.42 GN + 0.20$$

where the GripNumber (GN) is measured using 0.25mm water film depth at a 50km/h survey speed.

11.1.2 Norsemeter ROAR

$$SC = 0.55\mu + 0.12$$

Where mu (μ) is measured using 34% fixed slip and 0.5mm water film depth at a 50km/h survey speed.

11.1.3 British Pendulum Tester

$$SC = 0.0071 BPN + 0.033$$

Where the British Pendulum number (BPN) is measured according to *TRL road note 27: Instructions for using the portable skid resistance tester* (TRRL 1969) or *Draft TNZ T/2: Standard test procedure for measurement of skid resistance using the British Pendulum Tester* (Transit NZ 2000).

11.2 Combined seasonal correction and skid tester correlation

When reviewing skid resistance from alternative tests it should be borne in mind that the results will not be seasonally corrected.

Rather than relying on absolute skid resistance values that have been converted from alternative testers, a better methodology is to perform a test from a section where the data appears credible, on the doubtful site and for a length after the doubtful site. By plotting both SC (or MSSC or ESC) and the alternative measure the true value for the doubtful section can be assessed.

11.3 Do nothing

Where the reason for a low SC or ESC at the time of the survey was temporary contamination that was then removed naturally, the action may be to do nothing to the surfacing. Confirmation of this decision must be obtained by inspecting adjacent sections of surfacing and comparing the SCRIM survey data, or repeat surveys using adjacent sections of network to allow for seasonal changes. Where decisions are based on inspection and survey data, care must be exercised to ensure the surfacing is not a length with a higher polishing stress.

12 New surfacing

12.1 Surfacing aggregate general

This section applies to all new surfacing unless it is under temporary traffic management (TTM). Where pavement is being constructed that will be trafficked on removal of the TTM it must be designed and constructed in accordance with the T10 Specification and these notes.

It is important to design surfacing for the minimum whole-of-life cost. For example, using a less expensive aggregate and resealing at an increased frequency to avoid problems of polishing may appear cheaper, but the additional cost of the earlier rehabilitation due to the creation of an unstable seal must be included. For a first-coat seal designed to last 12 months the aggregate only needs to resist polishing for this period.

The polished stone value (PSV) equation for selecting surfacing aggregate as set out in the 2002 version of the T10 Specification has been shown to have limitations. Traffic stress is expressed in terms of heavy vehicle numbers only. Recent research has shown that aggregates from a given quarry tend to perform in a reasonably consistent manner, or produce a limited range of SC on the road for a given polishing stress. Hence two methods for selection of surfacing aggregate are included in the 2012 version of the T10 Specification.

1 Aggregate performance method: a more rigorous method that will ensure the most economic choice of aggregate for surfacings

2 PSV method: the simplest design method.

12.2 Selection of surfacing aggregate

Quarried aggregate has its maximum microtexture as quarried. Hence the ESC will be at a maximum for new surfacings and will normally polish to an equilibrium value over one to three years, two years for most of the state highway network. This level of skid resistance is not strictly an equilibrium value as polishing continues with most aggregates for the life of the surfacing, although at a slow rate. Better aggregates polish only very slowly after the initial equilibrium value, but some continue to polish at a more rapid rate. Recent work has attempted to duplicate this effect in the laboratory. The PSV12 test has shown promise but not enough data is available to apply it to aggregate selection on the road.

Recent studies of the state highway network have shown that on average aggregates polish at a rate of 0.005 SC per year. Similar results have also been obtained in British studies.

With mixes, and two coat seals where a second coat of bitumen is sprayed, the bitumen masks the microtexture and reduces the SC (and ESC) until the bitumen wears off. For most aggregates and bitumen thicknesses the sharper microtexture of new aggregate compensates for the effect of the bitumen and adequate skid resistance is maintained. Conversely when bitumen is tracked onto polished aggregate there is a reduction in the ESC to well below the polished value, and normally to below the TL.

For river quarried aggregate there is a limitation on the percentage of unbroken faces as the river polished faces have low skid resistance. With Glenbrook melter slag, initial skid resistance is good and it may improve over time.

12.3 Aggregate performance method

The first principle is:

- Should an aggregate perform satisfactorily (at or above the IL before resurfacing is required for other reasons) this aggregate or a better aggregate (more resistant to polishing by traffic) may be used for the resurfacing.
- Should polishing to below the IL occur before resurfacing is required for other reasons, a better aggregate is required.

The following is an outline of the aggregate performance method:

1. Check by video or other means that any low values of ESC are due to polishing rather than flushing, tracking or other contamination. Flushing can be patchy (less than 10m) or extensive, but polishing tends to be over longer lengths. Hence data should generally be averaged over lane lengths of SAL.
2. Review the ESC over the treatment length to assess if the polishing stress is reasonably uniform, or if it is higher over discrete portions. For example, there is often higher polishing stress in the braking zone approaching a sharp curve and higher stress at the sharpest point of the curve.
3. Check that the surfacing has reached the equilibrium level of polish. Assess this from the age of surfacing, the change in the ESC and performance of the aggregate in other locations.
4. Assess the polishing stress using the extract from the PSV equation, T10 Specification, section 12.4:

$$\text{Polishing stress} = 0.00663 * HCV + PSF$$

5. Retain assessment data and list aggregates used in the region in order of resistance to polishing stress, with the range of polishing stress encountered. It should be noted this is not an exact process and some expert assessment will be required.

Further guidance is available in NZTA Research report 470, 'Selection of aggregates for skid resistance' (Cenek et al 2012) http://www.nzta.govt.nz/resources/research/reports/470/ .This report contains an initial list of a wide range of aggregates in order of resistance to polishing. The usefulness of the research is limited in some instances due to lack of consistency in the naming of some quarries within the RAMM database.

Where there is evidence an aggregate has performed differently from that indicated in the research report referred to above, the regional values (table) should be used. Where the aggregate is used in other regions they should also be consulted.

12.4 Polished stone value method

The PSV equation used in the 2002 T10 Specification was derived for reasonably low polishing stress sections of surfacing. It was subsequently found that this equation was not suitable for selecting aggregates for higher stress sections of the network. To overcome this, the constant of 2.4 has been replaced by a polishing stress factor that ranges from 3 to 9.

The PSV method is easier to implement than the aggregate performance method, but it is not as accurate.

The success of the PSV method depends on the accuracy of the PSV data. To assist with maintaining the integrity of the system the National Pavements Manager, HNO, should be advised when an aggregate with an appropriate PSV has polished to below the TL.

The specification states 'the preferred method for aggregate selection is the aggregate performance method'. However, if sufficient information is not available then the PSV method may be approved for use by the NZTA Regional Operations Manager or their nominee within the NZTA. Care must be exercised when approving use of the PSV method on higher stress sites. Factors to consider are:

1. The PSV required. At a PSV of 55 the risk is low, but at 60 or above more certainty is required.
2. Experience with the aggregate, particularly in higher polishing stress situations. Where the aggregate is similar to one that has performed well in higher polishing stress situations this fact may give confidence in the new aggregate. Conversely, where the aggregate is similar to one that has polished excessively its use should be limited to lower polishing stress sites.
3. While experience with the use of PSV12 is limited, where the PSV12 value is equal to or above the required PSV, it should be possible to use the aggregate on the site under consideration with confidence. Refer to *NZTA M6: Specification for sealing chip* (NZTA 2011) for the calculation of PSV from laboratory test results. A similar method should be used with PSV12 data.

12.5 Specification of surfacing aggregate

Once the aggregate is selected for a treatment length, the polishing resistance must be specified appropriately:

- Where the aggregate performance method has been used, aggregate requirements are specified in terms of a regional list of aggregates.
- Where the PSV method has been used, the aggregate is specified in terms of a minimum PSV.

12.6 Alternative aggregates

The T10 Specification states that surfacing aggregates should be selected with the objective of maintaining the skid resistance at or above the IL for the life of the surfacing. Where it is not cost effective to select an aggregate to achieve this requirement the following strategy may be implemented where the required IL is greater than or equal to 0.50. The process is:

a. Estimate the minimum cost of surfacing type and aggregate that will maintain the skid resistance at or above the IL for the life of the surfacing.

b. Where the cost calculated in (a) is not considered to be a reasonable strategy, aim for the skid resistance to not drop more than 0.05 below the IL for the design life of the surfacing.

c. In all cases, ensure the surfacing design includes a strategy to maintain the skid resistance above the TL.

d. Following construction of the new surfacing with the alternative aggregate, review the SC achieved. Report this and any crashes, at least annually, to the NZTA Regional Operations Manager or their nominee within the NZTA.

Following construction the consequences of the alternative aggregate strategy must be reviewed. If a significant number of crashes occur the whole strategy should be reviewed promptly and consideration given to use of an aggregate that will provide skid resistance at or above the IL.

Calcined bauxite should only be considered for short road lengths with high wet crash rates. Before installing calcined bauxite, checks should be made to confirm that funding will be available to maintain the surfacing indefinitely. It is not acceptable to construct calcined bauxite surfacing and then allow areas of delamination or other failure to remain.

12.7 Site sampling and testing of surfacing aggregate

The T10 Specification requires PSV testing of samples obtained from aggregate supplied to a site. This requirement is not intended to replace the quarry quality assurance system but to be another data set providing additional information. Although not mandatory, one sample in every three should be tested for PSV12, (note this will provide both a PSV value and a value of PSV12).

Care is required to ensure an accurate name (and quarry name if different) for the aggregate. Where stockpiles are sampled from beside the state highway an accurate route position should be added to the sample record.

The PSV test requires chips of certain size (see the T10 Specification). These are within the range of chip size provided by grade 4 chip. Where samples are taken from other chip sizes larger sample sizes should be taken (say 20kg). With the agreement of the testing laboratory site sieving may reduce these sample sizes.

The significance of PSV12 is still under investigation. Testing recommended here will assist with assessment of the benefits, correlation with on-road performance and any problems with the test procedure.

Send all site-sampled PSV test data to the Senior Surfacings Engineer, Pavements Section, HNO, National Office. It would be appreciated if this could be in the form of a summary spreadsheet and the test certificates. When quarry supplied data is sent this should include copies of test certificates.

12.8 Cost and life of surfacing treatments

It is important to keep records of the cost, performance and life of all surfacing treatments to optimise future surfacing. These records will tend to be more specific to the individual region but full records should be kept for review by the National Office, and possible dissemination to other regions or nationally.

12.9 Range of polishing resistance or PSV

There is a tendency to specify high polishing-resistant aggregate over long lengths of network. This is on the assumption that contractors do not want to manage two chip sources. However, regions should ensure contract documents specify the actual aggregate requirements to enable the use of cheaper aggregate (more readily available but more prone to polishing) where premium aggregate is not required. It will then be the responsibility of the contractor to assess the economics of using multiple aggregate sources.

12.10 Surfacing and resurfacing of curves

Generally rural curves should be surfaced with a uniform surfacing from the point where the radius goes below 800m to the point where this radius is exceeded again. For urban curves this applies at the point where the radius goes below 250m to the point where this radius is exceeded again.

Exceptions to this rule may be considered, see section 4.2 of these notes.

13 New alignments

For capital projects and road reconstruction, an appropriate IL and ILM must be designed and applied for both the first coat and any subsequent surfacing on the project. The design ILs and associated aggregates are subject to approval by the NZTA Regional Operations Manager or their nominee within the NZTA.

This assessment and approval must be undertaken to ensure project costs and future maintenance costs are optimised to give total long-term minimum cost to the NZTA.

13.1 RAMM inventory data for new alignments

Inventory data for new alignments that are open to traffic should be entered in RAMM prior to 1 September. If this is not done data collected may have significant errors. Network openings programmed after 1 September should be discussed with the National Asset Manager before 1 September and final data entered as a matter of urgency.

The first HSDC survey after the project or reconstruction will re-measure the displacement and GPS coordinates for the full reference station (RS) length in both directions.

Where only a short realignment is constructed, the whole reference station length must be resurveyed. While the GPS locations remain accurate to around 1m the linear label may be moved by up to 50m. Hence care is required when comparing year-on-year data following any network realignment.

14 Review of investigatory levels and site categories

This should be undertaken using the methodology in section 14 of the T10 Specification and these notes.

It should be noted that the risk of the curves may be amended which will change the IL.

14.1 Amending investigatory levels

The default ILs should be assessed to confirm they are appropriate. There is provision to allocate an alternative IL. A list of criteria for changing ILs is set out in appendix B of the specification.

Reference is made to a national average crash risk. Until this data is available regions may compare a section under consideration with the rest of that region.

14.2 Typical examples of reasons to amend ILs

Examples where modification of the IL is justified for any site category include the following: (for additional specific details see appendix B of the T10 Specification):

Multiple wet road crashes should prompt consideration of increasing the IL.

1. Multiple risk factors (such as those included in table 1 of the T10 Specification, under ‘Site description’) occurring at the same location should prompt consideration of increasing the IL.

2. Experience gained in assessing the risk of crashes from site investigations over multiple sites or substantial lengths has highlighted a need for amendment, either up or down.
3. High traffic volumes with an associated high number of crashes, or conversely low traffic volumes with an associated very low number of crashes, may indicate that the IL should be amended.
4. An unforgiving roadside environment with associated high severity crash outcomes should prompt consideration for increasing the IL.

Note: ILs must not be modified due to a lack of funding, see the prioritisation process set out in the T10 Specification, section 8.

14.3 User defined table in RAMM

Following completion of the annual survey, all changes to ILs are to be approved by the NZTA Regional Operations Manager or their nominee within the NZTA prior to being entered in a user-defined table within RAMM. This is entitled ‘Skid site (user defined)’ and is to be completed by the network consultant or supplier for each change generated from the:

- annual analysis of the discrepancy report
- review of investigatory levels and site categories.

It is expected that all changes and approval to amend ILs will be undertaken annually between 1 April and 31 August to enable inclusion in the skid data supplied to the contractor for the subsequent survey year. The National Office is responsible for ensuring that any approved changes are captured in the data provided annually on 1 September to the survey contractor.

The user-defined table also contains an audit trail to record the reasons for a change and the person making the change.

Further details of event codes, site categories and the user-defined table spreadsheet to be used in making changes will be issued annually with the exception report and skid event discrepancy report.

At the next release of RAMM software, it is envisaged that this user-defined table will be automated for completion directly in RAMM by the regional office (or suppliers). An audit trail requiring both regional and national approval will also be activated in RAMM to ensure that only approved changes to data are allowed to be added to the ‘live database’.

15 Reviews of regions

The National Office (HNO) will undertake reviews of individual network management areas to confirm compliance with policy and make recommendations for improvements, both locally and nationally.

16 References

British Standards Institution (BS) (1989) *BS 812: 1989. Testing aggregates. Part 114 – method for determination of the polished-stone value*. London.

Cenek PD, RJ Henderson and Davies RB (2012) Selection of aggregates for skid resistance January 2012. *NZ Transport Agency research report 470*

Cenek, P, C Brodie, R Davies and F Tate (2011) A prioritisation scheme for the safety management of curves. *3rd International Surface Friction Conference, Safer Road Surfaces, Saving Lives, Gold Coast, Australia, 2011.*

European Committee for Standardisation (2009) *BS EN 1097-8:2009. Tests for mechanical and physical properties of aggregates – part 8: determination of the polished stone value*. Brussels.

NZ Transport Agency (NZTA) (2011) *Register process manual for network standards & guidelines*. Version 3.0. Accessed 4 August 2012. www.nzta.govt.nz/resources/process-manual-network-standards-guidelines/docs/process-manual-network-standards-guidelines-july2011.pdf

NZ Transport Agency (NZTA) (2011) *NZTA M6: Specification for sealing chip*. Wellington.

Transit NZ (2000) *Draft TNZ T/2*: *Standard test procedure for measurement of skid resistance using the British Pendulum Tester*. Wellington.

Appendix A: Site inspection sheet

SCRIM data site investigation sheet	**Survey year:**	

Network management area	**SH**	**Ref station**	**Location (start/end)**
Name of NMA	SH number	RS number	Displacement

Site inspection			
Date:	Inspected by:	Method used:	
	Name	On site	Desktop

Site location and use	
Location and nature of site	Urban/rural
Current site category and IL:	Site category review required?
State current site category and investigatory level.	Y/N & recommendation

Pavement condition data
Skid resistance and texture depth:
Attach skid survey data
Any major pavement defects:

Crash data						
Period		**Number of crashes**			**Analysis length**	
From:	To:	Total:	Wet:	Wet skid:	Length (m):	Traffic (AADT):
Accidents linked to surface condition?		**Y/N**	Consider crash data 200m either side of site location.			

Visual assessment	
Type and condition of surfacing:	Aggregate name and PSV (If known)
Local defects (flushing, stripping, roughness etc):	
Presence of debris or other contamination:	
Does visual assessment concur with survey data?	Y/N – and recommendation to confirm.

Recommendation		
Treatment proposed and completion date.		(also record here if “do nothing”)
What type of treatment?	Y/N	
Review IL?	Y/N	If yes give details of recommendation

Treatment completed		
Print Name	Signature	Date

Appendix B: Test method for PSV12

1. Complete a standard PSV test in accordance with BS EN 1097-8:2009.
2. Return the specimens to the accelerated polishing machine and continue step 10.5 of the PSV standard (polishing with emery flour) for an additional nine hours (total of 12 hours emery flour polishing). Do not clean the specimens during the additional nine hours polishing.
3. Complete steps 10.6 to 10.9 of the PSV standard for the specimens.
4. Complete step 12 of the PSV standard 'Calculation and expression of results' using the same control stone values as in the standard PSV test.
5. For the test report:
    a Report the standard PSV calculated from step 1 above.
    b Note that an additional nine hours of polishing was undertaken and report the results as PSV12 in accordance with the NZTA T10 Notes.

Appendix C: List of abbreviations

B/C	benefit cost (ratio)
ESC	equilibrium SCRIM coefficient
GPS	global positioning system
HNO	Highways and Network Operations (National Office, NZTA)
HSDC	high-speed data collection
IL	investigatory level
ILM	investigatory level for macrotexture
MPD	mean profile depth
MSSC	mean summer SCRIM coefficient
NZTA	New Zealand Transport Agency
OGPA	open-graded porous asphalt
PSV	polished stone value
RAMM	the NZTA's road assessment and maintenance management database
RS	reference station
SAL	skid assessment length
SC	SCRIM coefficient
SCRIM	sideway-force coefficient routine investigation machine
SCRIM +	sideway-force coefficient routine investigation machine with additional measurement equipment.
SFC	side-way force coefficient
SH	state highway
TL	threshold level
TLM	threshold level for macrotexture
TTM	temporary traffic management