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## Appendix

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### The Biggest Fear in RCA Minds of PBC: Consuming Residual Life and being left with a liability

Resealing and Pavement Reconstruction budgets invariably comprise the largest value in any long term maintenance and construction contract with significant downstream effects, and therefore need to be well controlled and well defined in the contract. After 8 years where do we sit with the Residual Life KPM's? Would we change them and why?

#### Seal Residual Life

##### Introduction:

The Seal Residual Life is a crucial aspect of a Performance Based contract in that it provides protection to the client of a major asset, which protects the pavement (the biggest part of a network's worth). However conventional methods of measurement can be counter productive.

The danger in any performance based contract is that contractual key performance measures can drive adverse practice that was never intended or foreseen at the time of document preparation. The residual seal life is such a performance measure. The setting of the residual seal life KPM at the time of PBC-01 tender was not designed to be optimal, but simply matched the initial apparent life available at handover. No attempted modelling of an optimal regime was undertaken at that time.

For example, within the district there are seals that have exceeded the expected design life and yet remain completely waterproof and are exhibiting no signs of ageing (stripping, scabbing, or oxidation). The requirement to seal these roads, simply to meet a contractual KPM is both costly and counter-productive.

##### Best for Network Philosophy

In our moisture sensitive pavements and subgrades consisting mainly of volcanic ash, the best long term performance of a pavement is directly proportional to having a waterproof seal at the surface. Once the seal malfunctions, then more expensive pavement repairs or even reconstruction becomes necessary within a short period of time. Thus conventional maintenance practice is to ensure that the surface is fit for purpose and functioning well.

Further, it is a generally held view that there is less risk if a network receives reseals sooner rather than deferring and risking expensive pavement repairs. This is reflected in the practice of most RCA's who seal when the theoretical life (e.g. RAMM life) has expired.

In the WBoP PBC Contract we have taken a different approach, in that as reseals are part of the lump sum with no underpinned quantities, reseals need to be justified and verified as necessary to meet a contractual KPM. This has driven an approach to carefully manage our Maintenance Intervention Strategy in order to extract the maximum life out of each seal.

The entire network is inspected each year by a senior team to determine the optimal timing for the next reseal, having full data summaries of all work undertaken and its known history. Where seals are beyond their expected default life, they get termed as "vulnerable seals" and have a special monthly report of the faults found from each one to six weekly programming/fault inspection. This ensures that at the first sign of deterioration from the monthly programme (e.g. scabbing, cracking, chip loss, surface failure) the need to advance a reseal and minimise the risk of expensive pavement repairs by ensuring a sealing surface can be reassessed and rapidly advanced if required. This model allows us to respond almost immediately to rectify any unforeseen problems

We are now in a position after many years of practice, comfortable to push some seals well beyond their theoretical default lives, until the first signs of distress in the seal. This needs to be well managed, with regular detailed targeted inspections of these vulnerable seals looking for the first signs of seal distress.

This process results in a "best for network" sealing regime where actual field performance of the seal is assessed in terms of the available data and a projected year for next reseal is estimated and recorded. This process has given us confidence to defer resealing some lengths of road to ensure the maximum life is extracted prior to constructing the next seal.

However as it is unwise to push seals more than 1 year out until a better understanding is developed on how far these "vulnerable" seals can be pushed, a potential "bow wave" of work appears ahead when compared to traditional years resealing. This is to ensure each vulnerable seal is assessed carefully each year in terms of its risk and actual performance.

Also, as unstable seal layers are the leading cause of reconstruction required towards the end of a pavements life cycle (in the multi layered seals), by avoiding resealing too soon, we can defer the onset of Pavement Reconstruction due to these unstable multi layered seals.

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### Has this approach worked?

In the majority of cases this has been beneficial. We still have 25 year old grade 3's and 20 year old grade 5's performing perfectly well, and it would be a waste to not get even more life out of them.

In a few cases where we missed the early signs of distress in our monthly inspections, failure has been sudden and more expensive than sealing early. The risks are high if you get it wrong, but the gains can also be high over time, provided they are well managed. Our analysis of this is that there is a 3:1 ratio. That is we must get it right three times more than getting it wrong to break even on cost. To date we have deferred approximately 180 km of resealing, and been wrong on less than 3 km, which is a 60:1 ratio.

In fact this approach was encouraged by WBoPDC in pre tender meetings, in that consuming any residual seal life was encouraged in order to realise any value available in the network. If less sealing could be undertaken then these savings would be reflected in the tendered price, and passed onto the client. Whole of life savings will also accrue by not having to rehabilitate due to seal failure. The consequences of expensive maintenance repairs if it was wrongly assessed rested with the Contractor.

### Can we define an optimal seal age profile?

The residual seal life profile or "seal age profile" of any network is the weighted sum of its individually unique residual seal life profiles, with each length based on a number of factors that contribute to each lengths unique life cycle. These factors include for example; Subgrade strength and elastic deflection characteristics, depth and quality of pavement, density and weathering properties, waterproofing, drainage, traffic stress applied, quality of construction, and bitumen characteristics. These factors uniquely contribute to the expected life of each successive seal and eventually the timing of its renewal or rehabilitation towards the end of a pavements life cycle.

How was the Residual Seal Life Profile set in WBoP in 2002? As there was no better model available at the time, the required residual life was measured at the start of the contract by comparing the actual seal dates to the theoretical expected life for each seal type (i.e. RAMM life), and summed over the network. The KPM required the network to be handed back at the same profile, with mechanisms to change to a more ideal profile through the Management Board's virtual bank.

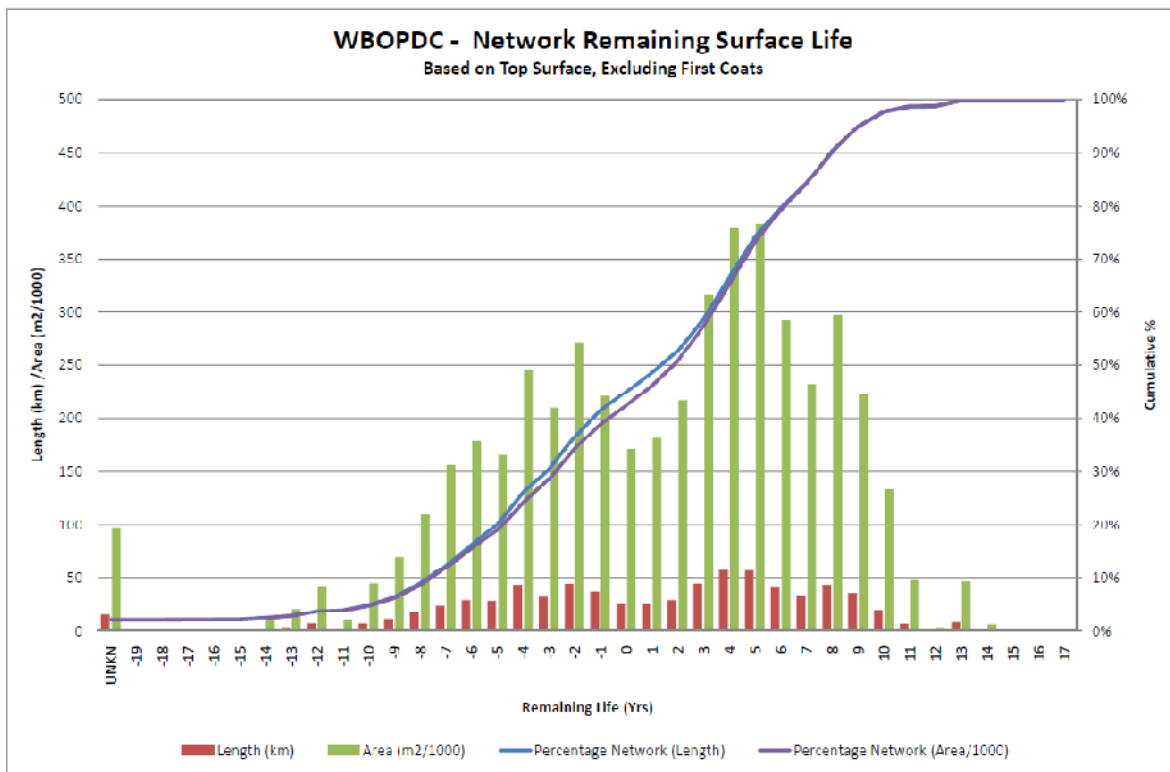
The profile snapshot at the start of the contract thus had no consideration able to be applied at that time as to if this was appropriate or not. In fact it is unlikely that the residual life profile at the time of benchmarking was in fact optimal, as conservative low risk sealing practices were in place and typically completed more sealing than was actually necessary, thereby decreasing the seal age profile to non optimal. To base future work requirements on an arbitrary RAMM age (i.e. residual life) alone is not a pro-active asset management technique when the past seal selection criteria has not been optimally/actively/consistently managed.

So, what is the optimal residual seal life profile for a networks seals? It is preferable to think of a network in terms of its actual seal age profile rather than its residual life profile, as the latter implies "life", whereas the former simply states age. For example a section of pavement with multiple seal layers typically exhibits shorter and shorter seal lives due to instability in the binder:stone ratio. If a residual life calculation is used then, the implied "life" is larger than it actually is. Conversely, a new well constructed pavement is likely to have a second coat that will exceed the average RAMM life by a considerable margin, yet the implied "life" will be negative.

It will take some time yet to have confidence that an optimal profile has been reached, as some seals are still performing well beyond their typical life. Even once we have extracted the maximum value out of the network, the profile will change over time and is not yet able to be modelled with confidence. The optimal seal age profile is only able to be accurately estimated by applying a consistent maintenance intervention strategy and tracking this over several reseal cycles. Having said that we feel we are getting close to being at optimum.

## How would we expect the Seal Age Profile of a network to track over time?

The Graph A1.1 is the current Seal Age profile for the WBoPDC sealed top surface. A recently constructed portion of the network would typically start at the right. As it ages and seal cycles pinch up, then there will be a general trend in the profile towards the left.



**Graph A1.1 Relative Remaining Life – WBoPDC Network Dec 2009**

It has been shown that when a pavements seal can be expected to continually last less than half its default life, then the least whole of life cost is to reconstitute the seal layers into the pavement, overlay and start again (i.e. pavement reconstruction).

## So now after 8 years would we change this KPM?

The tools available to an RCA to include in a PBC Contract in order to drive a Contractor to reseal, together with an opinion as to their suitability are as follows.

- **Maintenance Costs:** avoiding maintenance costs (patches, potholes, pavement repairs etc) by advancing a reseal is a major driver. This is entirely a PBC Contractor risk and is unlikely to change in the next contract.
- **Residual Seal Life:** This will drive unnecessary sealing if the targets set are non-optimal. If this type of measure is to remain, and until an optimal model can be understood, the targets need to be flexible. It could be removed if the contract period was significantly more (say double) the typical seal life cycle (12 years) to say 25 years. This would ensure a full transfer of risk and consequences to the Contractor for decisions to seal or not. As such a long contract period is unlikely, and optimal models are not well defined, then this type of KPM should remain in PBC Contracts. Changing the method of measurement from Residual Seal Life using default seal lives to a Seal Age Profile would help to promote better models and understanding of behaviour over time.
- **Texture:** some limiting control on minimum texture needs be in place. Skid resistance is a function of texture and networks need minimum thresholds. Mean Profile Depth standards ensures the macro texture levels are controlled.
- **Surface Condition Index (SCI)** – some way of assessing compound factors associated with e.g. potholes, patches, cracking, and other surface/pavement distress symptoms needs to be included. A single index which combines both visually measured surface condition defects (RAMM Rating) and surface age information, as an indication of surface asset consumption is important. These are difficult to measure on a continuous basis. Snapshot RAMM rating is the current way. Data from the network inspectors one to six weekly inspections has potential, provided these are consistently and methodically measured.
- **Roughness** – if sealing is deferred too long, the binder will age and crack letting water in, deforming the pavement through saturation increasing roughness. Roughness needs to be controlled, and affects the sealing strategy.

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Roughness targets set in the KPM's will affect the level of aged seals present on the network, by motivating the contractor to undertake the reseal before seal permeability allows water ingress and the consequential weakening of the pavement.

- Minimum Under pinned Reseal Quantities – not currently in this contract, and could drive non optimal profiles and wasted investment if rigidly enforced. If this was included then would need to be flexible. Flexibility would provide an equitable mechanism from which to trade value and provide a means of more accurately comparing tender programmes.

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## Pavement Residual Life

### Introduction

One of the reasons for WBoPDC moving to a Performance Based contract was to transfer the risk of early failure in reconstruction work, and ensure rework or maintenance costs would sit with those who designed and built it. Typically WBoPDC were finding that approximately 15% of their major construction work had excessive maintenance cost following construction and/or significant failure within the first few years of completion. When trying to find reasons for the failures, consultants would confirm that their design assumptions were valid, based on the limited testing, and so implicate the quality of construction processes and/or materials. Similarly contractors would be able to verify that they built everything to specification, followed the process and could verify the same. The RCA was left with the consequences, and faced over conservative design, no guarantees from construction and the high costs from maintenance. If the whole reconstruction design, build and maintenance could be transferred to the Contractor under a PBC environment, then this was seen to be a significant improvement.

Another reason for moving to a performance based environment was to ensure that the rate at which pavement was replaced (i.e. reconstruction) at least matched the average consumption by traffic. Thus the long term residual life of the pavement over the whole network would not be reduced (consumed).

The PBC was thus designed to reduce WBoPDC risk by specifying performance outcomes for new reconstruction and required the WBoPDC to endorse the magnitude (minimum underpinned quantities) of renewal, but did not specify the location or timing. These were left up to the Contractor's asset management processes to ensure the overall KPM's were met.

The performance outcomes or KPM's that control Residual Life are the Structural Condition KPM and the Treatment Design KPM. The structural Condition KPM is a network level tool that calculates the volume of granular overlay required (assuming a 25 year design life) based on a FWD network survey every 3 or so years. The Treatment Design KPM requires a specific design and a technical specification is produced at a project level and that the Contractor demonstrate a "post production" residual life of 25 years has been achieved through a layered elastic response model in accordance with AUSTRROADS Pavement Design Manual.

In reality however this is not a performance outcome "post production", but merely a verification of the design "post production", which essentially becomes an input specified design. This is borne out of the underlying issues associated with adequately measuring Residual Life and these are further expanded below.

### Design Theory Summary

We design pavements empirically based on what has mostly worked in the past (say 95%). Based on allowable subgrade strain, we place materials of a given quality for a given depth to protect this allowable strain. The theory however, cannot and does not guarantee that a pavement will behave as predicted. It merely offers a statistical distribution, with inherent uncertainty as part of the design process. Austroads expect 5% to fail before the design life is reached even if everything was constructed correctly.

Thus 95% of pavements can be expected to meet the 25 year design life requirements. Also 50% will last twice as long as the average, or say 50 years. This is what we see in the WBoPDC local roads.

Also the FWD result on a pavement is expected to remain the same over all of its life until it reaches its point of failure (end of life) at which point deflections are seen to increase.

Also, a further examination of warnings and clarifications in the notes of AUSTRROADS include the following:

- There is no absolute certainty that the desired performance will be achieved
- The procedures in this guide are intended for the design of pavements, the primary distress mode of which is load induced. Where other modes of stress, such as environmental distress, have a significant effect on pavement performance. Their effect should be separately assessed.
- Pavements are assumed to be constructed to the usual quality standards specified by Austroads Member Authorities.
- It is emphasised that this document should be used as a guide only; it should not be referred to as a design specification. Judgement must be exercised by the designer in arriving at decisions regarding the parameters that are incorporated into particular designs.
- It should also be emphasised that pavement design is only one aspect associated with the achievement of sound pavement performance. Sound pavement performance depends on a number of factors. The primary factors are illustrated in figure 1.2

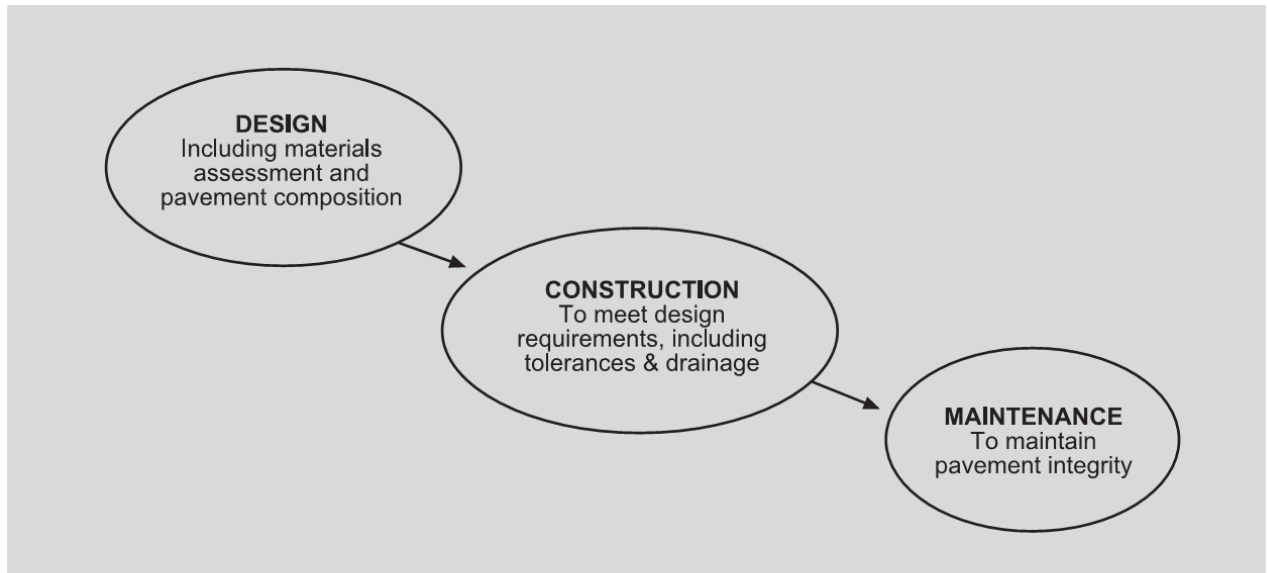


Figure 1.2 A global and integrated approach is required if high levels of pavement performance are to be achieved. In the context of unbound granular pavements, the only load induced failure criteria considered is the accumulation of vertical compressive strains at the subgrade interface which manifests as “permanent deformation”. However, no further description of the terminal condition is provided.

#### Implications to Performance Based Contracts

While the short term (up to say 8 years) maintenance implications are indeed covered by the contractor, assumptions during design can cut short the actual life (e.g. allowable Subgrade strain, bound material properties). We are unable to test with any certainty as to where any particular pavement sits. Post construction deflection measurements (FWD) cannot accurately predict how long a pavement will last into the future. Further, we cannot reliably test in order to predict when a specific pavement will fail, or have any certainty of its remaining life.

So the consequences of poor design assumptions, or poor construction may well not appear until well after the PBC has been completed, to latter custodians. Any destructive testing undertaken can only determine (at best) if materials conformed to specifications.

#### So where does this leave the risk ?

While the risk for the short term consequences can be transferred, long term any issues arising will still reside with the principal or later custodians. Inadequate design assumptions may only come to light in the long term and the power to decide the long term implications on the principal now rests with the contractor.

#### Summary

This has led us to rely more on inputs such as robust design criteria and detailed Quality Control during construction to ensure life which are not output or performance based in essence.

However as pavement reconstruction is approximately 25% of our budget and at these levels maintenance activity still dominates, it is not unreasonable to continue to include pavement reconstruction in performance contracts, considering the gains in maintenance efficiency and overall cost savings that can be observed.

A better option going forward into the next contract may be to make pavement life assessed by rut progression and roughness progression, but this approach really requires a long period of time to be truly effective, with a tenure closer to that of the pavement life (say 25 years) or even an evergreen (continuous) type contract model.

Regardless of the arguments of extending the contract period beyond ten years, provided the RCA maintains a performance based type contract at each change the WBoPDC risk of the consequences of inadequate actual residual life pavements is reduced. However the new custodian (i.e. the new PBC Contractor) will inherit the consequences of previous custodians’ decisions, their quality of construction, and their maintenance intervention strategies.