Civil Engineering Report

CQCN Ballast Fouling Rates 2018 - 2020

29 September 2021

Executive Summary

This report provides an estimate of the average ballast fouling rate for the CQCN and for each system within it. It presents the findings from an analysis of Ground Penetrating Radar (GPR) measured Percent Void Contamination (PVC) values recorded in 2018 and 2020.

The analysis was requested by Aurizon Network Finance and Regulation for input to their ballast life cycle model. Along with residual PVC following ballast cleaning operations, the results will be used to calculate annual ballast replacement requirements.

The results of the analysis are presented in Table 1.

Table 1: System and CQCN Average Fouling Rates

System / Route ID	Track Name	PVC%/100MNT	Data samples
Blackwater Avg		**3.8**	**536,723**
BW-01ML	North Coast Line Up Rd	3.5	63,431
BW-02ML	North Coast Line Dn Rd	3.1	64,468
BW-03ML	Central Line Dn Rd	1.8	124,027
BW-04ML	Central Line Up Rd	6.2	137,369
Goonyella Avg		**12.7**	**310,248**
GA-01ML	Goonyella Line Dn Rd	20.0	126,155
GA-02ML	Goonyella Line Up Rd	1.9	86,045
Moura Avg		**0.6**	**137,087**
MA-01ML	Moura Short Line	0.6	137,087
Newlands Avg		**7.3**	**129,279**
NL-01ML	Newlands Line	7.0	120,365
NL-03ML	Newlands Briaba Dn Rd	11.6	8,914
CQCN Avg		**6.0**	**867,861**

The overall CQCN average fouling rate of 6% PVC for every 100 million net tonnes is in the range expected, being similar to the currently used value of 5%. The variation between different systems, and between some Route IDs within the same system, is also similar in magnitude to the results previously obtained - although largely unexplained at this time.

The fouling rates provided are based on GPR measured PVC values, currently available gross tonnages, and recorded maintenance works. Collection of this data should be more comprehensive and accurate in the future through the uptake and refinement of OneSAP. Repeating this analysis in a few years may therefore show if some of the variation observed is a result of poor data rather than actual ballast fouling behaviour.

Document Version Table

Version	Description of changes from previous version	Issue Date
Initial issue		29 September 2021

Approval of latest version

Function	Name / Position / Section	Signature	Date
Author:	Mark Boyce Principal Engineer, Civil Asset Mgt	M. Boyce	29/09/2021
Approved:	Simon Larsen Engineering Leader Civil		05/10/2021

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CQCN Ballast Fouling Rates 2018 - 2020

1. Introduction

This report provides a current estimate of the average ballast fouling rates for the CQCN and each of the four system within it. It presents the findings from an analysis of the change in Percent Void Contamination (PVC) values for ballast between 2018 and 2020 as measured by Ground Penetrating Radar (GPR).

The analysis was requested by Aurizon Network Finance and Regulation for input to their ballast life cycle model. Along with residual PVC following ballast cleaning operations and other inputs, these results will be used to calculate annual ballast replacement requirements.

The work was completed in 2021 by members of the Civil Engineering and Asset Data teams in Network Asset Management.

2. Background

As discussed by Shelley in 2014 [1], ballast fouling rates have previously been determined based on GPR data calibrated for PVC and determined in terms of % PVC per 100 million net tonnes (MNT) of coal carried. These rates ranged between 1% and 15% per 100MNT. A network wide average fouling rate of 5% per 100MNT was established.

In its 2015 review of Aurizon's ballast undercutting scope [2], the QCA acknowledged that while GPR has its limitations, overall Aurizon Network's use of GPR data to determine mainline ballast condition was more efficient and had advantages over the traditional trial pit, tonnage usage wear and design life methodology employed previously.

3. Ballast Life without Fouling

In the context of the CQCN, healthy ballast life under design loading and no adverse environmental conditions is quoted to be in the range of 15 to 20 years [2].

Findings published by Professor Ernest Selig (North America's leading rail geotechnical authority) indicated that the expected life of ballast with no coal fouling is 1,600 million gross tons, or about 1450 MGT [3]. This is from Canadian Pacific data and is at the high end of expected ballast life, based on optimal ballast design, construction, and abrasive strength of the ballast particles. North American track uses predominantly timber sleepers.

Further work by the Vilnius Gediminas Technical University in Lithuania, published in 2017 [4], modified the North American results to allow for different ballast aggregate strengths and concrete sleepers. Their results are presented in Figure 1.

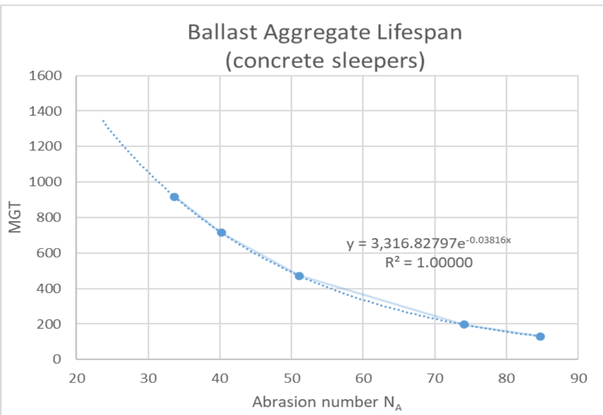

Figure 1: Ballast aggregate life based on Abrasion Number (N_A)

The Abrasion Numbers (N_A) for quarries supplying ballast to the CQCN are given in Appendix A. The range of these values and the resulting estimated life in MGT is shown in Table 2.

Table 2: CQCN ballast aggregate life based on Abrasion Number (N_A)

	N_A	MGT
Min	20.0	1550
Avg	28.8	1110
Max	38.0	780

These values could be used to estimate a maximum ballast life independent of ballast fouling, although further work may be required to verify their applicability to the CQCN.

4. Methodology

This section describes the steps taken to calculate the fouling rates for each system, and the reasoning for the decisions made in the process. Details are provided in Table 3.

Table 3: Analysis methodology

	Step	Reasoning
1.	Collect PCV data from the 2018 and 2020 GPR runs.	These are the most recent GPR runs and therefore the most relevant. The more recent data for steps 5 and 7 is more reliable.
2.	Use only the centre channel data.	A separate analysis of these GPR runs showed the majority of PVC change occurred on the centre channel. This was also an approach suggested by the QCA [2].
3.	Use Route IDs for the main trunk routes in each system.	These carry the most traffic, reducing error. The most reliable data is available.
4.	Remove any PVC values over 80%.	PVC measurement by GPR is known to have an error around ±20% for highly fouled ballast.
5.	Remove any PVC values captured over bridges, turnouts, crossings, or track undercut/resurfaced between the 2018 and 2020 GPR runs.	The plain track fouling rate is required – features with exceptionally high fouling rates are managed separately. Track must have had no ballast cleaning activities.
6.	For each 1 metre of track, allocate the maximum PVC sample value (4 samples per metre).	This is a balance between a manageable volume of data and not artificially inflating the fouling levels.
7.	Find MGT between turnouts for each track and assign to each metre of track.	Traffic volumes along a track can only change at turnouts.
8.	Remove any PVC values with MGT less than 5.	Removes data errors from very low traffic volumes.
9.	Calculate the fouling rate for each metre as the PVC change per 100 million net tonnes, and average over the Route ID.	$PVC/100MNT = \dfrac{(PVC\,2020 - PVC\,2018)}{(MGT/100/1.6)}$ where 1.6 is the conversion factor for MGT to MNT.

5. Analysis and Results

The analysis was begun using Power BI, but due to resource constraints it was completed using Microsoft Excel. The volume of data was too large for a single Excel worksheet, and was split into one worksheet per system.

The spreadsheet is stored here:
\\bneprdfps001\PD\4. Sections\4. InfraEng\a. CivElec\b. Track\40. Materials\Ballast\Ballast asset life review 2021\PVC fouling rate review\2.Working\Data&Calcs\Ballast Fouling Rates CQCN v3 MB250821.xlsx

The final location for the data and analysis from this project is intended to be the Power BI report, the early draft of which can be found here:
https://app.powerbi.com/groups/me/apps/ffab314a-dd2e-4cd2-92b6-ff6707cc1c68/reports/1c2e2505-4bf2-4f48-9850-81c14108aeb4/ReportSection991c5080ed5a50629c11?ctid=a74a1efc-372d-476c-802c-9cbbe5a5c71e

The results from the Excel analysis are presented in Table 4. They include Route ID, system average, and overall CQCN average fouling rates.

Table 4: System and CQCN Average Fouling Rates

System / Route ID	Track Name	PVC%/100MNT	Data samples
Blackwater Avg		**3.8**	**536,723**
BW-01ML	North Coast Line Up Rd	3.5	63,431
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NL-01ML	Newlands Line	7.0	120,365
NL-03ML	Newlands Briaba Dn Rd	11.6	8,914
CQCN Avg		**6.0**	**867,861**

6. Discussion

The resulting overall CQCN average fouling rate of 6% PVC for every 100 million net tonnes carried is in the range expected, being similar to the currently used value of 5%. The variation between different systems, and between some Route IDs within the same system, is also similar in magnitude to the results previously obtained - although largely unexplained at this time.

It was noted that the results can be sensitive to the filter values chosen in step 4 (maximum PVC) and step 8 (minimum MGT). This is illustrated below with two examples. Figure 2 shows how the calculated fouling rate for the Goonyella Up road (GA-02ML) remains fairly constant at around 2 as the filter for maximum PVC value is altered, while the Down road (GA-01ML) varies uniformly between about 2 and 24. Figure 3 shows how the calculated fouling rate for the Moura Short Line (MA-01ML) varies inconsistently between about -2 and 14 as the filter for the minimum MGT value is altered.

It may not be possible to determine why the available data gives these results. With the adoption and maturing of OneSAP, repeating this analysis in future years may show if these features are a result of poor data rather than actual ballast fouling behaviour.

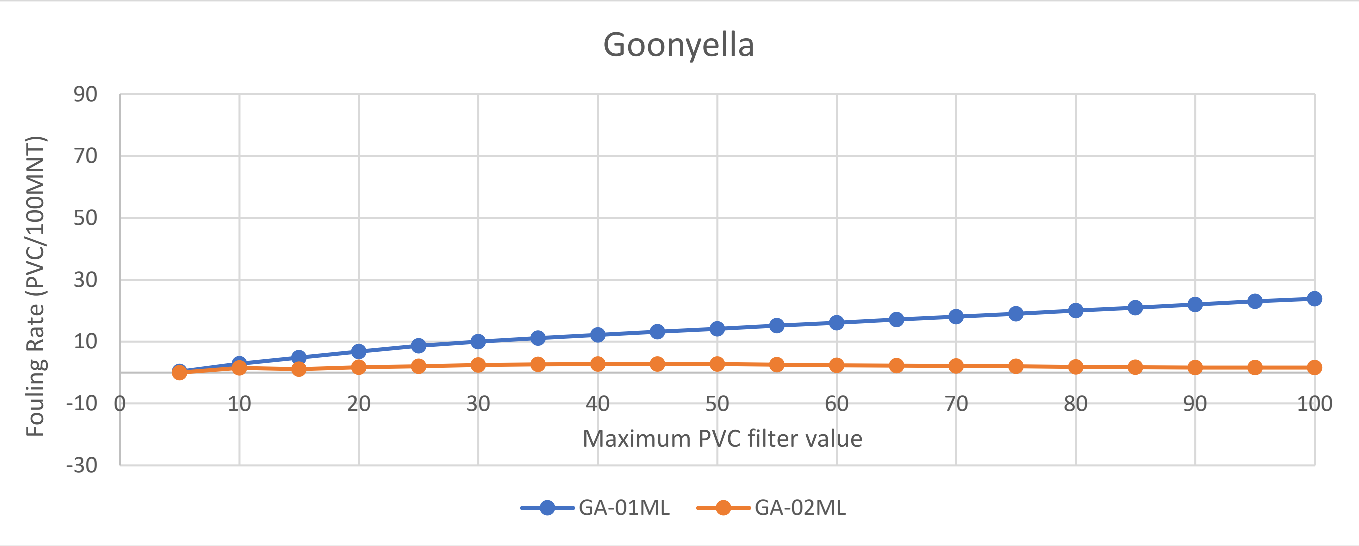


Figure 2: Effect of varying maximum PVC

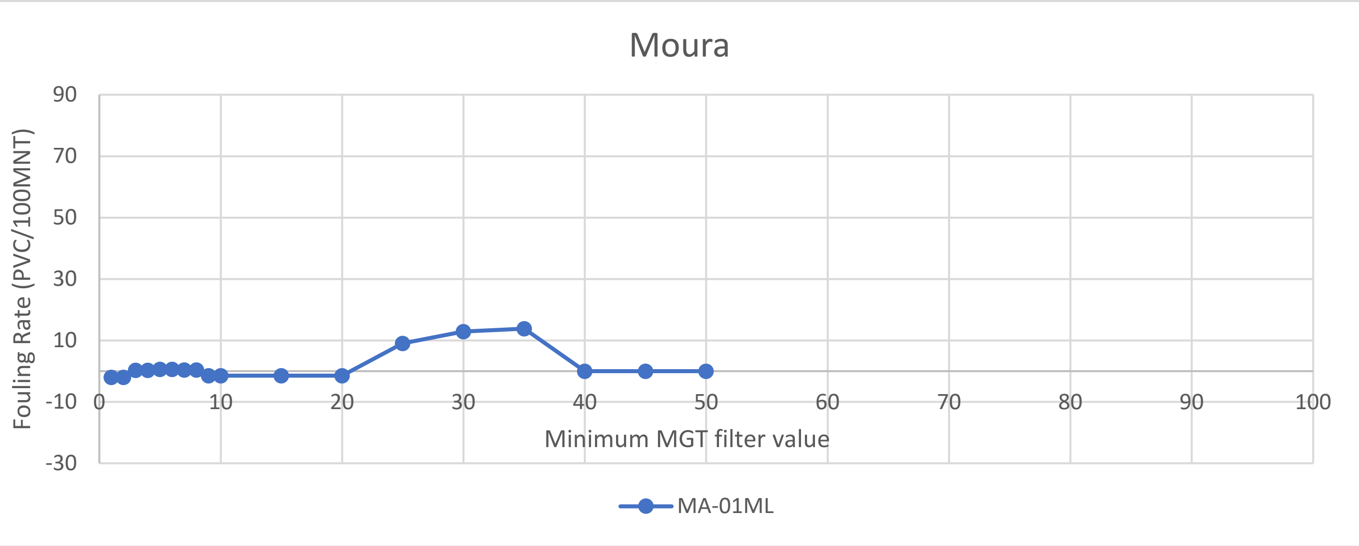


Figure 3: Effect of varying minimum tonnage

The MGT life of the ballast aggregate discussed in Section 3 above also needs to be considered when estimating ballast replacement cycles. For tracks with low levels of fouling indicated such as Moura, the breakdown and rounding of the ballast particles leading to poor track support may govern ballast life.

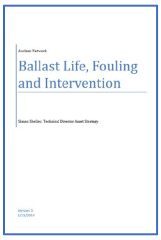
It should also be noted that net tonnage was not available in a form that could be used in this analysis. The required conversion from gross to net tonnes (refer to Appendix B) assumes that each track carries round trips; that is, there are equal numbers of loaded and unloaded trains. This is not always the case.

7. Conclusion

The fouling rates provided are based on GPR measured PVC values, currently available gross tonnages, and recorded maintenance works. Collection of this data should be more comprehensive and accurate in the future through the uptake and refinement of OneSAP. Repeating this analysis in a few years may therefore show if some of the variation observed is a result of poor data rather than actual ballast fouling behaviour.

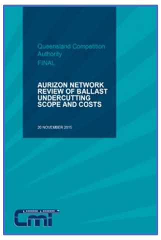
References

[1] Ballast Life, Fouling and Intervention, 15 January 2014, Simon Shelley, Aurizon



Ballast Life, Fouling and Intervention

[2] Aurizon Network Review of Ballast Undercutting Scope and Costs, 20 November 2015, QCA



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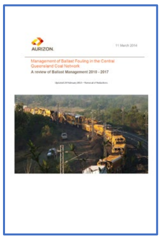
AURIZON NETWORK REVIEW OF BALLAST UNDERCUTTING SCOPE AND COSTS

[3] A Review of Ballast Management 2010 – 2017, 11 March 2014, Aurizon



[4] Prediction of Lifespan of Railway Ballast Aggregate According to Mechanical Properties, September 2017, Baltic Journal of Road and Bridge Engineering, Vaidas Ramūnas

Appendix A – Ballast Lot Register and Test Results

[redacted]

[redacted]

Appendix B – Conversion from Gross Tonnes (MGT) to Net Tonnes (MNT)

$$\frac{Gross\ Tonnage}{Net\ Tonnage} = \frac{[2\ \times Number_{Loco} \times Gross_{Loco}] + [Number_{Wag} \times Gross_{Wag}] + [Number_{Wag} \times Tare_{Wag}]}{Number_{Wag}\ \times [Gross_{Wag} -\ Tare_{Wag}]}$$

System	Num Loco	Gross Loco	Num Wag	Gross Wag	Tare Wag	Gross/Net
Goonyella	3	130	126	106	21	1.57
Blackwater	3	130	102	106	21	1.58
Newlands	3	120	84	106	21	1.59
Moura	4	120	100	106	21	1.61