

New PBS Requirements:  
Replacement Pro-forma  
Designs for 23m Truck and  
Trailer Combinations  
Addendum

Prepared for:

New Zealand Transport Agency

December 2020

Transport Engineering Research New Zealand Limited (TERNZ) is a research organisation providing high quality independent research services to the transport industry.

TERNZ has expertise across a broad range of transport-related areas including vehicle safety, vehicle dynamics, vehicle-infrastructure interaction, fuel efficiency, driver behaviour, driver performance, impacts on communities and other social issues. Our customers also span the range of industry stakeholders and include government agencies, vehicle manufacturers and suppliers, industry associations, individual transport operators and community groups.

***TERNZ prides itself on the quality, timeliness and independence of its work.***

Authorship: This document was written by John de Pont. For further information, please contact John at [j.depont@ternz.co.nz](mailto:j.depont@ternz.co.nz) or by phone on 09 579 2328.



**TERNZ Ltd**

49 St Vincent Ave | Remuera | Auckland

Phone +64 9 579 2328

[info@ternz.co.nz](mailto:info@ternz.co.nz)

[www.ternz.co.nz](http://www.ternz.co.nz)

## INTRODUCTION

In association with the 2016 review of the Vehicle Dimensions and Mass (VDAM) Rule, the NZTA also initiated a project to formalise the performance-based standards (PBS) for use in New Zealand. The current pro-forma designs were developed using a set of performance measures largely based on those originally developed in the Road Transport Association of Canada (RTAC) study in the 1980s and the Australian PBS system which came into force in 2008.

The pass/fail criteria for low speed turning performance were based on the performance of the worst case standard legal vehicle; the quad-axle semi-trailer combination. Observations undertaken of some limit-case HPMVs in operation found that, at some pinch point curves on the network, the vehicles occupied the full lane width. Thus, if two such vehicles were to meet at one of these curves there would be little safety margin. The NZTA therefore required that the low speed turning performance requirements in the proposed New Zealand PBS system be more demanding so that the limit-case vehicles use less road width at the pinch-point curves. The new PBS system has now been developed. Because the low speed turning performance requirements are more demanding than those used for the current pro-forma designs, all the current pro-forma designs will need to be reviewed and modified. This provides an opportunity to rationalise these pro-forma designs into a more coherent set.

A review of the three main 23m truck and trailer pro-forma designs was undertaken with a view to replacing them with two new pro-forma truck and trailer designs. However, based on industry feedback, a set of six new pro-forma designs was developed. A report entitled "New PBS Requirements: Replacement Pro-forma Designs for 23m Truck and Trailer Combinations v5" and dated November 2020 describes the development of these designs. However, during the implementation process we realised that the designs included an implicit assumption that the users would be aiming to maximize the payload capacity of the vehicles and thus we had not set any minimum values for some of the key dimensions. Although this will not affect the low speed turning performance requirements, large coupling offsets with short drawbars will negatively impact high speed dynamic performance and thus it is necessary to determine some minimum values for these dimensions.

This addendum to the original report determines what these minimum dimension limits should be and revises the pro-forma designs accordingly. Note that none of the existing dimensional limits in the design were changed and just one additional dimensional constraint was added for each design.

# THE NEW PRO-FORMA DESIGNS

As noted in the introduction six new pro-forma designs were developed. These are:

1. 23m Truck and Full Trailer
2. 23m Truck and Long Trailer – 1600HO
3. 23m Truck and Long Trailer – 1800HO
4. 23m Truck and Long Trailer – 2000HO
5. 23m Truck and Long Trailer – 2200HO
6. 23m Truck and Long Drawbar Trailer

The first of these designs is based on a truck with a maximum nominal forward length of 8200mm while the other five designs are based on a truck with a maximum nominal forward length of 7500mm. Designs 2-5 are similar. In each case, the numerical suffix represents the minimum hitch offset from the rear axis on the truck in millimetres. A larger hitch offset enables a longer trailer wheelbase to be used while still achieving the low speed swept width requirements. For these first five designs, a minimum trailer wheelbase of 5400mm was also specified. This was necessary for achieving the high-speed dynamic performance measures (rearward amplification and dynamic load transfer ratio) with the maximum value for hitch offset. Industry feedback indicated that this minimum trailer wheelbase was not sufficiently small for some tipper truck applications and thus design 6 was developed. This has a smaller minimum trailer wheelbase of 4700mm but offsets this with a reduced maximum hitch offset of 2200mm.

In undertaking the performance analyses of the limit cases of these pro-forma designs, we implicitly assumed that the vehicle designers would be aiming to maximise the gross combination weight capacity of the vehicles and thus, if the vehicle had a shorter wheelbase trailer, it would have a longer drawbar so that the axle spacings would be maximised. However, there was nothing in these proposed designs to prevent the combination of a large hitch offset with a short drawbar and a short trailer wheelbase. This combination of dimensions could potentially result in a vehicle that has poor high-speed dynamic characteristics, particularly if the vehicle also has a relatively low static rollover threshold (SRT). Also, all the modelling had been done with a 5-axle trailer because this is a requirement for 50MAX operations. However, in principle, there is no reason why an HPMV permit at higher weights cannot be issued to a vehicle with a 4-axle trailer. This permit would be route specific and the vehicle would not be able to be used for 50MAX operations but, potentially, there may be applications where this is appropriate. Using a 4-axle trailer instead of a 5-axle trailer with the same wheelbase has little effect on the low speed turning performance of the vehicle but it does affect the high-speed dynamic performance.

The four 23m truck and long trailer designs all have the same maximum hitch offset and minimum trailer wheelbase limits and we modelled this combination with these limit values to determine the minimum drawbar length that could be used in conjunction with these limit values. In this analysis we considered both 4-axle and 5-axle trailers. Because of the differences in axle spacings, the maximum gross combination weight achievable was different for the two trailer types. The 5-axle trailer combination was modelled at 58 tonnes while the 4-axle trailer combination was modelled at 56.5 tonnes. The minimum drawbar length that could be used in conjunction with the minimum trailer wheelbase while still achieving satisfactory high-speed dynamics was 4.6m. It was also found that changes in the trailer wheelbase had a larger effect on high-speed dynamic performance than changes in the drawbar length. The sum of the trailer wheelbase and the drawbar length is the trailer forward distance and the minimum value for this is 10m. If we specify a minimum value for the trailer forward distance, increases in trailer wheelbase can be matched by decreases in drawbar length without degrading the high-speed dynamic performance.

The results of a PBS assessment of the limit case vehicles with the 4-axle trailer and 5-axle trailer configurations is shown in Table 1. The centre of gravity height of the payload was adjusted to give an SRT value of 0.35g, which represents a worst-case load. As expected with a large hitch offset and a short trailer wheelbase, the low speed turning performance characteristics of these vehicles are good, while the high-speed dynamics (rearward amplification and dynamic load transfer ratio) and the high speed offtracking are all approaching the acceptable limit values.

**Table 1. Performance assessment of truck and long trailer design with max hitch offset, minimum drawbar length and minimum trailer wheelbase.**

Performance Measure	Acceptability Level	23m truck and long 4-axle trailer design	23m truck and long 5-axle trailer design
Low Speed Swept Width (m)	Less than 6.95	6.10	6.12
Tail Swing (m) - Load	Less than 0.3	0.14	0.14
Frontal Swing (m)	Less than 0.75	0.51	0.51
Steer-Tyre Friction Demand	Less than 0.50	0.34	0.34
Steady State Low Speed Swept Width (m)	Less than 5.20	4.53	4.54
High Speed Offtracking at 0.2g (m)	Less than 0.46	0.45	0.45
High Speed Offtracking at 0.25g (m)	Less than 0.68	0.63	0.63
Static Rollover Threshold (g)	Greater than 0.35	0.35	0.35
Dynamic Load Transfer Ratio	Less than 0.6 (0.7)	0.58	0.57
Rearward Amplification	Less than 2	1.98	1.98
High Speed Transient Offtracking (m)	Less than 0.6	0.43	0.43
Yaw Damping Ratio (%)	Greater than 15	27	27

The above analysis used trucks with the maximum allowable forward length (7500mm). The pro-forma designs do not specify a minimum truck forward length or wheelbase and thus it is possible to use a shorter truck. Although reducing the truck wheelbase would be expected to have a negative impact on high-speed dynamic performance, the shorter truck wheelbase also reduces the maximum allowable hitch offset, which has a positive effect, and reduces the maximum gross combination weight.

**Table 2. Performance assessment of shorter truck and long trailer design with max hitch offset, minimum drawbar length and minimum trailer wheelbase.**

Performance Measure	Acceptability Level	23m shorter truck and 4-axle trailer design
Low Speed Swept Width (m)	Less than 6.95	5.95
Tail Swing (m) - Load	Less than 0.3	0.11
Frontal Swing (m)	Less than 0.75	0.49
Steer-Tyre Friction Demand	Less than 0.50	0.31
Steady State Low Speed Swept Width (m)	Less than 5.20	4.41
High Speed Offtracking at 0.2g (m)	Less than 0.46	0.43
High Speed Offtracking at 0.25g (m)	Less than 0.68	0.60
Static Rollover Threshold (g)	Greater than 0.35	0.35
Dynamic Load Transfer Ratio	Less than 0.6 (0.7)	0.55
Rearward Amplification	Less than 2	1.95
High Speed Transient Offtracking (m)	Less than 0.6	0.40
Yaw Damping Ratio (%)	Greater than 15	28

Table 2 shows the performance assessment results of reducing the truck forward length by 0.5m. This requires the hitch offset to be reduced. Because the axle spread is less for this truck, the gross combination weight is reduced by 0.5 tonnes. Compared to the results for the longer truck shown in Table 1, the low speed turning performance has improved a little and the high-speed dynamics has also improved a little. Thus, it appears that specifying a minimum trailer forward length off 10m will still result in satisfactory performance when the truck is shorter.

The above analysis applies to all the proposed truck and long trailer pro-forma designs (designs 2 to 5). We then still need to consider pro-forma designs 1 and 6. Design 1 provides for a longer truck (max 8200mm forward length) to be used and reduces the maximum trailer forward length to offset this. A shorter minimum trailer forward length is possible for this design when the truck is at maximum length. Table 3 shows the results of a performance assessment of the truck and full trailer pro-forma design with a maximum forward distance truck, maximum hitch offset, minimum trailer wheelbase and 9.8m trailer forward distance. However, the 8200mm truck forward length limit is a maximum and there is no minimum value specified. The effective minimum truck forward length for this design is 7500mm because below this length the truck and long trailer pro-forma designs give greater flexibility with the trailer dimensions and would be used instead. When the truck forward length is 7500mm or less the hitch offset limit and minimum trailer wheelbase are the same as for the truck and long trailer pro-forma designs and thus for shorter truck forward distances the minimum forward distance of the trailer is 10m and this is the value that needs to be applied to the pro-forma design.

**Table 3. Performance assessment of the standard (8200mm) truck and full trailer design with maximum hitch offset, minimum trailer wheelbase and 9.8m trailer forward distance.**

Performance Measure	Acceptability Level	Standard 23m truck and trailer design with max HO and min trailer WB
Low Speed Swept Width (m)	Less than 6.95	6.30
Tail Swing (m) - Load	Less than 0.3	0.18
Frontal Swing (m)	Less than 0.75	0.55
Steer-Tyre Friction Demand	Less than 0.50	0.37
Steady State Low Speed Swept Width (m)	Less than 5.20	4.69
High Speed Offtracking at 0.2g (m)	Less than 0.46	0.46
High Speed Offtracking at 0.25g (m)	Less than 0.68	0.65
Static Rollover Threshold (g)	Greater than 0.35	0.36
Dynamic Load Transfer Ratio	Less than 0.6 (0.7)	0.59
Rearward Amplification	Less than 2	2.00
High Speed Transient Offtracking (m)	Less than 0.6	0.44
Yaw Damping Ratio (%)	Greater than 15	27

The final design to be considered is the 23m truck and long drawbar trailer (no 6). This design was developed to meet the requirements of bulk transport tipper trucks and provides for an extra short wheelbase trailer with a long drawbar. The constraints on the truck dimensions for this design are the same as those for the truck and long trailer 1600HO design except that the maximum hitch offset is limited to 2200mm. For consistency we undertook a performance assessment of this vehicle with a 10m trailer forward length. The results are shown in Table 4. The dynamic load transfer ratio is at the limit value so there is no scope for reducing the trailer forward length further.

**Table 4. Performance assessment of the truck and long drawbar pro-forma design with 2200mm hitch offset, minimum trailer wheelbase and 10m trailer forward length.**

Performance Measure	Acceptability Level	Standard 23m truck and trailer design
Low Speed Swept Width (m)	Less than 6.95	6.22
Tail Swing (m) - Load	Less than 0.3	0.05
Frontal Swing (m)	Less than 0.75	0.51
Steer-Tyre Friction Demand	Less than 0.50	0.34
Steady State Low Speed Swept Width (m)	Less than 5.20	4.62
High Speed Offtracking at 0.2g (m)	Less than 0.46	0.43
High Speed Offtracking at 0.25g (m)	Less than 0.68	0.61
Static Rollover Threshold (g)	Greater than 0.35	0.35
Dynamic Load Transfer Ratio	Less than 0.6 (0.7)	0.60
Rearward Amplification	Less than 2	1.92
High Speed Transient Offtracking (m)	Less than 0.6	0.41
Yaw Damping Ratio (%)	Greater than 15	26

As with the original analysis, the vehicles have been modelled at HPMV weights. In some cases, the gross combination weight used was less than the 58 tonnes or 59 tonnes used in the original analysis because the axle spacings were less which reduced the allowable weights. The height of the centre of gravity of the payload was adjusted to give an SRT value close to the 0.35g minimum allowed. This should generate the worst-case performance for the high-speed performance measures. In practice, many vehicles will operate with higher SRT values and will have superior performance for some of the high-speed standards.

## CONCLUSIONS

The six pro-forma truck and trailer designs that were developed to comply with the new PBS requirements contained a “loophole” whereby it would be possible to use vehicles with a large hitch offset and both a short drawbar and a short trailer wheelbase. Using this combination of dimensions would give good low speed turning performance but could result in unacceptable high-speed dynamic performance.

In this addendum to the original study, we have developed an additional constraint on the minimum trailer forward distance which creates a limit on the extent of the minimum drawbar length that can be used for a given trailer wheelbase. This constraint ensures satisfactory high speed dynamic performance.

In addition, there was a typographical error in note 3 on the designs. The maximum allowable rear overhang for the trailers was intended to be the same as is required by the VDAM Rule for standard legal vehicles. For full trailers this is 50% of the wheelbase. The 70% of wheelbase value shown in the original report is the value for semitrailers.

The resulting updated six pro-forma designs are shown in Figure 1, Figure 2, Figure 6, Figure 4, Figure 5 and Figure 6.

## 23m truck and full-trailer

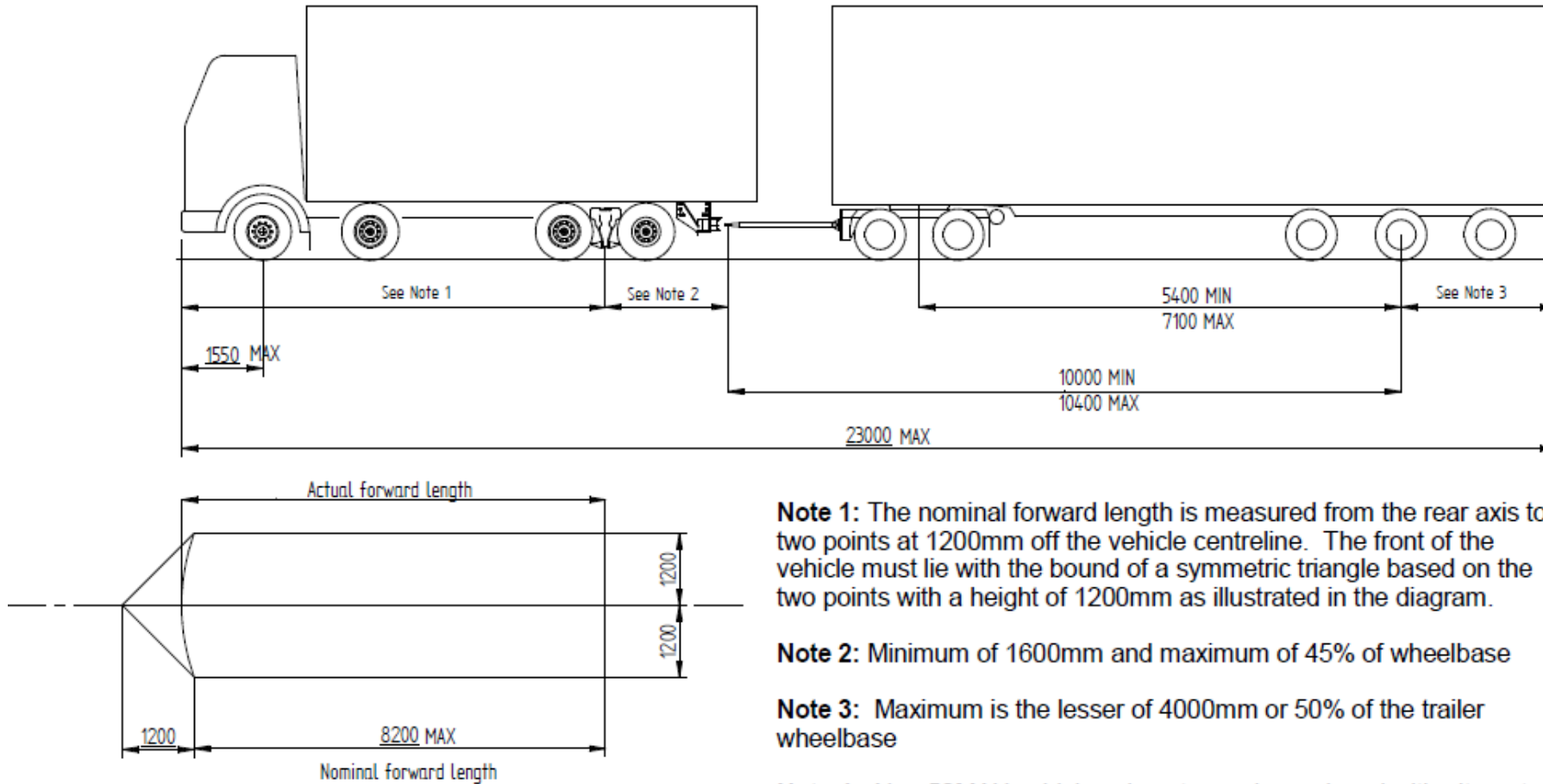


Figure 1. Proposed new 23m truck and trailer pro-forma design.



## 23m Truck and long trailer-1600HO

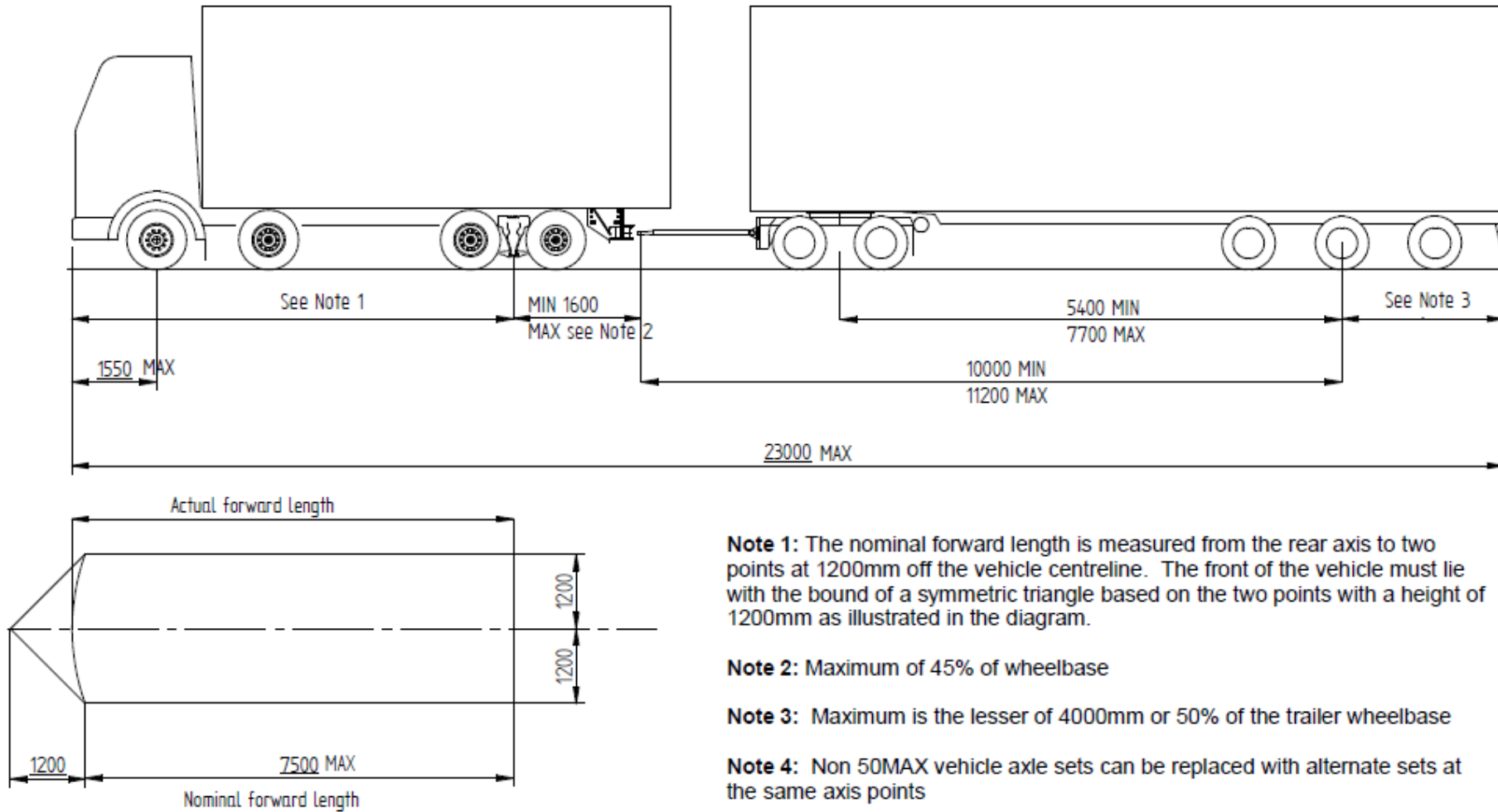


Figure 2. Proposed new 23m truck and long trailer pro-forma design with 1600mm minimum hitch offset.

## 23m Truck and long trailer-1800HO

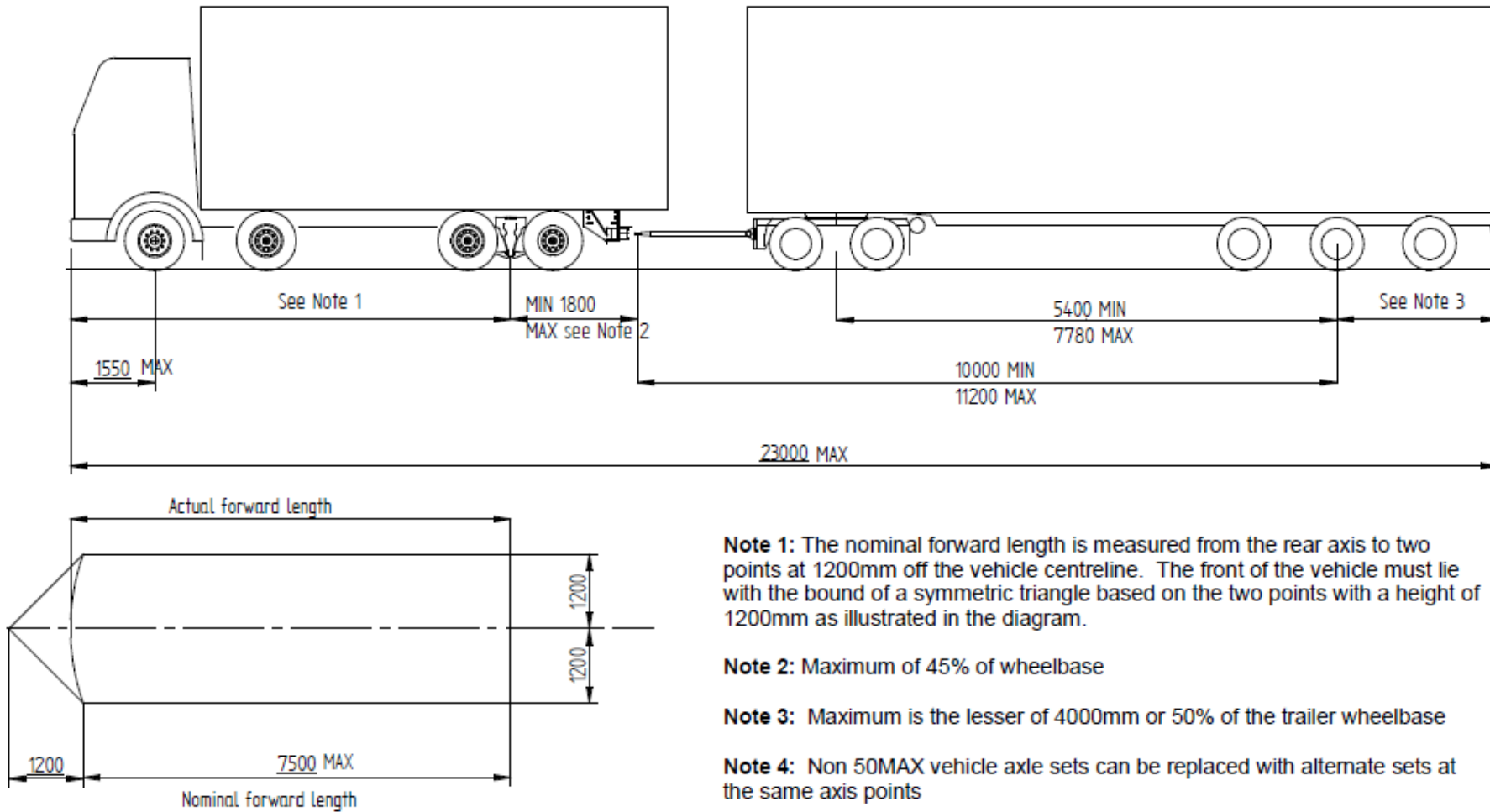


Figure 3. Proposed new 23m truck and long trailer pro-forma design with 1800mm minimum hitch offset.

# 23m Truck and long trailer-2000HO

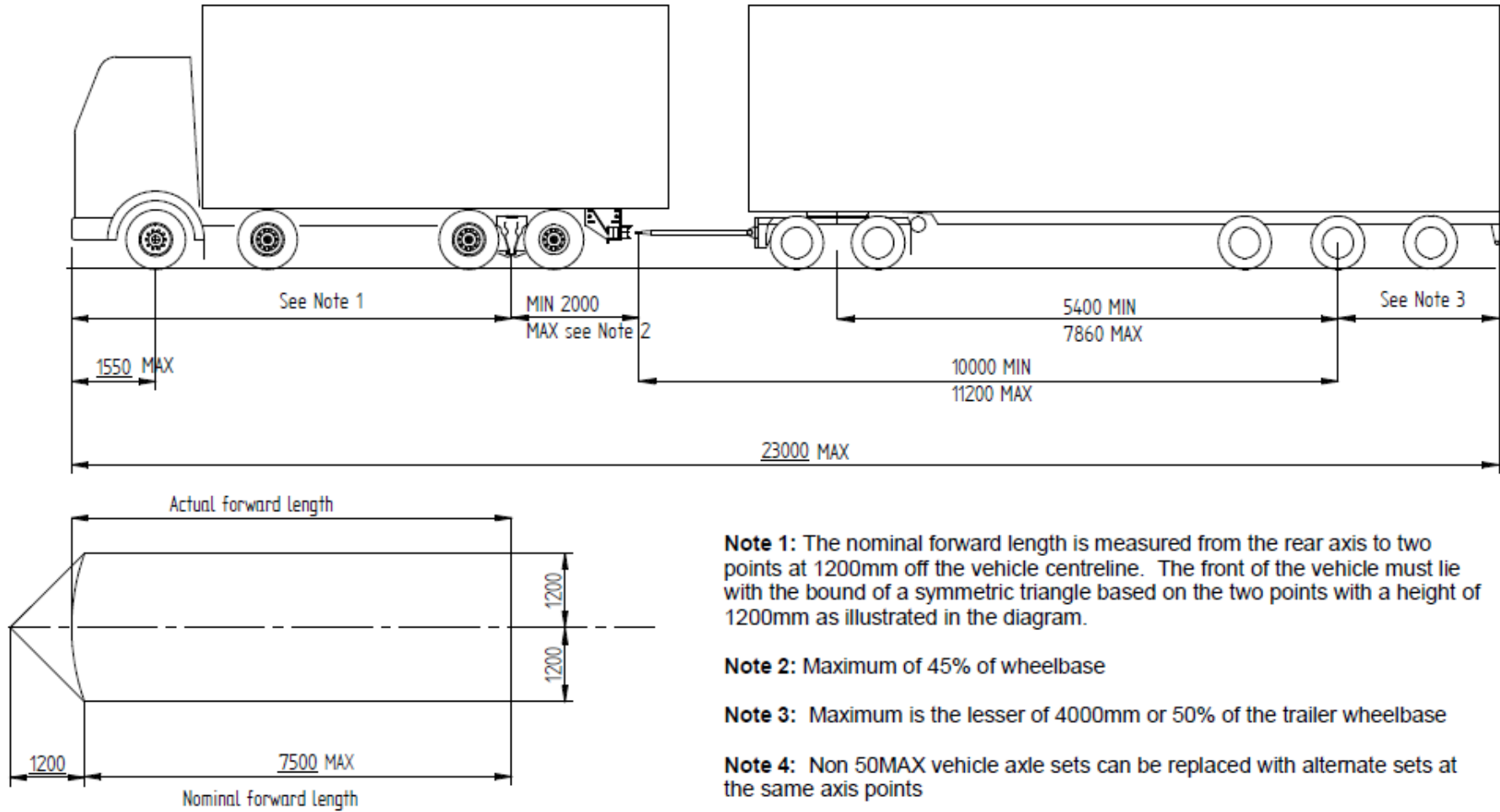


Figure 4. Proposed new 23m truck and long trailer pro-forma design with 2000mm minimum hitch offset.

## 23m Truck and long trailer-2200HO

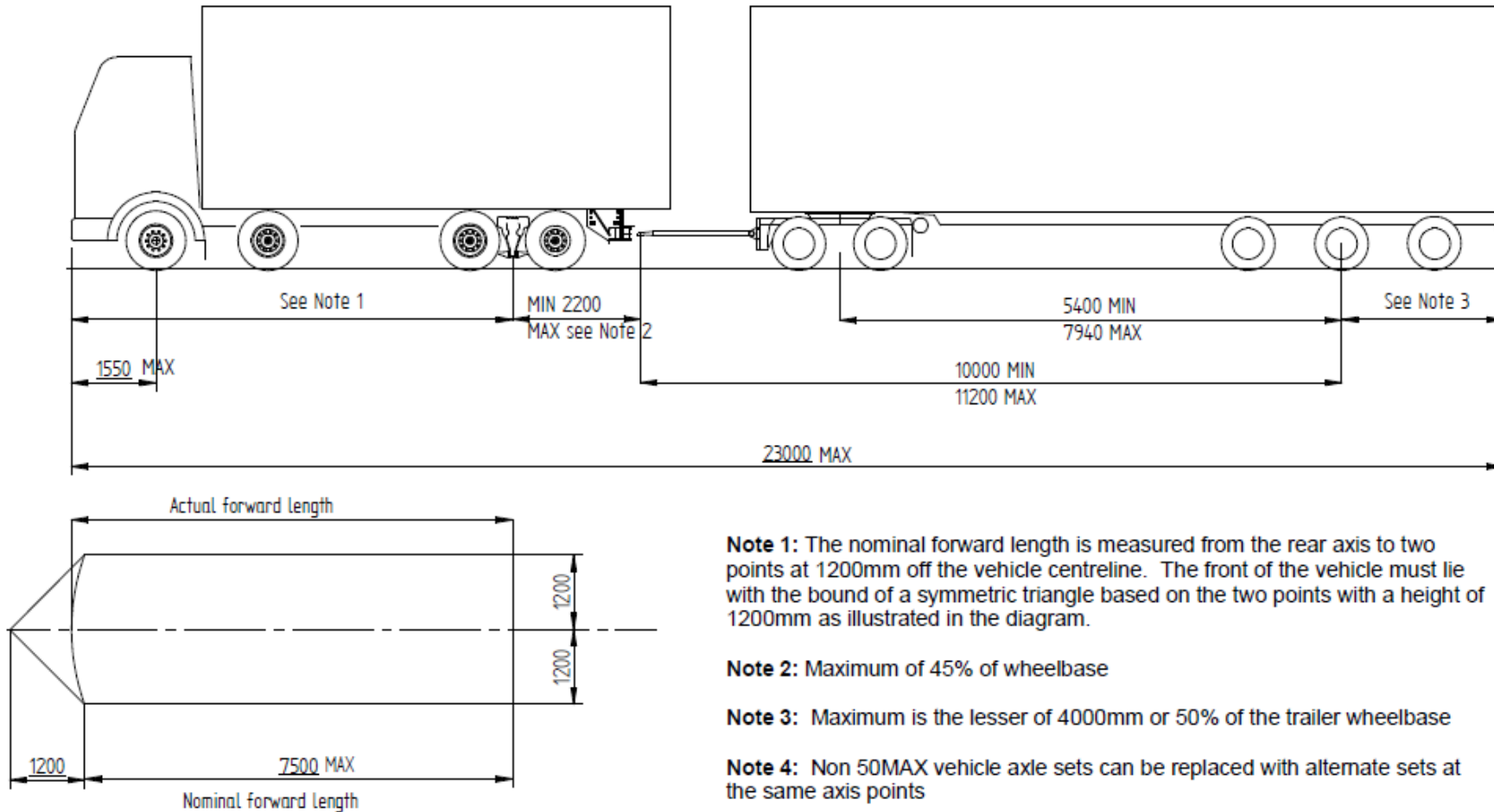


Figure 5. Proposed new 23m truck and long trailer pro-forma design with 2200mm minimum hitch offset.

## 23m Truck and long drawbar trailer

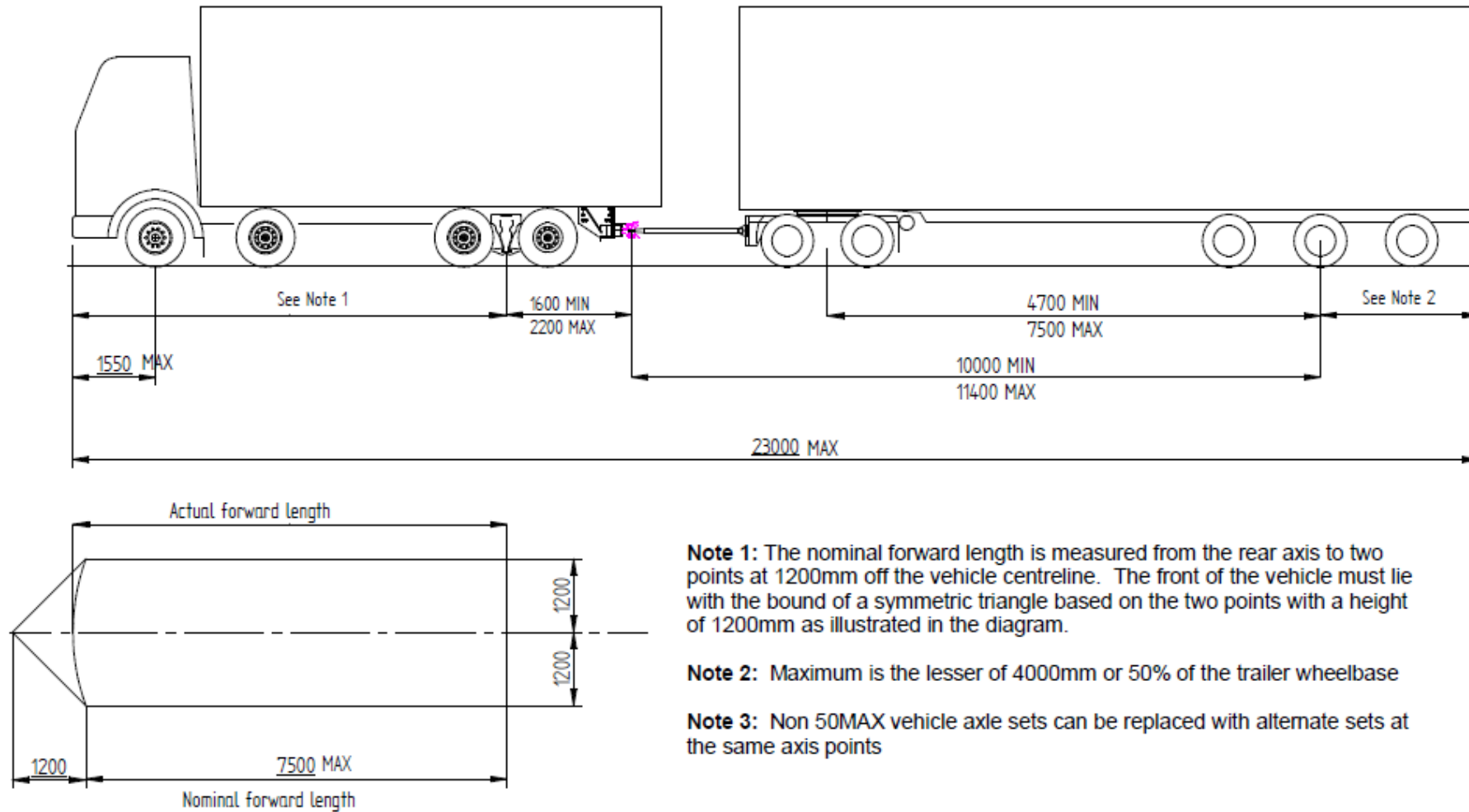


Figure 6. Proposed new 23m truck and long drawbar trailer pro-forma design.