

DESIGN BULLETIN #66/2010

Highway Geometric Design Guide Chapter B, Climbing Lane Warrants for Two Lane Undivided and Four Lane Divided Highways - Revised

Summary

This Design Bulletin is being issued as an amendment to Chapter B.5.3.1 – Climbing Lane Warrants for Two Lane Undivided Highways and Chapter B.5.3.2 – Climbing Lane Warrants for Four Lane Divided Highways of the Alberta Transportation Highway Geometric Design Guide 1995, Updated 1999. The revisions are needed due to changes in vehicle performance, average running speeds and due to a need to make all geometric improvements cost-effective.

Key Changes

Changes have been made to the department's practice for constructing climbing lanes on rural **two-lane highways** as follows (Refer to Section B.5.3.1 of the Design Guide for the current warrant):

- Climbing lanes are considered “warranted” when either all of the first three conditions OR condition 4 is met. The four conditions are for 1) speed reduction of the design vehicle 2) heavy traffic volume 3) level-of-service in the upgrade direction during the design hour is “C” or lower and 4) economic justification as shown below.
- Condition 1: A 15 km/h speed reduction is experienced by the design vehicle. For the purpose of calculating the speed reduction it is assumed that the design vehicle entry speed is 95 km/h and the mass power ratio is based on the 85th percentile design vehicle (i.e. at least 85% of the heavy vehicles travelling in the upgrade direction in the design hour must be able to perform as well as the design vehicle). The standard mass power ratio for the design truck is 180 g/W. Exceptions to the standard design vehicle mass/power ratio should only be made where records of the actual mass/power ratio of the vehicles in the traffic stream indicate that a different value would more closely represent the 85th percentile heavy vehicle. Vehicle performance curves are provided in the Design Guide for 200 g/W, 180g/W, 150g/W, 120g/W and 60g/W.
- Condition 2: The heavy traffic (T) must exceed 45 heavy vehicles on the grade in the design hour (i.e. counting heavy vehicles travelling in both directions on the grade). The AADT that would meet this warrant is dependent on the design hour factor (k) and the % of heavy vehicles however for example, if $k = 0.15$ and % heavy vehicles = 15%, then the design AADT meeting this warrant would be 2000 (i.e. $2000 \times 0.15 \times 0.15 = 45$).

- Condition 3: Traffic travelling in the upgrade direction in the design hour must experience a Level-of-Service of “C” or lower to warrant a climbing lane. The analysis should be based on the methodology for undivided highways as shown in the Highway Capacity Manual, TRB (HCM 2000 - Metric).
- Condition 4: The economic justification of a climbing lane must be established using the department’s Benefit Cost Guidelines. Benefits shall include predicted improvement in collision experience and reduced road user costs due to reduced delay. When all costs and benefits are considered and discounted as per the standard methods, the Internal Rate of Return for the climbing lane work must be at least 4% at year 20 to be considered “justifiable”.

In the case of **divided highways**, the current warrant is unchanged except that the Level-of-Service in the upgrade direction in the design hour must drop to “C” or lower in order to meet the warrant for climbing lane. Refer to Section B.5.3.2 of the Design Guide for the current warrant. The analysis should be based on the methodology for multi-lane highways as outlined in the Highway Capacity Manual, TRB (HCM 2000 - Metric).

The new warrants as indicated in this Bulletin are to be implemented immediately as per the usual practice. For new construction projects that meet the warrant, the construction of climbing lanes should normally be included in the construction project (subject to the usual programming constraints).

Obsolete Tables - Highway Geometric Design Guide, 1995, Updated 1999 - Tables (dated April 1995):

- *Table B -5.3.1b: Volume Warrants for Truck Climbing Lanes on Two Lane Highways – Passing Opportunity = 100%*
- *Table B -5.3.1c: Volume Warrants for Truck Climbing Lanes on Two Lane Highways – Passing Opportunity = 70%*
- *Table B -5.3.1d: Volume Warrants for Truck Climbing Lanes on Two Lane Highways – Passing Opportunity = 50%*
- *Table B -5.3.1e: Volume Warrants for Truck Climbing Lanes on Two Lane Highways – Passing Opportunity = 30%*

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Contact

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References

Highway Geometric Design Guide, 1995 (Updated 1999) – Alberta Transportation
 Highway Capacity Manual, TRB (HCM 2000 - Metric)

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B.5 CLIMBING AND PASSING LANES

B.5.1 Introduction

Auxiliary lanes are additional lanes that can be provided at selected locations along highways to facilitate turning, deceleration, acceleration, passing or low velocity climbing (climbing lanes). Auxiliary lanes for turning, deceleration, or acceleration are normally provided at intersection treatments and therefore are included in Chapter D. Climbing lanes and passing lanes are generally required due to the characteristics of the vertical and horizontal alignment, together with other factors, and therefore are covered in this chapter.

B.5.2 Geometric Features of Climbing and Passing Lanes

The following geometric criteria should be met in provision of climbing or passing lanes.

B.5.2.1 Lane Width

The width of the auxiliary lane should be the same as the through lane, that is, 3.7m for design designation of RAU-211.8 and higher or 3.5m for design designations of RAU-210 and lower.

B.5.2.2 Shoulder Width

The shoulder adjacent to the auxiliary lane should be equal to the lesser of 1.5m or the standard shoulder width on that design designation of highway.

B.5.2.3 Superelevation

Superelevation on the climbing lane portion of the roadway surface should generally be the same as on the adjacent through lane. However, where operating speeds of heavy vehicles can be expected to be much lower than design speed, the designer may use judgment in selecting a lower superelevation rate. Superelevation on the passing lane portion of the roadway surface should be the same as the adjacent through lane.

B.5.2.4 Tapers

The taper at the beginning and end of climbing/passing lane should be 60:1. The 60:1 taper on the diverge should promote use of the right hand lane by all vehicles except those intending to overtake slower vehicles.

B.5.2.5 Proximity to Intersections

Locations that include or are in close proximity to intersections should be avoided because of possible operational difficulties. Where these situations cannot be avoided, a site specific analysis should be undertaken to determine the intersection treatment required. The treatment may require construction of an additional lane or relocation of the intersection.

B.5.2.6 Start and End Points and Length

The full width of a climbing lane should begin when the design truck has experienced a 15 km/h speed reduction. It should not be terminated until the design truck has regained the speed that it had at the beginning of the climbing lane.

A climbing lane could be started earlier or ended later if this would result in a noticeable improvement in traffic operations; for example, on roadways where the passing demand is high (due to high volume and/or high percentage of heavy vehicles) and the length of grade is short. Where it has been decided that a climbing lane should be lengthened, it is generally preferable to add to the beginning of the climbing lane. Beginning a climbing lane earlier (that is, before heavier vehicles have decreased their speed by 15 km/h) will allow following vehicles to pass without having to decelerate to 80 km/h. This results in a more efficient climbing lane when the passing demand is high and a generally higher level of service for the roadway. It is preferable that the length of climbing lane be minimized to less than two to three km to provide greater cost-effectiveness. Very long climbing lanes, especially on lower volume roads, tend to be under-utilized.

The desirable length of a passing lane is between 1.5 km and 2.0 km. This range is long enough to be adequate for dispersing queues while still being short enough to be cost effective.

With long continuous grades, it is occasionally impractical to continue a climbing lane for the

complete length required for the design truck to regain the entry speed. In this case, it is necessary to terminate the extra lane prematurely. It is important to ensure that there is good sight distance using decision sight distance criteria at the end point. It is also good practice to provide an extra wide shoulder (3.5m) for some length after the termination point. This length of wide shoulder should be sufficient to allow a vehicle travelling in the upgrade direction to come to a safe stop in an emergency situation, assuming the vehicle is at a reduced speed on the upgrade as shown by the design vehicle performance charts. The designer may use the appropriate stopping sight distance as a guide. The wide shoulder will serve as an escape lane and should reduce the occurrence of collisions at the merge area. The merge area can be very problematic for recreational vehicles and trucks, especially if the lane is ended prematurely. Under these circumstances, the absence of an escape lane can reduce the utilization and effectiveness of a climbing lane.

Very long passing or climbing lanes are especially undesirable on high volume two-lane highways because of the restricted passing for the opposing traffic stream. Current pavement marking guidelines in Alberta suggest that a double solid barrier line (prohibiting passing in the single lane direction) be painted at all passing/climbing lane locations on undivided highways where the AADT exceeds 4000. Where the AADT is less than 4000, passing is permitted in the single lane direction provided that passing sight distance is available. This is illustrated on Figure B-5.2.7.

B.5.2.7 Sight Distance at Start and End Points

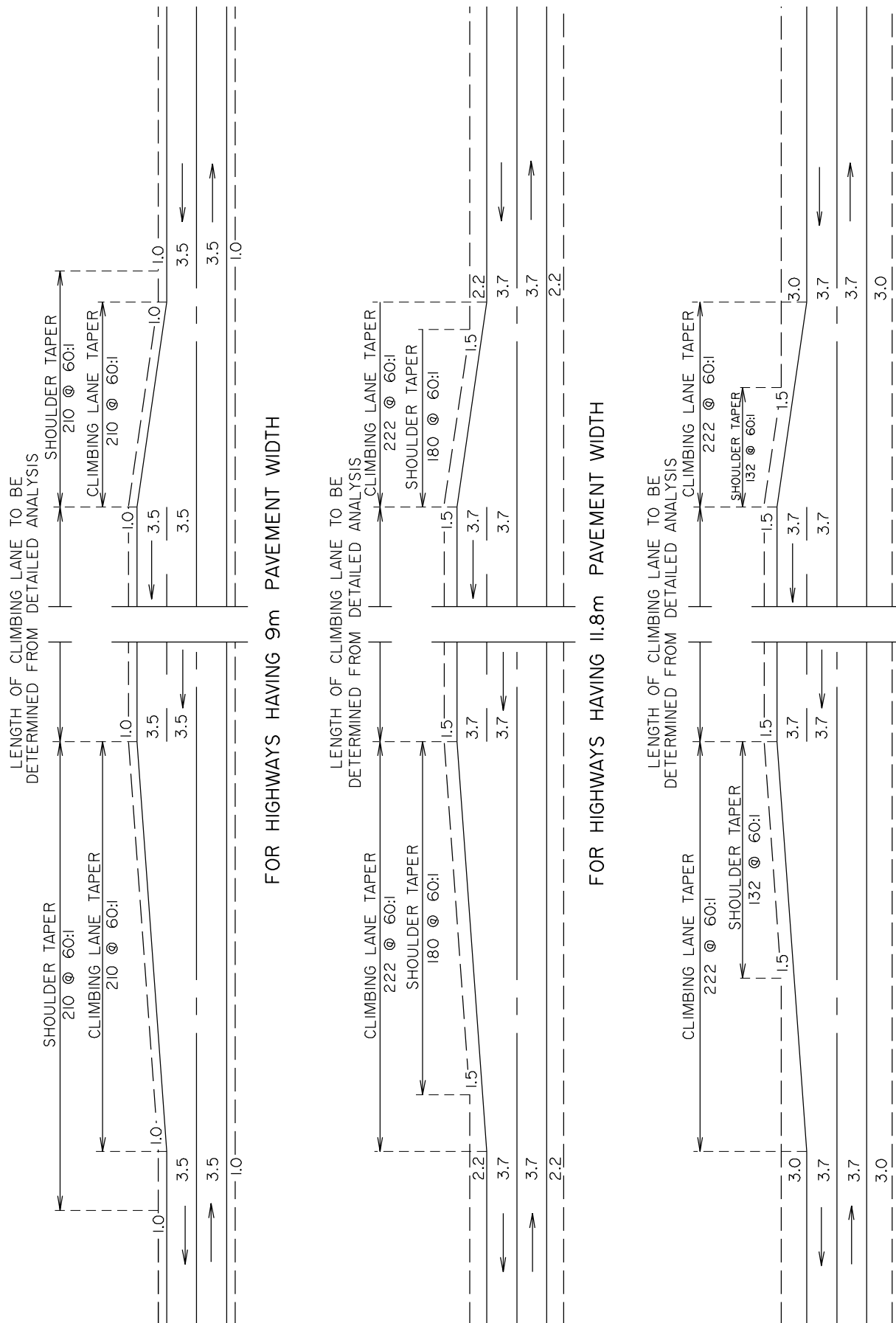
Decision sight distance should be available for drivers of passenger vehicles to see the pavement surface in the first half of the taper at the termination of a climbing lane or passing lane. A similar sight distance is desirable but not essential at the beginning of climbing or passing lanes. When measuring the decision sight distance, a height of eye 1.05m (corresponding to a passenger vehicle) and a height of object of 0 (corresponding to the roadway surface) should be used. The range of decision sight distances suggested for the termination of an auxiliary lane is shown on Table B.2.6.

For the purpose of measuring decision sight distance, the object can be assumed to be 120m past the beginning of taper at the termination of the climbing lane. The reasons for selecting this location are as follows:

1. A driver seeing the pavement surface at this point will know that there is a taper. (That is, the driver will already have seen the two arrows on the pavement, the end of the auxiliary lane line and the narrower pavement.)
2. The decision sight distance requirement includes four seconds for a manoeuvre (lane change) which could occur on the first half of the taper (a vehicle travelling at 110 km/h will travel approximately 120 m in four seconds).

For example, for a design speed of 110 km/h, the driver of a passenger vehicle should be able to see the pavement surface over the first 120m of taper from a point 210m - 310m before the taper begins. This should enhance the safety of merging operations. Figure B-5.2.7 illustrates the general layout of a climbing/passing lane including typical signing and pavement markings and the decision sight distance requirement.

FIGURE B-5.2 CLIMBING/PASSING LANES FOR VARIOUS PAVEMENT WIDTHS



FOR HIGHWAYS HAVING 13.4m PAVEMENT WIDTH

NOTE:
DIMENSIONS SHOWN ARE FINISHED SURFACE PAVEMENT WIDTHS.
ADDITIONAL SUBGRADE WIDTHS TO BE PROVIDED TO ALLOW FOR
DEPTH OF BASE COURSE AND PAVEMENT.

B.5.3 Climbing Lanes

Level of service and safety of operation on two-lane highways are impacted by the extent and frequency of passing sections. They are also adversely affected by heavily loaded vehicles operating on grades of sufficient length to result in speeds that could impede following vehicles. Because of the high number of collisions occurring on grades involving heavy vehicles, climbing lanes are commonly included in new construction of busier highways and additional lanes on existing highways are frequently built as safety improvement projects. The justification for these safety improvements is demonstrated by a plot of collision involvement rate for trucks on two-lane roads versus speed reduction. See Figure B-5.3.

It is desirable to provide a climbing lane as an extra lane on the upgrade side of a two-lane highway where the grade, traffic volume and heavy vehicle component combine to degrade traffic operations from those on the approach to the grade. Where climbing lanes have been provided, there has been a high degree of compliance in their use by truck drivers. On highways with low volumes, only the occasional car is delayed. Climbing lanes, although desirable, may not be justified economically even where the critical length of grade is exceeded. A warrant system is used to identify those cases where a climbing lane is called for based on safety and overall cost-effectiveness.

B.5.3.1 Climbing Lane Warrant for Two-Lane Undivided Highways

Climbing lanes for two lane undivided highways are considered “warranted” when either all of the first three conditions are met OR condition 4 can be demonstrated. The four conditions are:

1. speed reduction of the design vehicle
2. heavy vehicle traffic volume (T)
3. level-of-service in the upgrade direction during the design hour must be “C” or lower OR
4. economic justification as shown below.

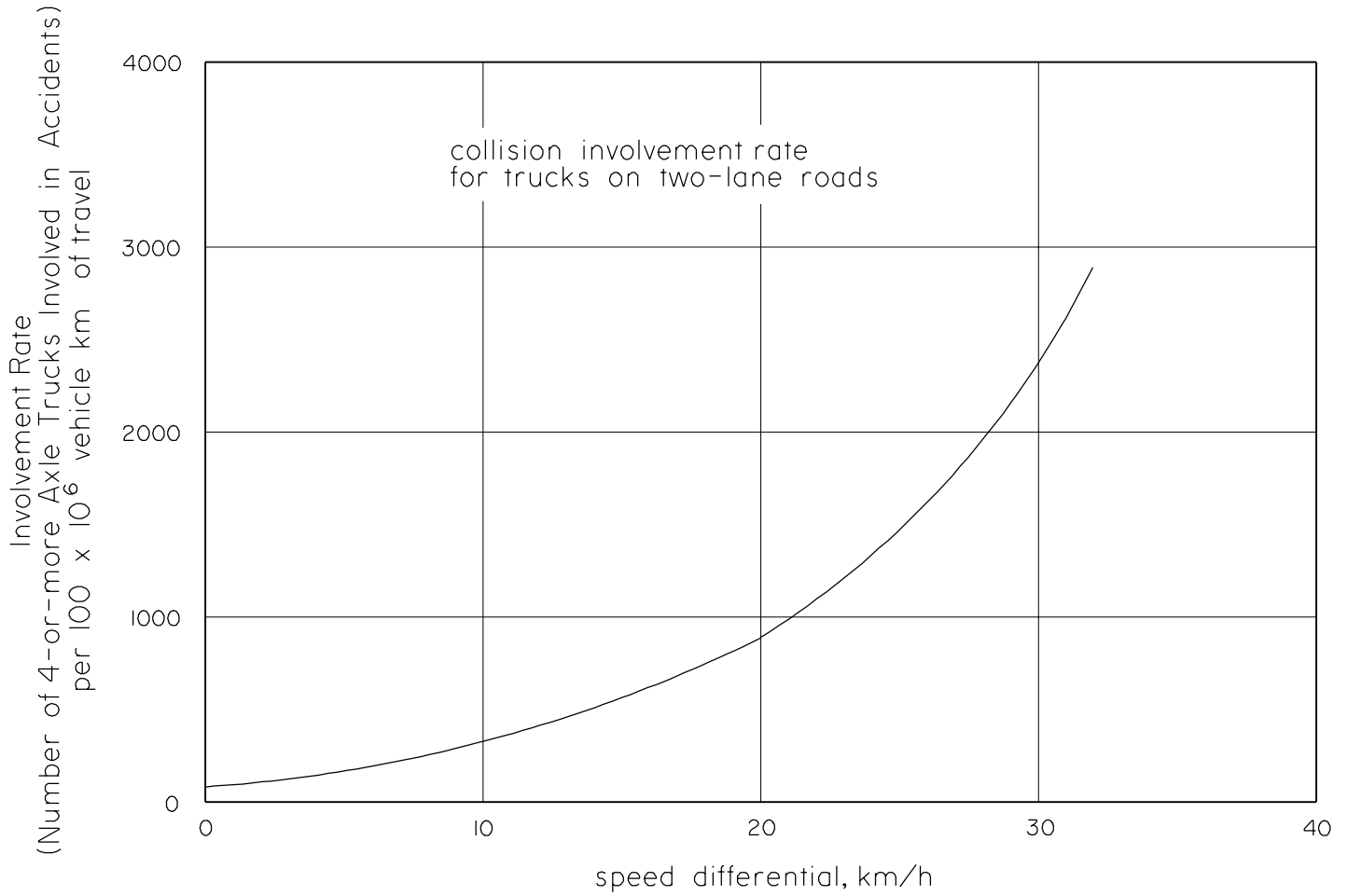
Condition 1: A 15 km/h speed reduction is experienced by the design vehicle. For the purpose of calculating the speed reduction it is assumed that the design vehicle entry speed is 95 km/h and the mass power ratio is based on the 85 percentile design vehicle (i.e. at least 85% of the heavy vehicles travelling in the upgrade direction must be able to perform as well as the design vehicle). The standard mass power ratio for the design vehicle is 180 g/W. Exceptions to the standard design vehicle mass/power ratio should only be made where records of the actual mass/power ratio of the vehicles in the traffic stream indicate that a different value would more closely represent the 85th percentile heavy vehicle. Vehicle performance curves are provided in the Design Guide for 200 g/W, 180g/W, 150g/W, 120g/W and 60g/W.

Condition 2: The heavy traffic (T) must exceed 45 heavy vehicles on the grade in the design hour (i.e. counting heavy vehicles travelling in both directions on the grade). The AADT that would meet this warrant is dependent on the design hour factor (k) and the % of heavy vehicles however for example, if $k = 0.15$ and % heavy vehicles = 15%, then the design AADT meeting this warrant would be 2000 (i.e. $2000 \times 0.15 \times 0.15 = 45$).

Condition 3: Traffic travelling in the upgrade direction in the design hour must experience a Level-of-Service of “C” or lower to warrant a climbing lane. The analysis should be based on the methodology for undivided highways as shown in the Highway Capacity Manual, TRB (HCM 2000 - Metric).

Condition 4: The economic justification of a climbing lane must be established using the department’s Benefit Cost Guidelines. Benefits should include predicted improvement in collision experience and reduced road user costs due to reduced delay. When all costs and benefits are considered and discounted as per the standard methods, the Internal Rate of Return for the climbing lane work must be at least 4% at year 20 to be considered “justifiable”.

FIGURE B-5.3 COLLISION INVOLVEMENT RATE OF TRUCKS FOR WHICH RUNNING SPEEDS ARE REDUCED BELOW AVERAGE RUNNING SPEEDS OF ALL TRAFFIC



Source: AASHTO, A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS, 1994 (PAGE 237)

Condition 1: Speed Reduction Warrant

A 15 km/h speed reduction is experienced by the design truck.

For the purpose of calculating the speed reduction of trucks on gradient the following assumptions are used:

- The design vehicle entry speed is 95 km/h
- The mass power ratio for the design vehicle is 180 g/W. (** refer to exceptions below)

The design vehicle entry speed is based on mean speed recorded for trucks on two-lane highways in Alberta. The mass/power ratio is based on a survey of the Alberta trucking industry together with a spot survey taken at provincial vehicle inspection stations. The 180 g/W rating, which corresponds approximately to 300lbs/hp used by many U.S. Transportation Departments, is based on the 85th percentile mass/power ratio, that is, 85 percent of the heavy vehicles in the upgrade traffic stream

should be able to perform as well or better than the design truck.

** Exceptions to the standard design vehicle mass/power ratio should only be made where records of the actual mass/power ratio of the heavy vehicles in the traffic stream indicate that a different value would more closely represent the 85th percentile heavy vehicle. Vehicle performance curves are provided in the Design Guide for 200 g/W, 180 g/W, 150 g/W, 120 g/W and 60g/W. An example of this may be a predominantly recreational route where more than 85 percent of the heavy vehicles are recreational, in which case a lower mass/power ratio (probably 120 g/W) would be appropriate.

Table B.5.3.1a may be used as a quick reference to determine if the speed reduction warrant is met on a particular grade. The truck performance curves should be used together with other considerations to determine the exact start and end point of the climbing lane.

Table B.5.3.1a - Critical Length of Grade in Metres for a Speed Reduction of 15 km/h

Design Vehicle Mass/Power Rating Metric Imperial	Grade in Percentage						
	2	3	4	5	6	7	8
60 g/W (100lb/hp)	N/A	N/A	740	410	240	190	180
120 g/W (200 lb/hp)	N/A	N/A	440	280	240	200	160
150 g/W (250 lb/hp)	730	360	280	220	170	140	-
180 g/W (300 lb/hp)*	550	340	260	210	160	120	-
200 g/W (325 lb/hp)	520	320	260	210	160	120	

Note: * 180 g/W is normally used for 2 lane highways.

1. Length of specified grade at which the designated design vehicle speed is reduced by 15 km/h from its entry speed (entry speed assumed to be 95 km/h)
2. Conversion factor: 1 g/W = 1.645 lb/hp
3. Values shown above have been rounded.

Condition 2: Heavy Vehicle Volume

The heavy traffic (T) must exceed 45 veh/hour in the design hour.

Note: T is defined as the total number of tractor trailer-combinations and single unit trucks plus half of the recreational vehicles plus half of the buses. Buses and recreational vehicles generally perform better than trucks on grades.

The daily volume to be used for design purposes is generally the AADT, unless the ASDT or AWDT is more than 15 percent greater than AADT, in which case the higher number should be used.

The reasons for recommending this volume warrant are as follows:

1. It is necessary to choose a minimum volume for which climbing lanes would be built. Use of the level of service criteria alone could result in some relatively low volume roads warranting climbing lanes, even though they are not cost effective, based on collision reduction or road user savings. A volume of 45 heavy vehicles/hour = 23 loaded heavy vehicles/hour = 12 loaded heavy vehicles/direction/hour. The presence of one loaded heavy vehicle travelling in the upgrade direction every 5 minutes in the design hour (100th highest hour of the design year) does not represent a serious congestion problem nor would it normally be a serious safety problem. The 50/50 percentage of loaded/unloaded trucks is a typical ratio and may vary depending on site conditions or known variances.
2. A warrant which is based on volume only without consideration of length of grade, steepness and traffic composition would be too simplistic. Alberta's warrant considers all those variables by using the level of service on the upgrade and the minimum number of heavy vehicles.
3. A review of the geometry and traffic conditions on existing climbing lanes on Alberta's Provincial highway system shows that neither the volume nor the level of service criteria recommended in this warrant are too high.

Condition 3: LOS Warrant: Two-Lane Undivided Highways

The level of service on the grade must be LOS C or lower in the design hour on the two-lane roadway, that is, if the level of service on the grade in the design hour is LOS B or LOS A, a climbing lane is not required.

If the LOS required for the warrant is projected to occur in the first half of the design life, the climbing lane shall be considered "**warranted**", that is, it is not necessary to justify a climbing lane based on the initial traffic volume provided that the warrant can be met in the first half of the design life.

Condition 4: Economic Justification

Although 45 heavy vehicles/hour (in the design hour) is set as a general warrant, it is noted that inclusion of climbing lanes in low volume situations should be considered if shown to be cost-effective. For example, construction of climbing lanes may be less costly on new construction projects or on projects where the existing or proposed shoulder is wide. The benefits of providing climbing lanes may be greater if:

1. There is a high percentage of loaded trucks in the upgrade traffic stream
2. If the geometry of the highway, prior to the grade, is very restrictive for passing, thus resulting in a high demand for passing.

On particular projects, it may be possible to show that the construction of climbing lanes is cost effective (Condition 4) even though one or more of the first three conditions has not been met. In this case, the construction of climbing lanes would be considered "**warranted**".

To be considered cost-effective, the benefits (considering road user costs, time savings and reduction in collision costs) should be sufficient to give a four percent internal rate of return on the extra investment required for construction of the climbing lane. The four percent internal rate of return should result before the end of the design life of the improvement. This is usually 20 years but may be less if future twinning is scheduled. The department's Benefit Cost Analysis guidelines should be followed for the economic analysis.

The following is an example of the use of the climbing lane warrant for two-lane highways.

Example of Use of Climbing Lane Warrant for Two-Lane Highways

Listed below is the geometric and traffic information for a particular segment of two-lane roadway where construction of a climbing lane is being considered.

Design Designation:	RAU-211-110
Length of Grade:	1000 m
Average Gradient:	3%
Percentage of Passing Zones on Upgrade Segment:	50%, i.e., on a 2 lane roadway 50% of the centreline would be painted as a barrier zone.
Design Truck (85 th percentile):	180 g/W
Design/Existing AADT:	2133/1422 Based on 20 year design life and 2.5% annual growth not compounded.
Traffic Composition:	TRTL: 8% SU: 3% RV: 6% BUS: 2% PV: 81%
Design Hour Factor (K)	0.15, i.e., Design Hour Volume = Design AADT × 0.15 = 320

Step 1: Check Speed Reduction Warrant

According to Table B.5.3.1a, a 15 km/h speed reduction would have occurred after 340 m at three percent using a 180 g/w design truck. Therefore, speed reduction warrant is definitely met on a **1000** m long three percent grade. The speed distance charts should be used to locate the points at which the 15 km/h speed reduction occurs on both the deceleration and acceleration portions of the vertical alignment.

Step 2: Check **LOS** Warrant

Based on the traffic composition, a value for T is calculated as shown below:

$$\begin{aligned}
 T &= \text{TRTL} + \text{SU} + 1/2 (\text{RV} + \text{BUS}) \\
 &= 8 + 3 + 1/2 (6 + 2) \\
 &= 15\%
 \end{aligned}$$

The LOS analysis should be based on the methodology for undivided highways as shown in the Highway Capacity Manual, TRB (HCM 2000 - Metric)..

Assume that the LOS =B prior to the specific grade . Using the following input data:

“HCM definition” Highway Class: Class 1
Shoulder width = 1.8 m Lane width = 3.7 m
Segment length = 1.0 km Grade = +3.0%
Peak Hour Factor = 0.88 Access Points/km = 0
Directional split = 60/40 % Trucks Crawling = 50
Truck Crawl Speed Difference = 30 km/h

HCM Output:
Average Travel Speed = 88 km/h
Percent Time Spent Following = 53%
LOS = C (or from HCM 2000, Exhibit 20-3, LOS (Graphical) for Two Lane Highways in Class 1)

Determine at what traffic volume and year would the LOS drop from LOS B to LOS C.

The existing AADT is 1422.

The design AADT is 2133, that is after 20 years with 2.5 percent annual growth not compounded. By an iterative process using HCM methodology, the drop from LOS B to LOS C would occur at about AADT 1900.

The projected AADT for the 13th year is 1900; that is, $1900 = 1422 \times [1 + X (0.025)]$.
 $X = 13$ th year

The LOS warrant for this grade is achieved in the 13th year and therefore a climbing lane is generally not warranted at this time.

Note: If the volume warrant was met on or before the 10th year, a climbing lane would generally be warranted.

TABLE B-5.3.1b VOLUME WARRANTS FOR TRUCK CLIMBING LANES
ON TWO-LANE HIGHWAYS - PASSING OPPORTUNITY = 100%
(on the two-lane highway)

Grade %	Length km	AADT									
		T=5%	T=10%	T=13%	T=15%	T=17%	T=20%	T=25%	T=30%	T=40%	T=50%
3	0.5	3,658	3,190	2,935	2,807	2,722	2,578	2,320	2,147	1,847	1,587
	1.0	3,374	2,833	2,610	2,441	2,315	2,147	1,933	1,727	1,447	1,273
	1.5	3,000	2,406	2,160	2,000	1,873	1,713	1,527	1,360	1,127	967
	2.0	3,000	1,660	1,433	1,300	1,220	1,067	927	820	633	567
	3.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
4	0.5	3,196	2,728	2,494	2,378	2,260	2,107	1,893	1,733	1,460	1,273
	1.0	3,000	2,265	2,040	1,887	1,773	1,640	1,453	1,260	1,040	893
	1.5	3,000	1,713	1,500	1,373	1,267	1,153	987	880	707	607
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
5	0.5	3,000	2,084	1,880	1,780	1,687	1,553	1,360	1,247	1,013	893
	1.0	3,000	1,593	1,413	1,287	1,213	1,087	933	847	667	580
	1.5	3,000	1,500	1,154	1,000	882	750	600	500	387	333
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
6	0.5	3,000	1,500	1,154	1,000	882	760	680	607	500	433
	1.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
7	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300

Warrant: AADT must exceed the numbers shown above to satisfy the traffic volume warrant for climbing lanes.

$$T = \% \text{ heavy vehicles} = \% [T.R.T.L. + S.U. + \frac{1}{2}(R.V. + BUS)]$$

T.R.T.L. = Tractor Trailers

S.U. = Single Unit Trucks

R.V. = Recreational Vehicle

Assumptions: Design speed 110 km/h. Passing opportunities 100% (based on pavement markings) peak hour factor 0.92, directional distribution 60/40, lane width 3.7m, shoulder width at least 1.8m, K=0.15 (Design Hour Volume = K x AADT).

This table is based on the principle that level of service A is acceptable on grade before climbing lane is warranted and that there should be at least 150 heavy vehicles on the grade each day before climbing lane is warranted on 2 lane roadways. With volumes exceeding the numbers shown on this chart, the heavy vehicle traffic (T) will exceed 150 per day and the level of service on the upgrade will be less than A in the design hour using the assumptions shown. Exceptions to this warrant may be made where cost-effectiveness is demonstrated. A designer should consider the traffic volume and composition over the design life of a facility when deciding whether or not a climbing lane is required. If the warrant is met at or before the 10th year on a project with a design life of 20 years, construction of a climbing lane is suggested.

OBSOLETE
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TABLE B-5.3.1c VOLUME WARRANTS FOR TRUCK CLIMBING LANES ON TWO-LANE HIGHWAYS - PASSING OPPORTUNITY = 70% (on the two-lane highway)

Grade %	Length km	AADT									
		T=5%	T=10%	T=13%	T=15%	T=17%	T=20%	T=25%	T=30%	T=40%	T=50%
3	0.5	3,000	2,488	2,280	2,187	2,120	2,007	1,807	1,673	1,440	1,233
	1.0	3,000	2,200	2,027	1,900	1,800	1,667	1,507	1,340	1,127	993
	1.5	3,000	1,873	1,680	1,553	1,460	1,333	1,187	1,060	873	753
	2.0	3,000	1,500	1,154	1,007	947	833	720	640	493	440
	3.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
4	0.5	3,000	2,127	1,947	1,853	1,760	1,640	1,473	1,353	1,133	993
	1.0	3,000	1,767	1,593	1,473	1,387	1,280	1,133	980	813	700
	1.5	3,000	1,500	1,173	1,073	987	900	767	687	553	473
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
5	0.5	3,000	1,540	1,387	1,313	1,247	1,147	1,007	920	747	660
	1.0	3,000	1,500	1,154	1,000	893	800	687	627	493	427
	1.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300
6	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	320
	1.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
7	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300

Warrant: AADT must exceed the numbers shown above to satisfy the traffic volume warrant for climbing lanes.

$$T = \% \text{ heavy vehicles} = \% [\text{T.R.T.L.} + \text{S.U.} + \frac{1}{2}(\text{R.V.} + \text{BUS})]$$

T.R.T.L. = Tractor Trailers

S.U. = Single Unit Trucks

R.V. = Recreational Vehicle

Assumptions: Design speed 110 km/h. Passing opportunities 70% (based on pavement markings), peak factor 0.92, directional distribution 60/40, lane width 3.7m, shoulder width at least 1.8m. $K=0.15$ (Design Hour Volume = $K \times \text{AADT}$). This table is based on the principle that level of service A is acceptable on grade before climbing lane is warranted on 2 lane roadways. With volumes exceeding the numbers shown on this chart, the heavy vehicle traffic (T) will exceed 150 per day and the level of service on the upgrade will be less than A in the design hour using the assumptions shown. Exceptions to this warrant may be made where cost-effectiveness is demonstrated. A designer should consider the traffic volume and composition over the design life of a facility when deciding whether or not a climbing lane is required. If the warrant is met at or before the 10th year on a project with a design life of 20 years, construction of a climbing lane is suggested.

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TABLE B-5.3.1d VOLUME WARRANTS FOR TRUCK CLIMBING LANES ON
TWO-LANE HIGHWAYS - PASSING OPPORTUNITY = 50%
(on the two-lane highway)

Grade %	Length km	AADT									
		T=5%	T=10%	T=13%	T=15%	T=17%	T=20%	T=25%	T=30%	T=40%	T=50%
3	0.5	3,000	2,127	1,956	1,871	1,815	1,719	1,547	1,433	1,233	1,060
	1.0	3,000	1,888	1,740	1,628	1,547	1,433	1,935	1,153	967	853
	1.5	3,000	1,604	1,440	1,333	1,253	1,140	1,020	907	747	647
	2.0	3,000	1,500	1,154	1,000	882	750	620	547	420	373
	3.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
4	0.5	3,000	1,855	1,696	1,617	1,540	1,433	1,287	1,180	993	867
	1.0	3,000	1,541	1,387	2,187	1,207	1,113	987	853	707	607
	1.5	3,000	1,500	1,154	1,000	882	787	673	593	480	413
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
5	0.5	3,000	1,500	1,160	1,100	1,040	960	840	773	627	553
	1.0	3,000	1,500	1,154	1,000	882	750	600	527	413	360
	1.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300
6	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300
7	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300

Warrant: AADT must exceed the numbers shown above to satisfy the traffic volume warrant for climbing lanes.

$$T = \% \text{ heavy vehicles} = \% [T.R.T.L. + S.U. + \frac{1}{2}(R.V. + BUS)]$$

T.R.T.L. = Tractor Trailers

S.U. = Single Unit Trucks

R.V. = Recreational Vehicle

Assumptions: Design speed 110 km/h. Passing opportunities 50% (based on pavement markings), peak hour 0.92, directional distribution 60/40, lane width 3.7m, shoulder width at least 1.8m, K=0.15 (Design Hour Volume = K x AADT). This table is based on the principle that level of service A is acceptable on grade before climbing lane is warranted and that there should be at least 150 heavy vehicles on the grade each day before climbing lane is warranted on 2 lane roadways. With volumes exceeding the numbers shown on this chart, the heavy vehicle traffic (T) will exceed 150 per day and the level of service on the upgrade will be less than A in the design hour using the assumptions shown. Exceptions to this warrant may be made where cost-effectiveness is demonstrated. A designer should consider the traffic volume and composition over the design life of a facility when deciding whether or not a climbing lane is required. If the warrant is met at or before the 10th year on a project with a design life of 20 years, construction of a climbing lane is suggested.

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TABLE B-5.3.1e VOLUME WARRANTS FOR TRUCK CLIMBING LANES ON
 TWO-LANE HIGHWAYS - PASSING OPPORTUNITY = 30%
 (on the two-lane highway)

Grade %	Length km	AADT									
		T=5%	T=10%	T=13%	T=15%	T=17%	T=20%	T=25%	T=30%	T=40%	T=50%
3	0.5	3,000	1,831	1,685	1,612	1,563	1,480	1,333	1,233	1,060	913
	1.0	3,000	1,626	1,498	1,402	1,327	1,233	1,113	993	833	733
	1.5	3,000	1,500	1,241	1,147	1,080	980	873	780	647	553
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	360	327
	3.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
4	0.5	3,000	1,582	1,447	1,379	1,313	1,220	1,093	1,007	847	740
	1.0	3,000	1,500	1,180	1,093	1,027	953	840	733	607	520
	1.5	3,000	1,500	1,154	1,000	882	750	600	507	413	353
	2.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
5	0.5	3,000	1,500	1,154	1,100	882	813	713	653	533	467
	1.0	3,000	1,500	1,154	1,000	882	750	600	500	375	300
6	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300
7	0.5	3,000	1,500	1,154	1,000	882	750	600	500	375	300

Warrant: AADT must exceed the numbers shown above to satisfy the traffic volume warrant for climbing lanes.

$$T = \% \text{ heavy vehicles} = \% [T.R.T.L. + S.U. + \frac{1}{2}(R.V. + BUS)]$$

T.R.T.L. = Tractor Trailers

S.U. = Single Unit Trucks

R.V. = Recreational Vehicle

Assumptions: Design speed 110 km/h. Passing opportunities 30% (based on pavement markings) peak hour 0.92, directional distribution 60/40, lane width 3.7m, shoulder width at least 1.8m, K=0.15 (Design Hour Volume = K x AADT). This table is based on the principle that level of service A is acceptable on grade before climbing lane is warranted and that there should be at least 150 heavy vehicles on the grade each day before climbing lane is warranted on 2 lane roadways. With volumes exceeding the numbers shown on this chart, the heavy vehicle traffic (T) will exceed 150 per day and the level of service on the upgrade will be less than A in the design hour using the assumptions shown. Exceptions to this warrant may be made where cost-effectiveness is demonstrated. A designer should consider the traffic volume and composition over the design life of a facility when deciding whether or not a climbing lane is required. If the warrant is met at or before the 10th year on a project with a design life of 20 years, construction of a climbing lane is suggested.

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B.5.3.2 Climbing Lane Warrant for Four-Lane Divided Highways

The addition of climbing lanes to four-lane divided highways need not be considered if the AADT is less than 12,000, regardless of grades or percentages of trucks, because of the generally high level of service provided by a four-lane divided facility with this traffic volume. If the AADT exceeds 12,000 and the design truck experiences a speed reduction exceeding 15 km/h, the level of service on the upgrade segment in the design hour should be compared to the level of service on the approach segment. The level of service in the upgrade direction in the design hour must be C or lower in order to meet the warrant for a climbing lane.

There has been little application of climbing lanes to divided highways in Alberta to date, due to the generally high level of service that exists on provincial divided facilities.

B.5.3.3 Determining Length and Location of Climbing Lanes

Once the need for a climbing lane has been established by satisfying the speed reduction and traffic volume warrants, the exact start and end points and length are determined using the truck performance curves (Figures B-5.3.3b through B-5.3.3k).

The following example illustrates the use of the truck performance curves.

Example of use of truck performance curves

The vertical alignment and truck performance curves are shown on Figure B-5.3.3a. The design truck is assumed to have a mass/power ratio of 180 g/W, as this is the standard truck. The dashed lines superimposed on the performance curves of Figure B-5.3.3a show the plot of the design truck speed throughout the alignment section as follows.

1. Entry speed = 95 km/h (assumed) at PI #1 (point of intersection)
2. Truck decelerates to 52 km/h at PI #2 due to 800m upgrade at four percent
3. Truck decelerates to crawl speed (26 km/h) due to 600m upgrade at six percent

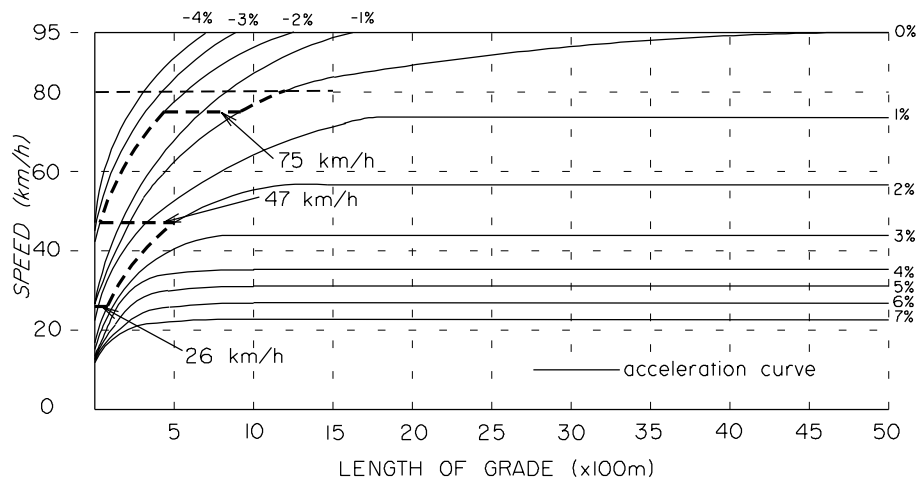
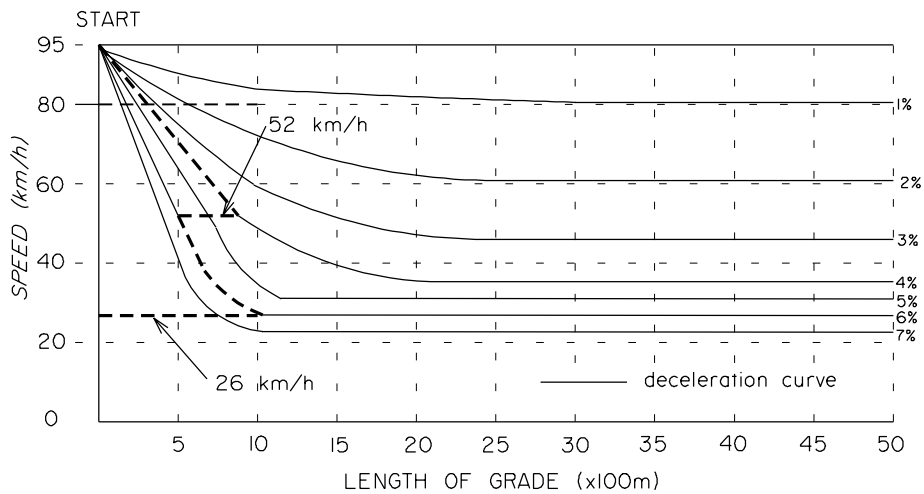
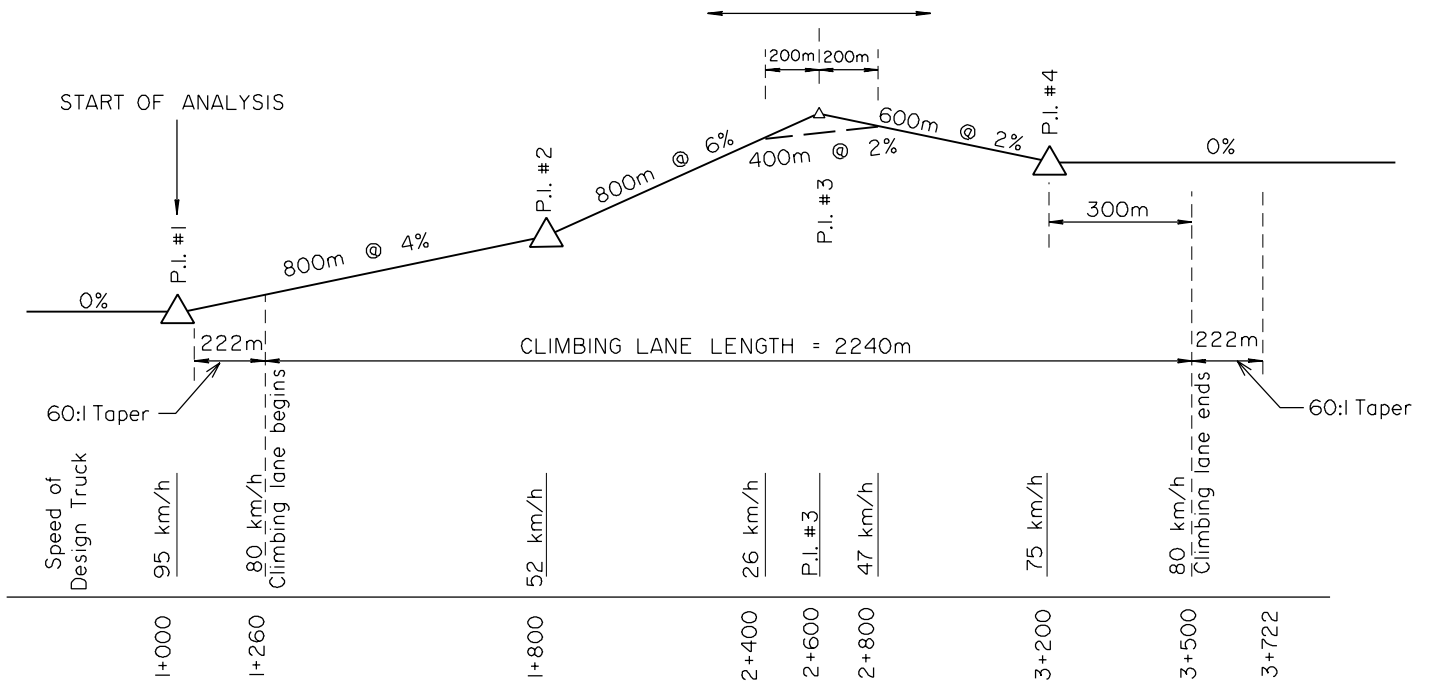
The design truck now experiences a grade change whose algebraic difference exceeds four percent; that is, $+6\% - (-2\%) = +8\%$.

When the algebraic difference exceeds four percent, the vertical curve connecting the grades is approximated through the average grades connecting the quarter points on the semi-tangents of the vertical curve. These quarter points act as new PI's for the purpose of estimating the design vehicle speed. In this example, the length of the vertical curve is 800m. Therefore the quarter points occur at 200m on either side of the real PI and the grade connecting the quarter points has been estimated at two percent. This approximated grade, 400m in length, reduces the length of the preceding and following grades by 200m each. (The dashed line now enters the acceleration portion of the chart, as the design truck accelerates on the two percent upgrade).

4. Truck accelerates from crawl speed (26 km/h) to 47 km/h on the 400m, two percent upgrade
5. Truck accelerates from 47 km/h to 75 km/h at PI #4 on the 400m, two percent downgrade
6. Truck accelerates from 75 km/h to 80 km/h (the merge speed) on a 300m, zero percent grade.

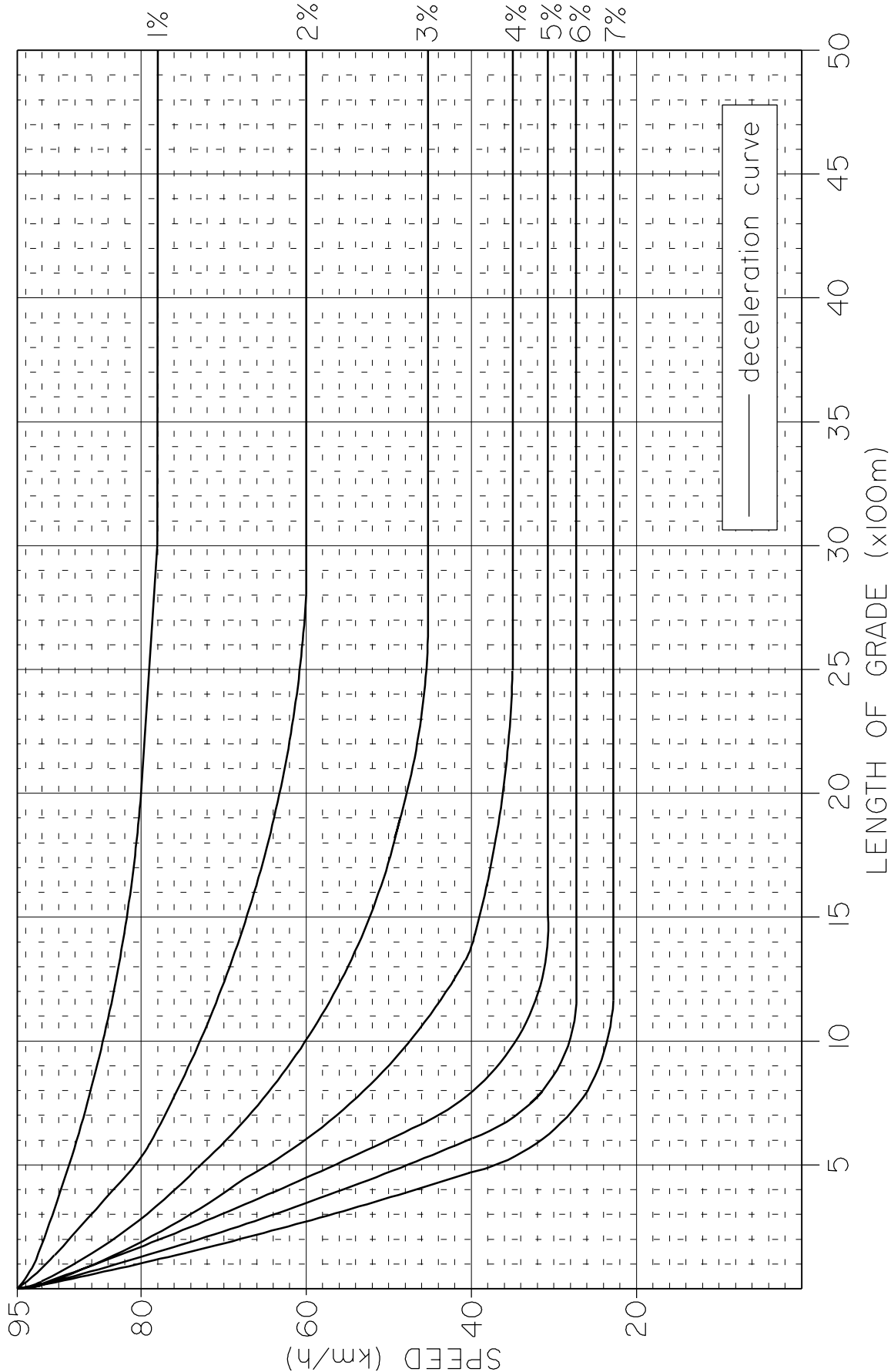
As per the plot shown on Figure B.5.3.3a, the climbing lane should begin when the design truck speed reaches 80 km/h (this occurs at 1+260). The 60:1 taper should be introduced before this point. The end point of the climbing lane can be placed anywhere after the merge speed has been achieved, that is, after 3+500, provided that the decision sight distance is available. The merge taper is placed after the end of climbing lane.

FIGURE B-5.3.3a CLIMBING LANE DESIGN EXAMPLE



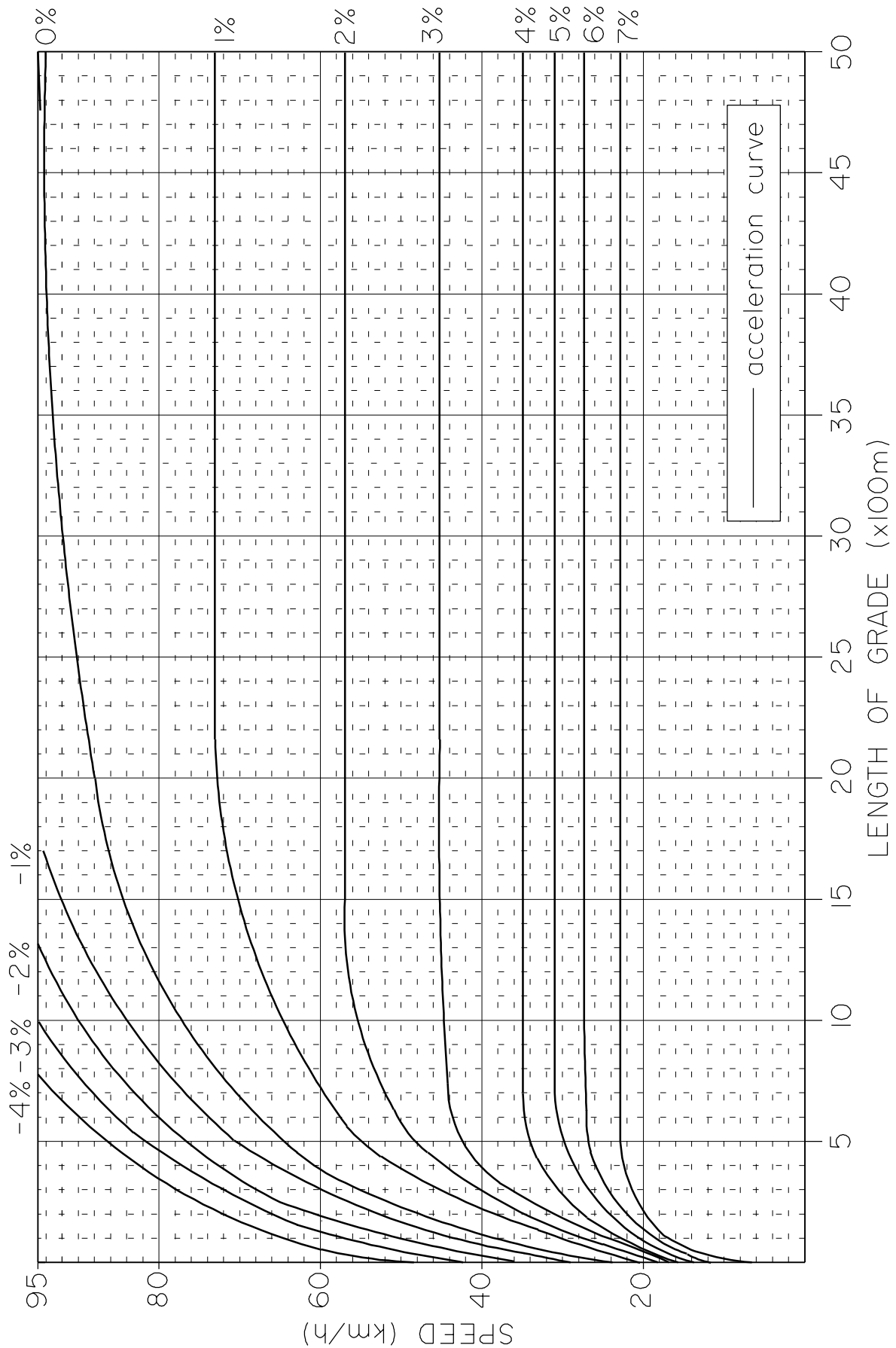
Performance Curves for Heavy Trucks (180g/W)
Adopted from Highway Capacity Manual 1985

FIGURE B-5.3.3b PERFORMANCE CURVES FOR HEAVY TRUCKS 180 g/w
DECELERATION CURVE



Adapted from Highway Capacity Manual, Figure 1.3-4, published by
Transportation Research Board, National Research Council, Washington D.C. (1985)

FIGURE B-5.3.3c PERFORMANCE CURVES FOR HEAVY TRUCKS 180 g/w
ACCELERATION CURVE



Adapted from Highway Capacity Manual, Figure 1.3-4, published by
Transportation Research Board, National Research Council, Washington D.C. (1985)

FIGURE B-5.3.3d PERFORMANCE CURVES FOR HEAVY TRUCKS 200 g/w
DECELERATION CURVE

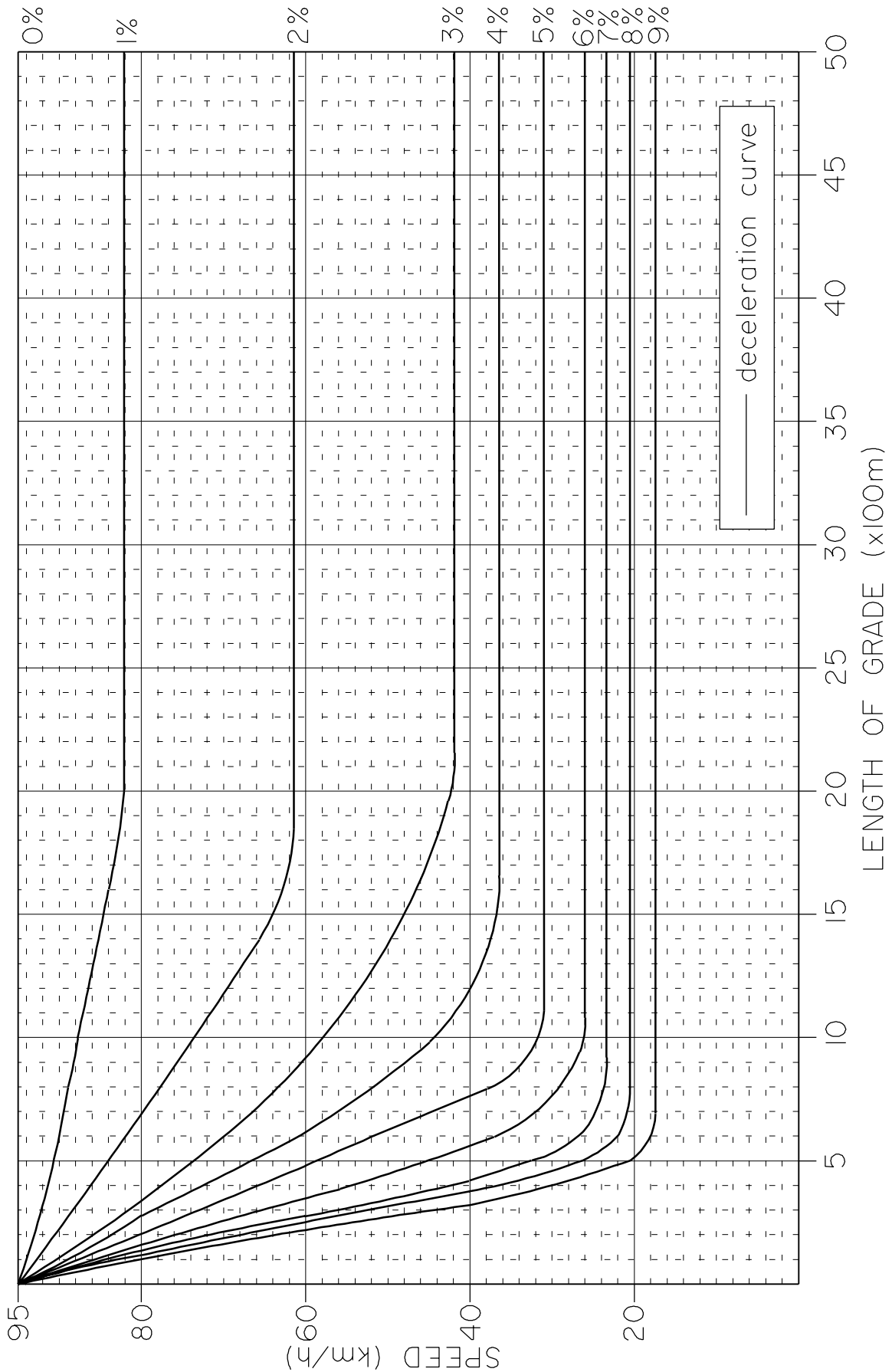


FIGURE B-5.3.3e PERFORMANCE CURVES FOR HEAVY TRUCKS 200 g/w
 ACCELERATION CURVE

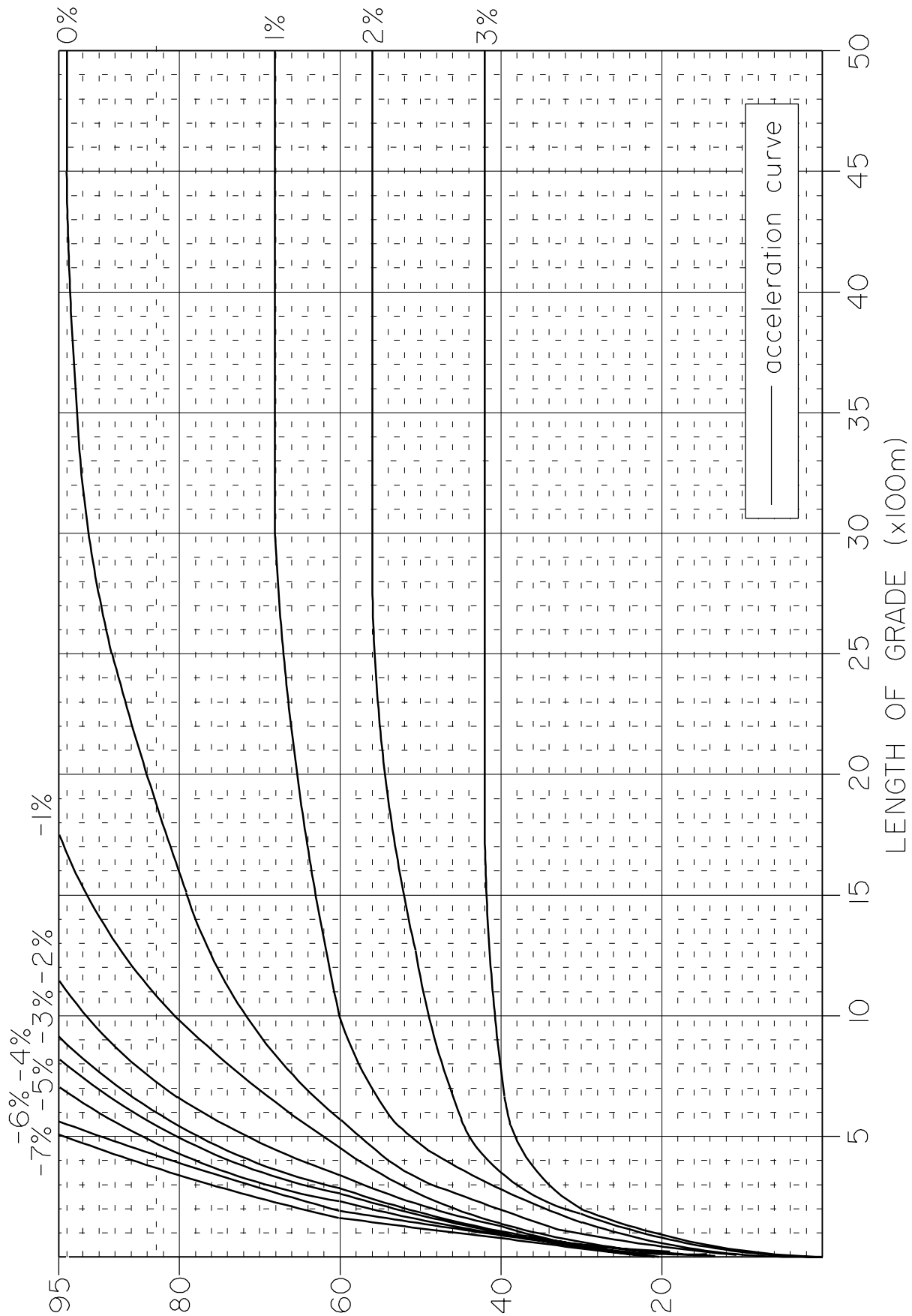


FIGURE B-5.3.3f PERFORMANCE CURVES FOR HEAVY TRUCKS 150 g/w
DECELERATION CURVE

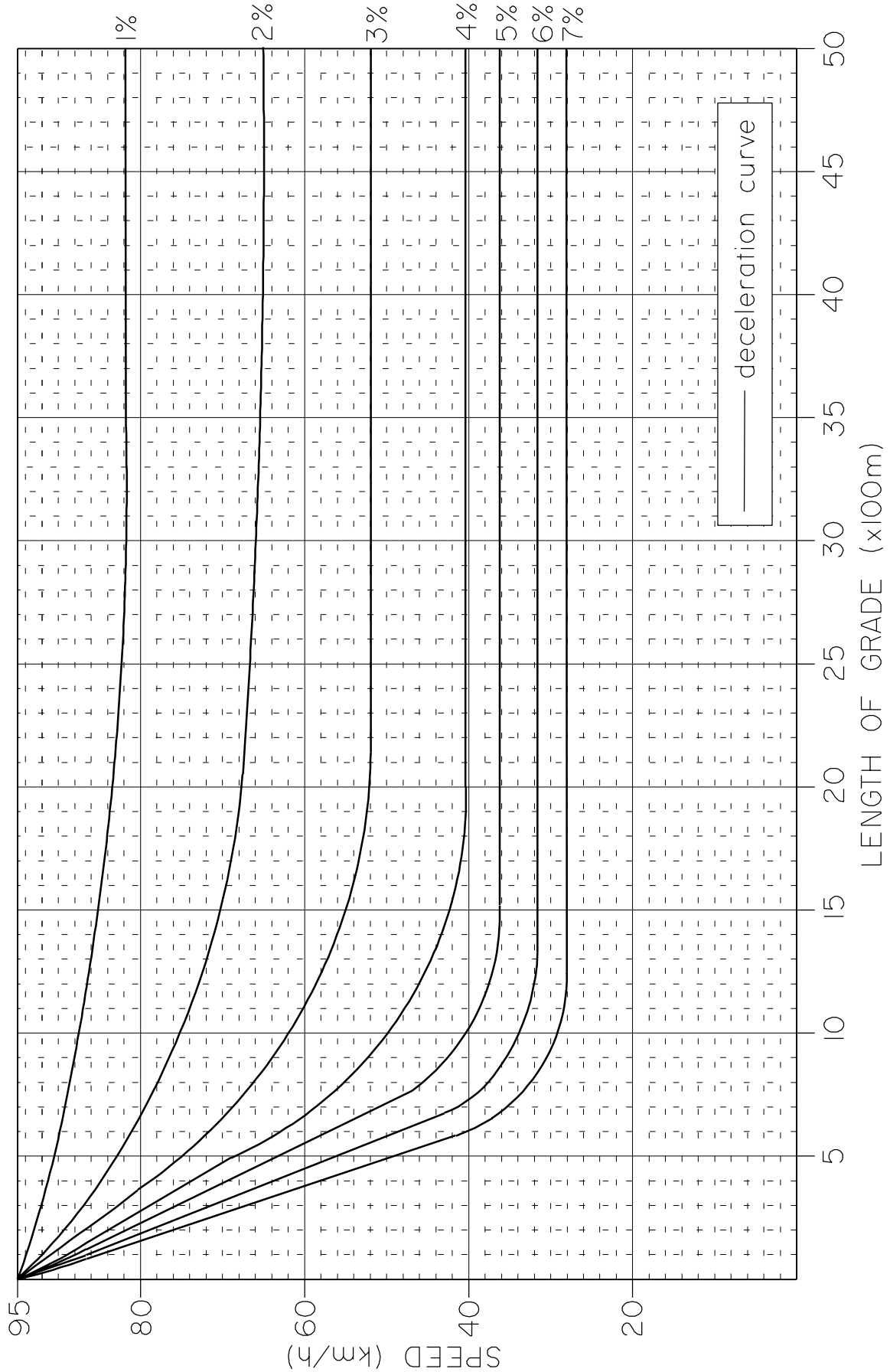


FIGURE B-5.3.3g PERFORMANCE CURVES FOR HEAVY TRUCKS 150 g/w
 ACCELERATION CURVE

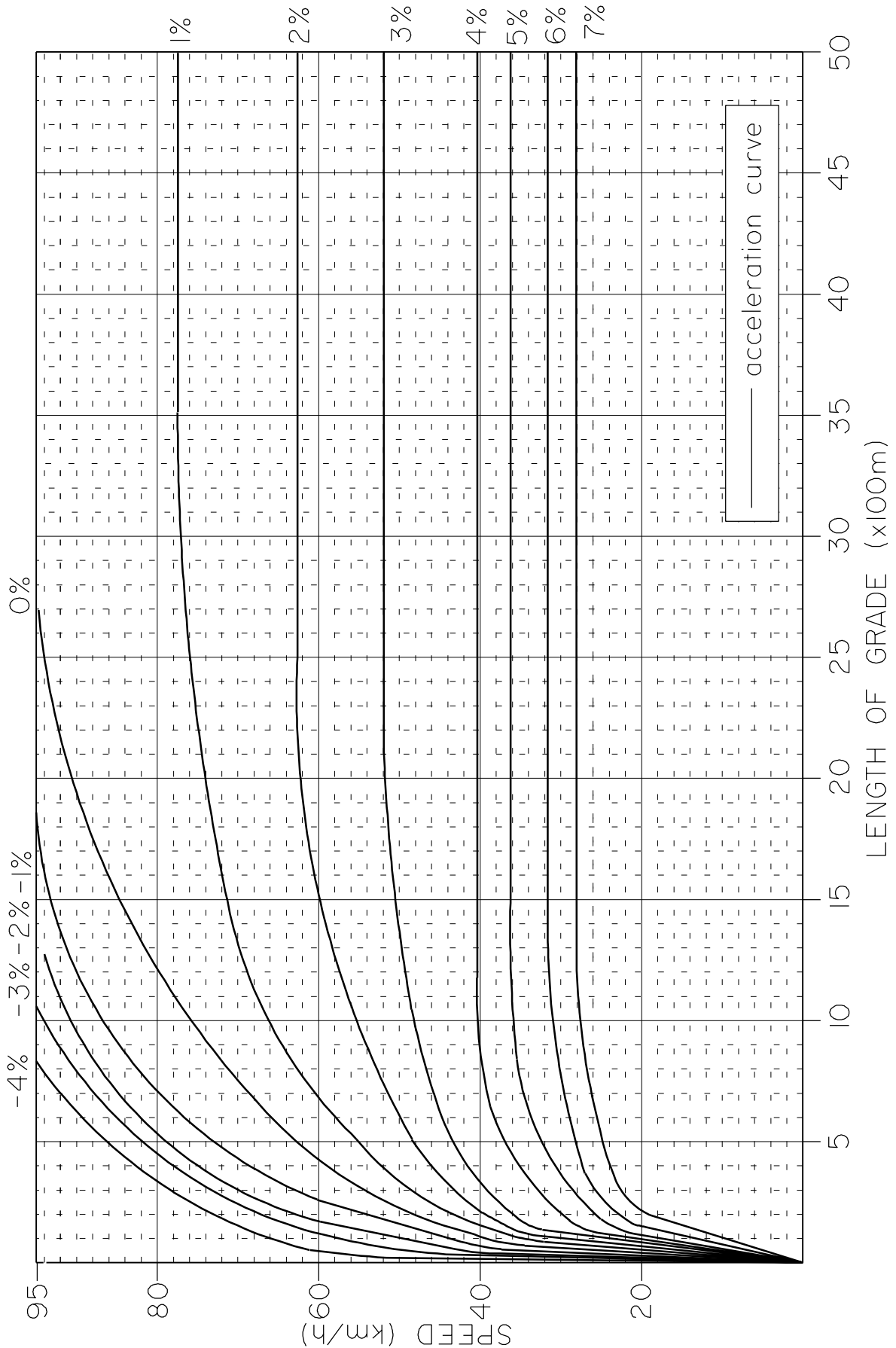
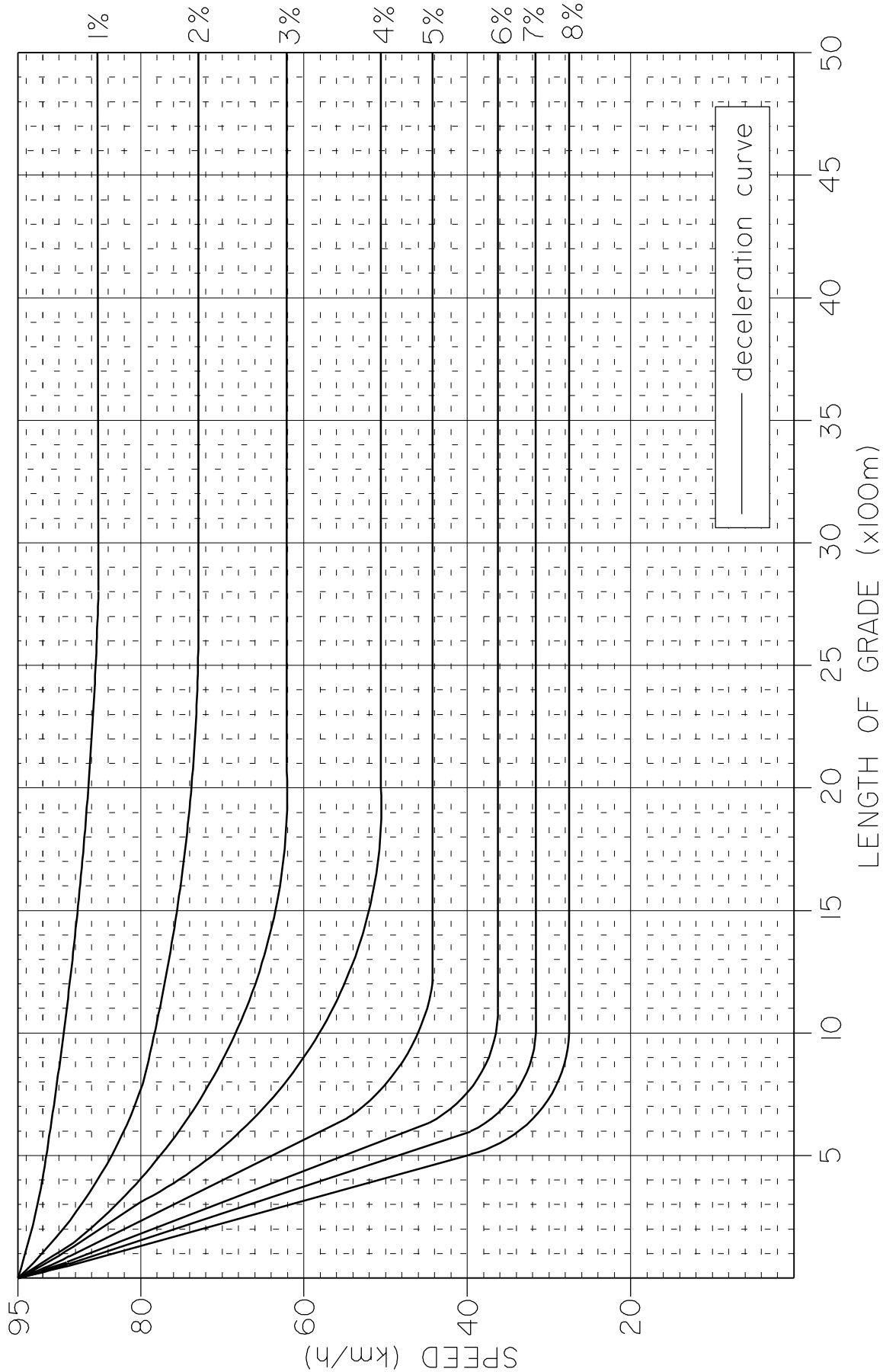
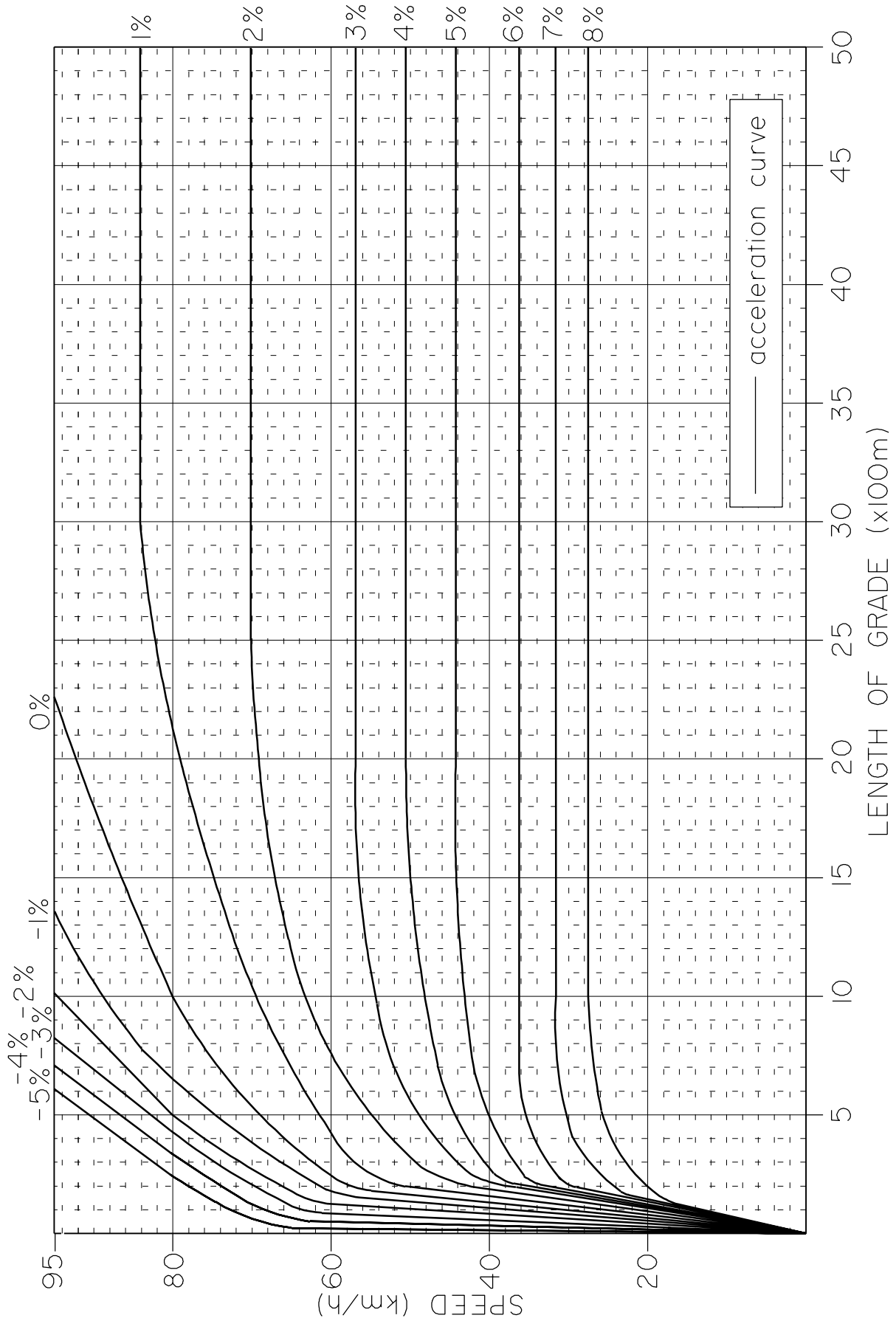


FIGURE B-5.3.3h PERFORMANCE CURVES FOR HEAVY TRUCKS 120 g/w
DECELERATION CURVE



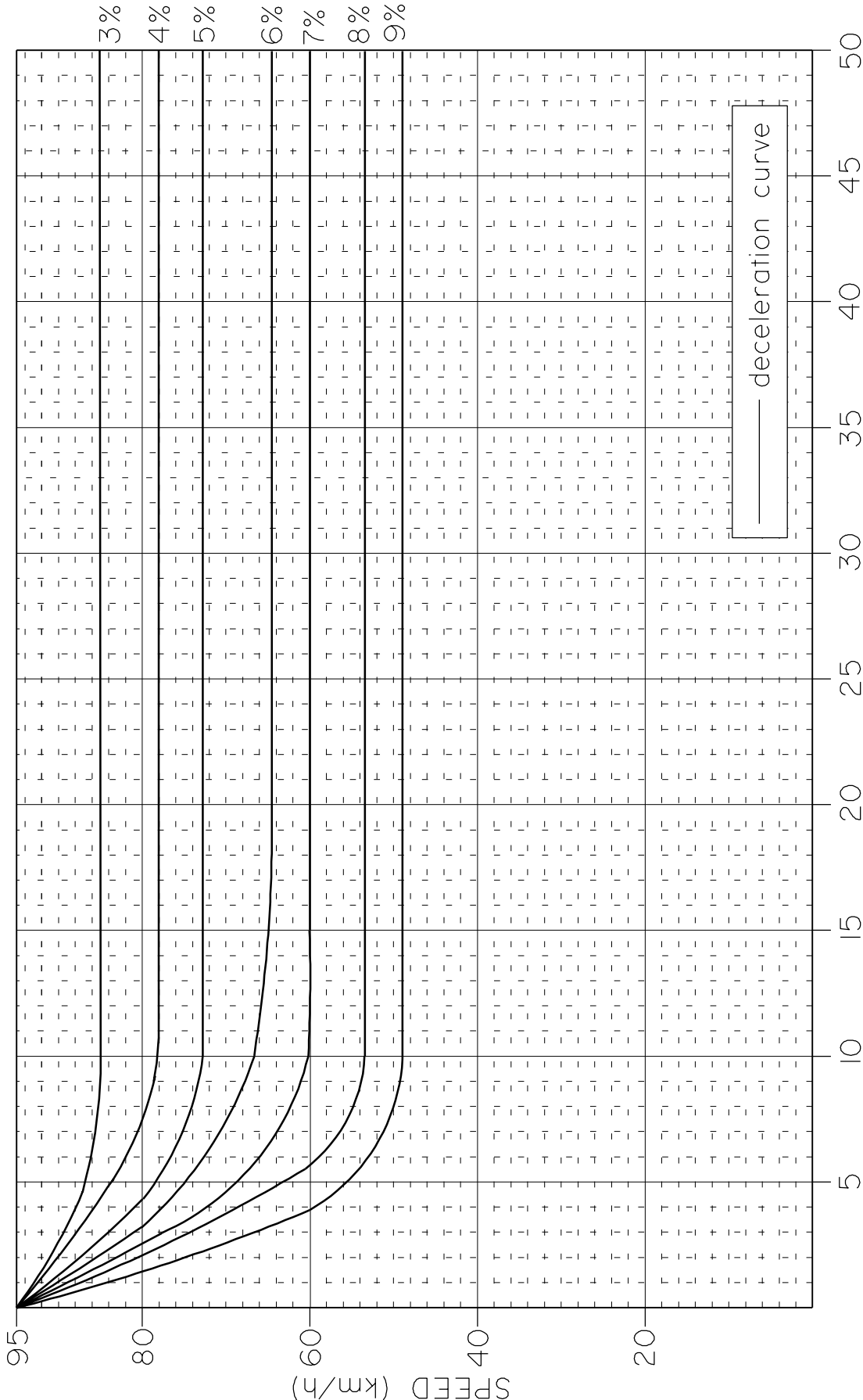
Adapted from Highway Capacity Manual, Figure 1-3.2 published by
Transportation Research Board, National Research Council, Washington D.C.

FIGURE B-5.3.3i PERFORMANCE CURVES FOR HEAVY TRUCKS 120 g/w
ACCELERATION CURVE



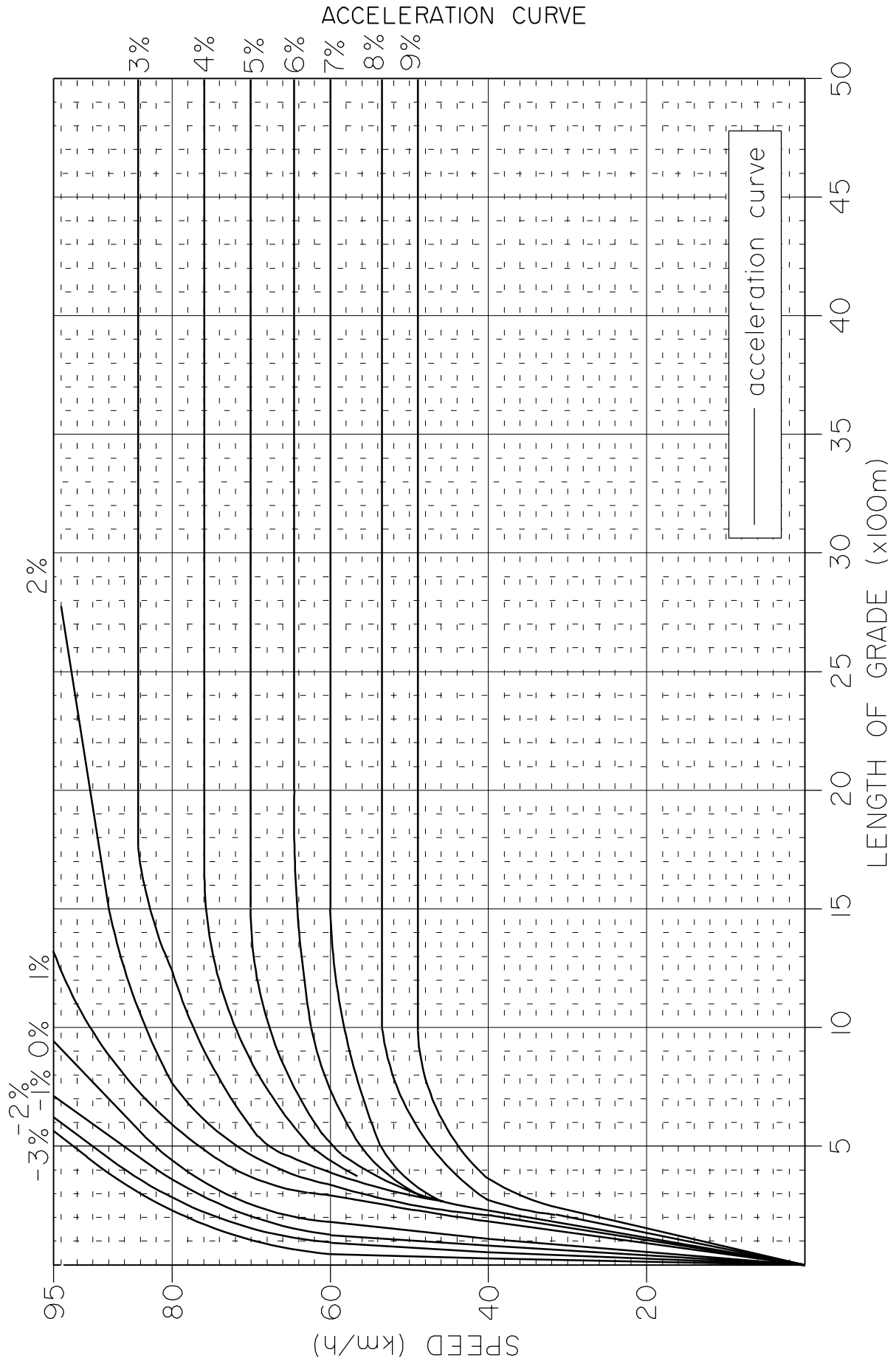
Adapted from Highway Capacity Manual, Figure I-3.2, published by Transportation Research Board, National Research Council, Washington D.C. (1985)

FIGURE B-5.3.3j PERFORMANCE CURVES FOR HEAVY TRUCKS 60 g/w
DECELERATION CURVE



Adapted from Highway Capacity Manual, Figure I.3-3, published by
Transportation Research Board, National Research Council, Washington D.C. (1985)

FIGURE B-5.3.3k PERFORMANCE CURVES FOR HEAVY TRUCKS 60 g/w



Adapted from Highway Capacity Manual, Figure I.3-3, published by Transportation Research Board, National Research Council, Washington D.C. (1985)