LA GRANDE ALLIANCE

CREE DEVELOPMENT CORPORATION

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VOLUME 6 - APPENDIX

SECTION 6.3 – Railway design criteria

Consultant Reference: LGA-1-GN-F-FRN-RT-0006_00_Appendix6.3

2023-03-10

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ENGINEERING CONSULTING SERVICES

Feasibility Study - Phase I
Railway Infrastructure Design Criteria

Consultant Reference: LGA-1-GN-T-RDC-RT-0001_02

2022-12-13

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Feasibility Study - Phase I

Railway Infrastructure Design Criteria

Consultant Reference:
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Table *of* Contents

List *of* Tables

List *of* Figures

1

Glossary

1. GLOSSARY

Term	Definition
Ballast	Ballast forms the trackbed upon which the ties are laid. It is packed between, below, and around the ties. It is used to bear the load from the ties, to facilitate drainage of water, and to keep down vegetation that might interfere with the track structure. Ballast also holds the track in place as the trains roll over it.
Bumping Post	Sometimes also called a buffer stop, bumper, bumper block or stopblock. It is a device to prevent railway vehicles from going past the end of a physical section of track.
Cant	Also known as Rail Inclination. It is the angle measured as a tangent between the normal to the running surface and the vertical axis.
Chainage	The relative distance, in kilometres (referred to as a kilometer post), measured along the track centreline between datum and the current position. It is also known as kilometric post or station (on the BDHR KP 0 is at Matagami and KP 253 is at the Rupert River).
Compound Curve	A curve formed by two circular curves of different radii which curve in the same direction. The two adjacent curves may be joined by a transition curve.
Crossover	A crossover is generally composed of two turnouts of the same hand and a closure panel, and which is used to permit a train to move onto the other track in double track territory. Double crossovers composed of four turnouts are also possible.
Cuts	The excavation from existing ground level needed to reach the bottom of the railway embankment.
Design speed	The speed used for the geometric design of horizontal curves and transition curves.
Embankment	A raised earth structure on which the railroad structure (rails, ties, ballast and sub-ballast) is placed. The upper layer will act as subgrade. The embankment maybe cohesive or cohesionless depending on the materials used.
Hand of switch	A switch rail is described as right or left hand according to whether the train diverges to the right or to the left respectively.
Horizontal Alignment	The longitudinal geometry of the track centreline.
Horizontal / Vertical Circular Curve	A curve of constant radius.
Reverse Curve	A reverse curve is formed by two circular curves in opposite directions linked with a tangent and, depending on operating speed, linked by transition curves.
Siding	A track used for marshaling and/or stabling vehicles.

Term	Definition
Sub-ballast	A layer of coarse-grained material or treated material provided between the Subgrade and ballast layers. It is provided to ensure better distribution of loads, to perform as a filter layer between the subgrade layer and the ballast layer to protect the subgrade layer against erosion and frost, and to improve the bearing capacity.
Subgrade	A layer of specified material of designed thickness and specified compaction provided between the embankment (or cut) and sub-ballast. The function of this layer is to minimize the deformation of the earthworks, improve bearing capacity, and to further prevent water from penetrating into the earthworks.
Subsoil	Soil of natural ground below embankments.
Super elevation	The amount by which the outer running rail in a curve is raised above the inner running rail in the track cross section.
Track Gauge	The distance between the inside faces of the rails, in the plane tangential to the top of the rails, measured 14 mm below the top of the rail.
Track spacing	In dual track sections, the minimum spacing between the centrelines of the tracks.
Transition curve	A curve of variable radius that serves as transition between tangent track and curved track.
Turnout	Special trackwork which enables trains to diverge from a main line track.

2

Acronyms and Abbreviations

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2. ACRONYMS AND ABBREVIATIONS

Acronyms	Abbreviation
AAR	Association of American Railroads
AEP	Aggregate Erosion Protection
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASTM	American Society for Testing and Materials
BDH	Billy-Diamond Highway
BDHR	Billy-Diamond Highway Railway
CSA	Canadian Standards Association
CSP	Corrugated Steel Pipe
KM/H	Kilometres per Hour
GPS	Global Positioning System
GSC	Geodetic Survey of Canada
MPH	Miles per Hour
MRE	Manual for Railway Engineering
MTMD	Ministère des Transports et de la mobilité durable
MTPA	Million Tonnes per Annum
NBCC	National Building Code of Canada
PGRE	Practical Guide to Railway Engineering
ROW	Right of Way
S&C	Signaling and Communications
SPC	Standard Practice Circular
TBD	To Be Determined
TOR	Top of Rail

3

Description of the Project

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3. DESCRIPTION OF PROJECT

3.1 INTRODUCTION

The Grande Alliance is an innovative Memorandum of Understanding between the Cree Nation and the Quebec government, focused on the economic development of the Nation's territory, namely the Eeyou Istchee - James Bay region. To ensure a true long-term collaboration, the basis of this alliance is focused on three main points: Connect, Develop, and Protect.

A logical continuation of the Paix des Braves Treaty (2002) established in the context of the James Bay and Northern Quebec Agreement (1975), this alliance mobilizes the participation of all Cree Nation communities ("Connect") to involve Cree actors in contributing to a common vision of socio-economic development of the territory ("Develop"), while protecting the ways of doing things and the heritage assets ("Protect") and fostering the building relationships between communities, entities and the Government of Quebec as well as their various ministries and crown corporations.

In the context of the Transportation Infrastructure studies, the Cree Development Corporation (CDC, the client) has proceeded with carrying out a Phase I Feasibility Study, which includes a road and rail network in the southern part of the territory, with the primary goal to be a respectful socio-economic development of the communities.

3.2 SCOPE OF WORK

The present document describes the criteria to be used in the feasibility design of the railway portion of the Phase 1 development plan. The Phase 1 development plan includes the construction of a new railway along the Billy-Diamond Highway from Matagami to the Rupert River (at approximately KP 257). It also includes the reopening of the Grevet-Chapais railway between Lebel-sur-Quévillon and Chapais. This document describes the criteria relating to alignment, earthworks, track, structures, hydrology, signaling and road geometry.

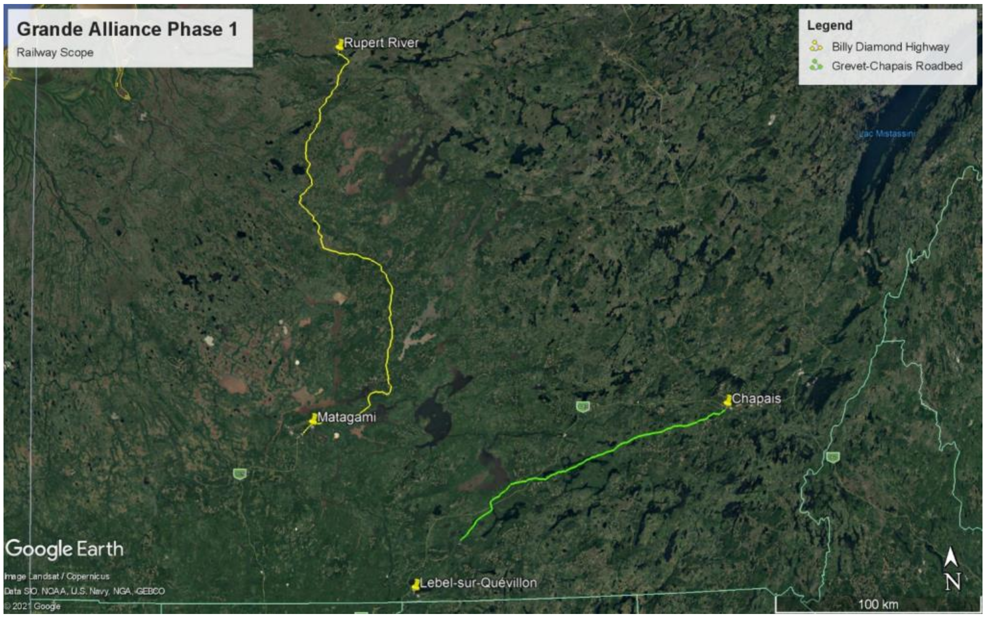

Figure 3-1: Grande Alliance Phase 1 Projected Railway Lines

4

Reference Documentation

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4. REFERENCE DOCUMENTATION

4.1 PROVINCIAL AND FEDERAL REGULATIONS

All relevant federal, provincial, and municipal regulations must be respected.

Provincial Laws and Regulations:

- Transport Act (chapter T-12)
- Railway Act (chapter C-14.1)
- Regulation respecting rail safety (chapter S-3.3, r.2)
- The codes, regulations, and standards of the *Ministère des Transports de Québec* (MTQ)
- Transportation of Dangerous Substances Regulation (chapter C-24.2, r. 43)

Federal Laws and Regulations:

- Canada Transport Act (S.C. 1996, c. 10)
- International Bridges and Tunnels Act (S.C. 2007, c. 1)
- Railway Relocation and Crossing Act (R.S.C., 1985, c. R-4)
- Railway Safety Act (R.S.C., 1985, c. 32 (4e supp.))
- The codes, regulations, and standards of Transport Canada (TC)
- Transportation of Dangerous Goods Act (S.C. 1992, c. 34)
- National Building Code of Canada (NBCC)

4.2 STANDARDS AND GUIDELINES

Where no specific requirements are set by the MTQ, Transport Canada or the present design criteria document, the design will follow the Standards and Specifications described in CN's Engineering Specifications for Industrial Tracks, and CN's Standard Practice Circulars. Where no specific guidance is provided by CN's documentation, the design will be done using the latest version of the Manual for Railway Engineering (MRE) and Practical Guide to Railway Engineering (PGRE) published by the American Railway Engineering and Maintenance-of-Way Association (AREMA).

The design of culverts and bridges must be done in accordance with the following standards and guidelines:

- Canadian Highway Bridge Design Code, published by the Canadian Standards Association (CSA)
- AISC Steel Construction Manual, American Institute of Steel Construction
- FHWA Standards – Federal Highway Administration

4.3 DATUM AND CONTROL LINE REFERENCES

Vertical control is based on Geodetic Survey of Canada (GSC) data. The reference/control line defines the centreline of the track, all transverse dimensions will be taken from this control line. The vertical profile of the control line is taken at the top of rail (TOR).

4.4 ENVIRONMENTAL CONDITIONS

Temperature and precipitation data from Matagami and from Chapais are provided below for reference.

Table 4-1: Environmental Conditions at Matagami and Chapais

Description	Matagami	Chapais
Average daily maximum temperature	5.5 °C	5.2 °C
Average daily minimum temperature	-6.9 °C	-5.2 °C
Extreme maximum temperature	39.4 °C	35 °C
Extreme minimum temperature	-44.1 °C	-43.3 °C
Temperature range	83.5 °C	78.3 °C
Extreme daily maximum precipitation (rain)	73.7 mm	75 mm
Extreme daily maximum precipitation (snow)	37.2 cm	32.4 cm
Average annual precipitation (rain)	617.7 mm	659.7 mm
Average annual precipitation (snow)	313.8 cm	301.7 cm

https://www.eldoradoweather.com/canada/climate2/Matagamia.html
https://www.eldoradoweather.com/canada/climate2/Chapais%202.html

The National Building Code of Canada (NBCC) provides climatic data for Val D'or, which is the closest location to the Billy-Diamond Highway and Grevet-Chapais railway. Climatic data from Val D'or will be used for the design of structures on the BDHR and Grevet-Chapais Railway (GCR).

Table 4-2: Wind Data at Val d"Or

Location	Design Temp Jan	Design Temp July Dry, Wet	15 Min Rain (mm)	One Day Rain 1/50 (mm)	Annual Rain (mm)	Annual Precipitation (mm)	Snow Load, kPa 1/50 Ss, Sr	Hourly Wind Pressure, kPa 1/10, 1/50
Val d'Or	-36	29, 21	20	86	640	925	3.4, 0.3	0.25, 0.32

https://nrc-publications.canada.ca/eng/view/ft/?id=c8876272-9028-4358-9b42-6974ba258d99

Seismic data from Val d'Or will also be used for the BDHR and the GCR.

Table 4-3: Seismic Data at Val d"Or

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA	PGV
0.135	0.093	0.056	0.029	0.0076	0.0032	0.081	0.074

https://nrc-publications.canada.ca/eng/view/ft/?id=c8876272-9028-4358-9b42-6974ba258d99

Site class C will be considered for seismic calculations until the geotechnical investigation reveals otherwise.

5

General Criteria

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5. GENERAL CRITERIA

5.1 DESIGN SPEED

Mainline tracks for the Billy-Diamond Highway Railway (BDHR) shall be designed as Class 3 tracks. As per Transport Canada, the maximum allowable operating speeds on Class 3 tracks is 60 mph (100 km/h) for passenger trains, and 40 mph (65 km/h) for freight trains. The design speed to be used for design of mainline track infrastructure and alignment shall therefore be **100 km/h** (60 mph). The maximum operating speed on siding tracks will be fixed by the size of the turnouts.

Mainline tracks for the Grevet-Chapais Railway shall be designed as Class 3 tracks. As per transport Canada, the maximum allowable operating speeds on Class 3 tracks is 100 km/h (60 mph) for passenger trains, and 65 km/h (40 mph) for freight trains. The design speed to be used for design of mainline track infrastructure and alignment shall therefore be **100 km/h** (60 mph) with some speed restrictions on certain curves. Bridges shall be designed for 60 mph, as there are no additional load reduction factors beyond this speed. The maximum operating speed on siding tracks will be fixed by the size of the turnouts.

Yards will be composed of Lead tracks and Yard tracks. Lead tracks will be designed for a maximum operating speed of 30 km/h (18 mph) and Yard tracks will be designed for a maximum operating speed of 15 km/h (9 mph).

5.2 AXLE LOAD

Mainline tracks shall be designed to accommodate freight locomotives with a maximum axle load of 32.4 tonnes/axle and freight wagons with a maximum axle load of 30 tonnes/axle. The reason for the reduced axle load for the freight wagons is due to CN's Matagami, Chapais and Cran subdivisions having a maximum permissible gross weight for wagons of 263,000 to 268,000 lbs (30 tonnes per axle). It is assumed that the 32.4 tonne/axle locomotives that would operate on the BDHR would be captive and not leave that line (making Matagami an interchange point for wagons) while the motive power on the Grevet-Chapais section would likely be CN's locomotives that are 30 tonnes/axles.

For passenger service, the tracks must be able to accommodate passenger locomotives with a maximum axle load of 30 tonnes/axle and passenger wagons with a maximum axle load of 30 tonnes/axle as it is surmised that that passenger trains could originate from further south than Matagami.

Note that the above assumptions may change as the study progresses.

5.3 DESIGN LIFE

All components of the track, structures and drainage systems should be designed for a lifespan targeting 50 years unless otherwise noted.

5.4 ROLLING STOCK

Mainline tracks shall be designed to accommodate freight trains composing of 75 wagons, and passenger trains composing a maximum of 4-6 wagons. This assumption must be validated at a later date.

5.5 Operations

It is expected that the BDHR will receive a single, one-way train 6 days per week and the Grevet-Chapais Railway will receive 1 round-trip train 3 days per week.

5.6 Classification of Tracks

Track Type	Description
Mainline Tracks (and Sidings Tracks)	Mainline tracks carry the majority of the traffic on the railways. Siding tracks allow for trains to pass one another where there is only a single mainline track.
Yard Tracks and Storage Tracks	Storage tracks used to store pieces of rolling stock. Yard tracks are used for re-arranging the train composition, or within maintenance facilities and freight facilities.

6

Alignment Criteria

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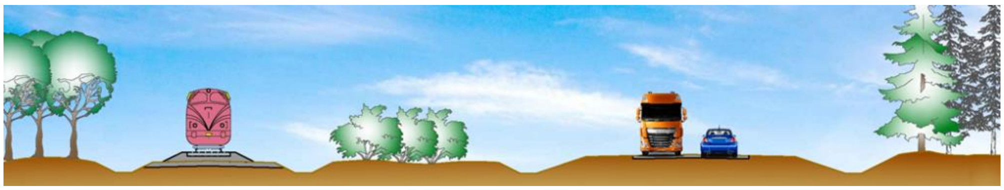
6. ALIGNMENT CRITERIA

6.1 ALIGNMENT CONSTRAINTS

6.1.1 Billy Diamond Railway

The alignment design will prioritize staying within 100m of the centreline of the Billy-Diamond Highway as much as possible.



Given the topography and the restricted right-of-way of 200 m dedicated to the railway line, including the Billy Diamond Highway in the center of this corridor, the railway shall exit this 200 m corridor to avoid the following situations:

1. Protected area
2. Cree Land Use area
3. Archeological sites
4. Urban area
5. Wetlands/water bodies
6. Sensitive flora and fauna locations
7. Areas of tight curvature on the BDH which would significantly lower train speed
8. Other Sensitive Areas

An example condition occurs at the industrial area in Matagami, which is located inside the 200 m zone of the BD highway, as shown below. Avoiding the industrial area requires the BDHR to deviate outside the 200 m zone for about 1.5 km.

Figure 6-1: Matagami Industrial Area

A large number of gravel forestry roads connect to the Billy-Diamond Highway and will be crossed by the Railway. At these intersections, level crossings will be installed to allow continued use of the forestry roads and provide access to the other side of the railway. It will be important to leave sufficient distance, approximately 30 m, between the highway and the level crossing to allow for acceptable approach gradients and warning signs. In some locations this might require the alignment of the railway to deviate further away from the highway.

A list of all the major existing interferences that need to be crossed by the BDHR will be provided in the final report Study document.

6.1.2 Grevet-Chapais Railway

The alignment of the Grevet-Chapais railway will follow the alignment of the existing trail subgrade. Priority will be given to remaining on the existing subgrade to limit the impact on social acceptance, existing structures, and land availability. If, due to geometric constraints, the alignment cannot attain the Class 3 speeds described in Section 5.1, consideration will be given to placing a speed restriction over that section of track.

6.2 Horizontal Alignment

6.2.1 Maximum and Minimum Horizontal Curve Radius

For the BDHR, the preferred mainline curve radius shall be 1750 m in radius (1 degree).

Mainline curves should not be less than 700 m in radius (greater than 2 degree 30 minutes).

Mainline curves under 700 m in radius (greater than 2 degree 30 minutes), can be used in exceptional circumstances where significant savings can be made by using tighter curves.

The preferred curve radius in yard track shall be 300 m (5 degrees 49 minutes).

The minimum curve radius on yard tracks shall be 190 m (9 degrees 11 minutes).

Curves up to 150 m in radius (11 degrees 39 minutes), will be allowed in yard tracks if verified against the curving capacity of the rolling stock.

6.2.2 Super-Elevation

Under CN SPC 1305, the maximum permitted actual superelevation (E_a) on mainline tracks is 125 mm (5 inches).

For the Billy-Diamond and the Grevet Chapais Railway, the maximum permitted superelevation shall be 100 mm (4 inches) and the minimum permitted superelevation shall be 25 mm (1 inch).

The AREMA MRE Chapter 5 Section 3.3.1 calculates the equilibrium superelevation with the simplified formula: $E_e = 0.0007V^2D$, which is in Imperial units.

In metric units this equation becomes:

$$E_e = \frac{11.8(V^2)}{R}$$

Where:

V is the maximum train speed in kilometres per hour.

R is the curve radius in metres.

As per CN SPC 3101, the maximum allowable unbalanced superelevation on Mainline tracks shall be 75 mm (3 inches).

The unbalanced superelevation (E_u in mm) is calculated using the following formula:

$$E_u = E_e - E_a$$

Where:

E_e is the equilibrium superelevation in mm.

E_a is the actual superelevation in mm.

6.2.3 Transition Curves

Transition curves, also known as spirals, are a section of horizontal alignment that connects tangent track to track that is comprised of a true circular curve. Unlike tangents and circular curves, which have constant superelevation and curve radius, a transition curve changes its superelevation and curve radius at a constant rate along its length. Spirals will be required for all mainline curves except where the radius of curvature is over 12,000 m (0 degrees 9 minutes). Spirals will not be required on yard tracks.

As per AREMA MRE Chapter 17 Section 3.5.7.8, the maximum rate of change of superelevation in spirals (E_a/L_s) for track speeds less than 97 km/h (60 mph) shall be 1.34 mm per meter (0.5 inch per 31 ft). For speeds over 97 km/h (60 mph), the maximum rate of change of superelevation shall be 1 mm per meter (0.375 inch per 31 ft).

The desirable length of spirals shall be calculated using the formulas presented in AREMA MRE Chapter 5 Section 3.1.1. which are shown on the right in parentheses.

The desirable length of spiral (L_s in metres) shall be the maximum of the follow equations:

EQ1: $L_s = \frac{(E_u)V}{82.28}$ $[L_s = 1.63(E_u)V]$

or

EQ2: $L_s = \frac{E_a}{1.34}$ $[L_s = 62E_a]$

If realigning existing tracks, replace EQ1 with EQ3

EQ3: $L_s = \frac{(E_u)V}{109.93}$ $[L_s = 1.22E_uV]$

AREMA MRE Chapter 17 Section 3.5.7.8 also requires that if

$97\ kph[60mph] < V \leq 201\ kph[125mph]$, replace EQ2 with EQ4

EQ4: $L_s = \frac{E_a}{1.01}$ $[L_s \geq 82.7E_a]$

Where:

E_u is the unbalanced superelevation in millimetres.

E_a is the actual superelevation in millimetres.

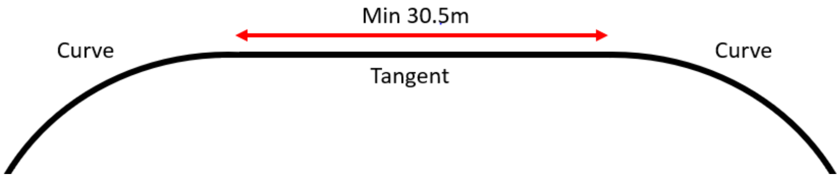
V is the maximum train speed in kilometres per hour.

6.2.4 Minimum Length of Tangent

For mainline tracks, AREMA's Practical Guide for Railway Engineering recommends that for freight trains, a minimum tangent length of 46 m (150 ft) should be used between reverse curves.

For passenger trains, the minimum tangent length should be the distance representing 2 seconds of travel time to retain maximum comfort for the passengers. At a speed of 100 km/h (60 mph), 2 seconds of travel represents a distance of 56 m (184 ft). The minimum tangent length shall therefore be 56 m (184 ft).

AREMA's MRE, Chapter 5 Section 3.5.2, provides guidance for the minimum tangent length between reverse curves for use on yard tracks and recommends that at least one wagon length be considered between curves of opposite direction. The desired minimum tangent length between curves of the same direction (not reverse curve) shall be 30.5 m (100 ft).



6.2.5 Compound Curves

Compound curves will not be permitted on mainline tracks on the BDHR under any circumstances, to allow a smoother alignment that reduces maintenance. On the Grevet-Chapais railway, compound curves may only be used when required to connect into existing railway bridges or other fixed points.

6.3 VERTICAL ALIGNMENT

6.3.1 Maximum and Minimum Gradients

The desirable maximum gradient on mainline tracks will be 1.5% compensated.

For passing loops not being used for the storage of equipment, the maximum allowable gradient will be the same as the mainline.

It is preferable that yard tracks and storage tracks be designed at 0% gradient. However, a gradient up to 0.1% is acceptable but should not be exceeded. Dead end tracks ending with bumping posts may have gradients up to 0.3% but the bumping post must be at the bottom of the grade.

Platform tracks will have a maximum gradient of 1.5%, and a minimum and desirable gradient of 0.5%.

Curve compensation for gradients will be calculated by using the formula from AREMA's MRE, Chapter 5 Section 3.7.1e. which is shown on the right in parentheses.

$$G_c = G - 0.04(\frac{1746.40}{R}) \qquad [G_c = G - 0.04D]$$

Where:

G_c is the compensated gradient expressed in percent.

G is the gradient before compensation in percent.

R is the radius of curve express in metres.

6.3.2 Abrupt Change of Gradient

Vertical curves are optional for changes in gradients with an absolute difference less than 0.2%, as per AREMA Chapter 5, Article 3.6.b.

6.3.3 Length of Vertical Curve

The minimum length of vertical curves is described in AREMA MRE Chapter 5 Section 3.6.f. which is shown on the right in parentheses.

$$L = \frac{D \times V^2}{12.96 \ \times A} \qquad \left[L = \frac{D \times V^2 \times K}{A}\right]$$

Where:

L is the minimum length of vertical curve in metres.

D is the absolute value of the difference in the rate of grades expressed as a decimal.

V is the speed of the train in km/h.

A is the vertical acceleration in meter/sec/sec (m/s^2).

For freight trains, A = 0.031 m/s^2 (0.10 ft/sec2);
For Passenger trains, A = 0.183 m/s^2 (0.60 ft/sec^2).

In any case, the length of vertical curves should never be less than 30.5 m (100 ft).

The preferred length of vertical curves shall be calculated using the formula, from AREMA's 1962 Manual for Railway Engineering, which is shown on the right in parentheses.

$$L = \frac{30 \times D}{R} \qquad \left[L = \frac{100 \times D}{R}\right]$$

Where:

L is the preferred length of vertical curve in metres.

D is the absolute value of the difference in rate of grades expressed as a percent.

R is equal to 0.1% for summits, or 0.05% for sags.

6.3.4 Minimum Length of Gradient

The preferred minimum length of gradient shall be calculated using the following equation from AREMA MRE Chapter 12 Section 3.5.8.3, which is shown on the right in parentheses.

$$L = \frac{V_{max}}{1.76}\ in\ metric\ (L\ in\ m, V\ in\ kph) \qquad L = 3V_{max}\ in\ imperial\ (L\ in\ ft, V\ in\ mph)$$

Where:

L = Absolute minimum tangent length between vertical curves in metres.

V_{max} is the maximum operating speed in kilometres per hour.

The minimum length of constant gradient track between vertical curves shall be 45 metres (147 ft) under normal circumstances. Under no circumstance should the gradient length be less than 30.5 metres (100 ft).

6.4 Locations of Alignment Elements

6.4.1 Superposition of Horizontal and Vertical Curves

It is not desirable to overlap vertical and horizontal curved elements. When geometric constraints are such that overlapping vertical and horizontal curves is unavoidable, AREMA specifically recommends not to overlap vertical curves with transition curves, hence the vertical curve must be entirely contained within the circular portion of the horizontal curve and must not overlap the horizontal transition curves (spirals). When the situation permits, it is desirable for maintenance purposes to leave 100m between the beginnings and ends of vertical and horizontal curves.

6.4.2 Locations of Turnouts

Back-to-back turnouts of the same hand should be spaced a minimum of 30 metres (100 feet) apart.

Where a turnout is placed after a curve in the opposite direction of the curve (forming a reverse curve), a minimum of 30 metres (100 feet), should be maintained between the end of the curve and the start of the turnout.

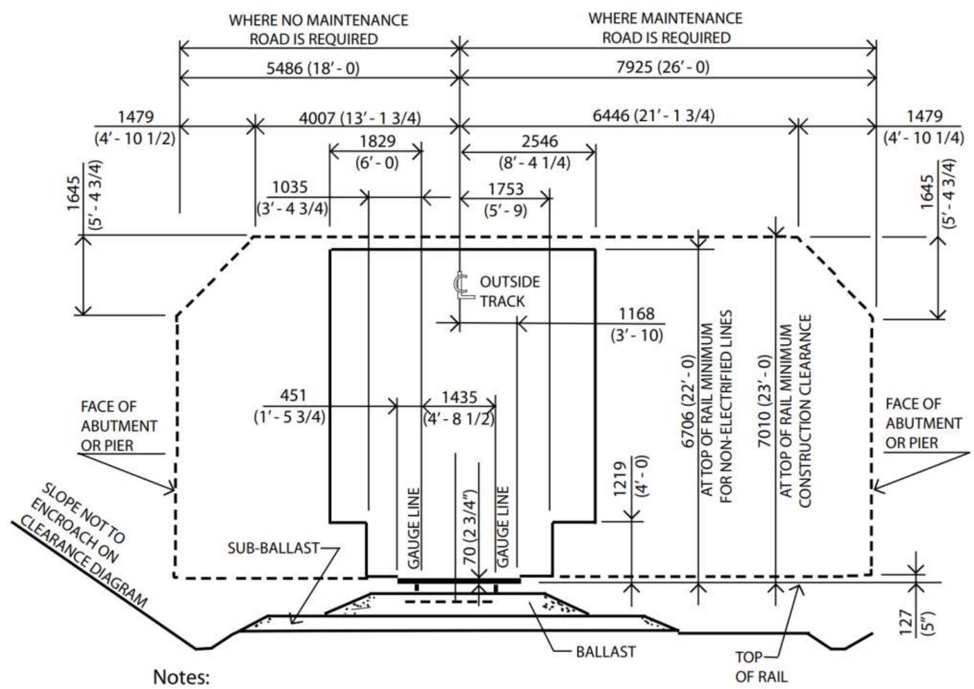
Back-to-back turnouts of different hands should be spaced a minimum of 5 metres (16 feet) apart.

Turnout shall be located on constant gradients which do not exceed 1.5% and shall not be located within horizontal and vertical curves, or within 15m of the end of a station platform (25 m is desirable).

6.5 CLEARANCES

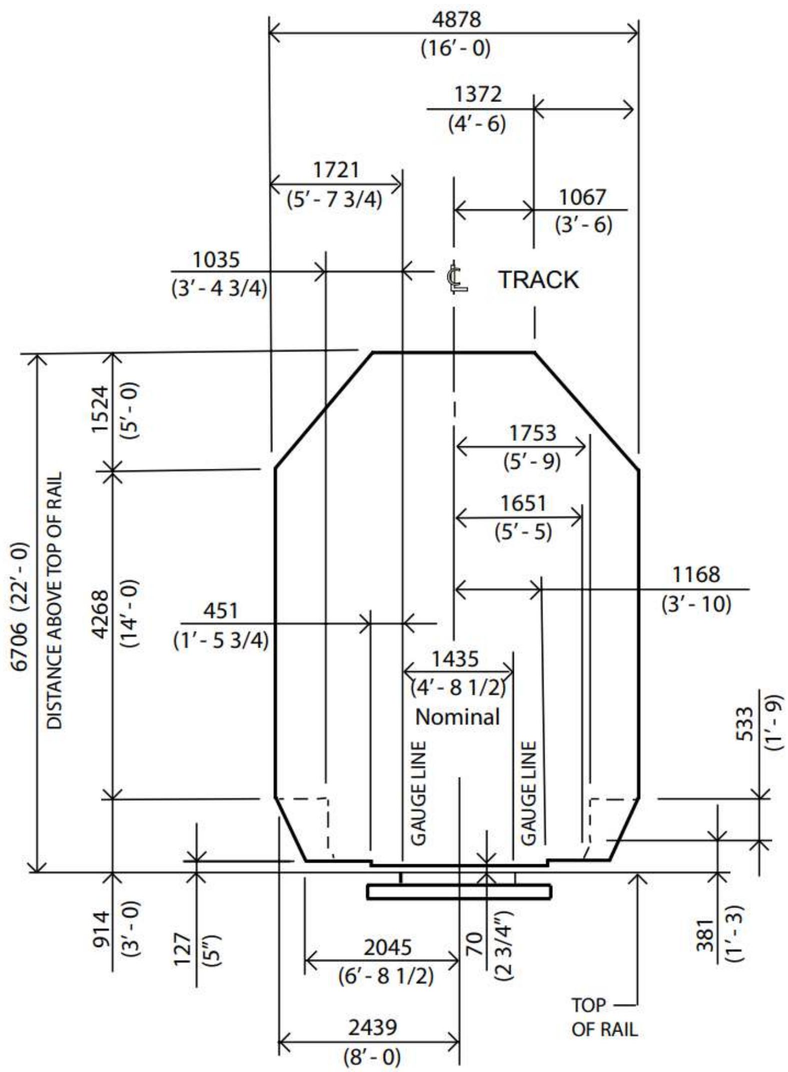
The alignment design will consider the clearance envelopes imposed by Transport Canada Standards Respecting Railway Clearances, TCE-05, Diagrams 1 to 4:

1. All Structures Over or Beside the Railway Tracks
2. All Railway Bridges, Snowsheds and Overhead Timber Bridges
3. All Railway Tunnels
4. Industrial Sidings

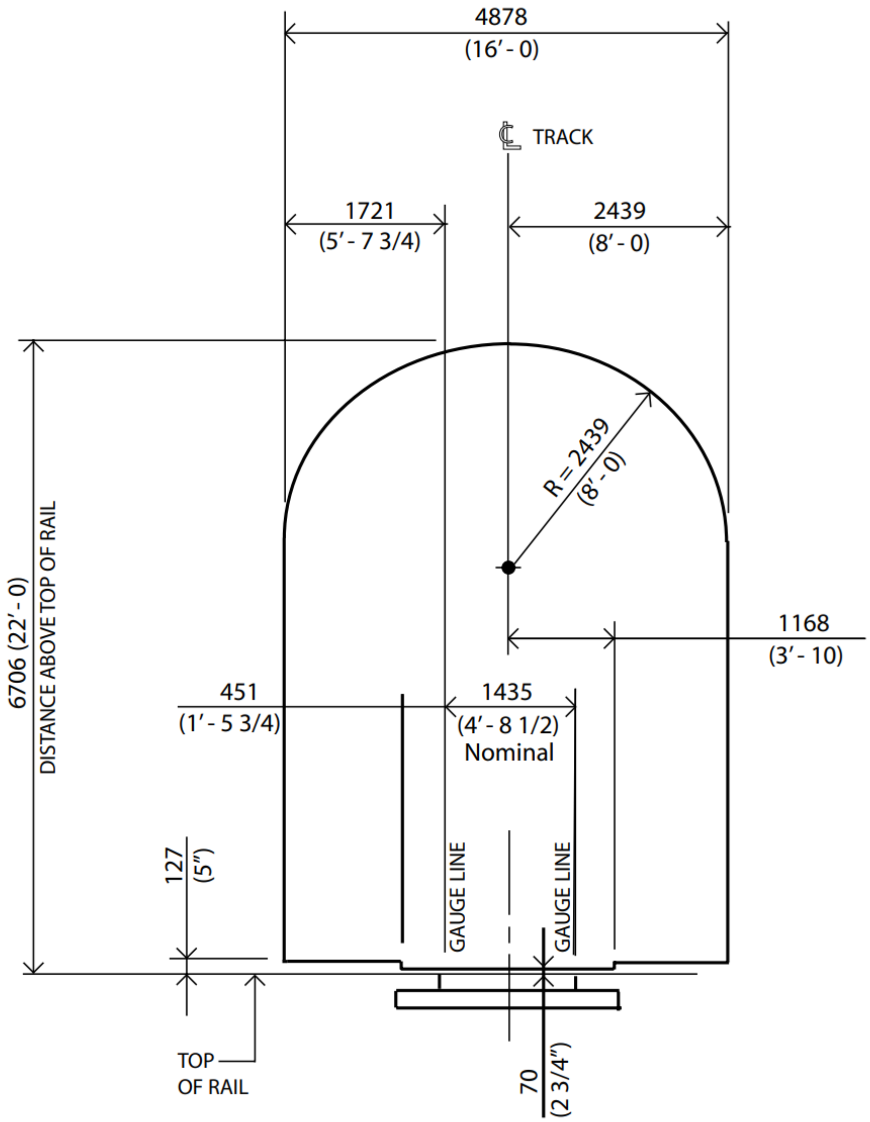


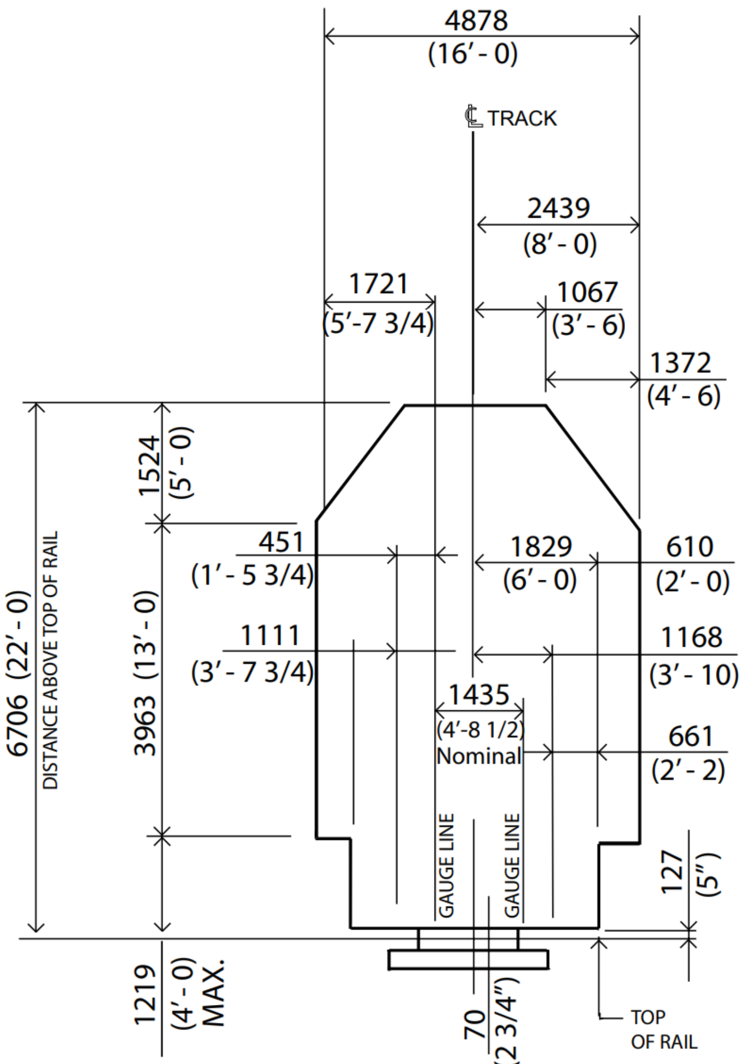
Notes:

- Solid lines indicate minimum standard clearances
- Broken lines indicate required clearances, where approved by the national transportation



Note: Broken lines indicate minimum clearances that may be used when authorized by the chief engineer.


4878
(16'- 0)
℄ TRACK
1721
(5'- 7 3/4)
2439
(8'- 0)
R = 2439
(8'- 0)
1168
(3'- 10)
451
(1'- 5 3/4)
1435
(4'- 8 1/2)
Nominal
6706 (22'- 0)
DISTANCE ABOVE TOP OF RAIL
127
(5")
GAUGE LINE
GAUGE LINE
TOP
OF RAIL
70
(2 3/4")



6.6 TRACK CENTRE SPACING

Track centre spacing must be designed in accordance with the requirements of Transport Canada Standards Respecting Railway Clearances, Section 5.

Transport Canada specifies the following minimum track centre spacing:

- Main tracks: 3.96 m (13 feet)
- Main and siding tracks: 4.27 m (14 feet)
- Yard tracks: 4.11 m (13.5 feet)
- Inspection tracks: 7.5 m (24.6 feet)
- Diverging tracks in yard storage: 3.05 m (10 feet)

6.7 SUMMARY OF ALIGNMENT CRITERIA

Table 6-1: Summary of Horizontal Alignment Criteria

<table>
<tr><th>Description</th><th>Criteria for BDHR</th><th>Criteria for GCR</th></tr>
<tr><td>Preferred horizontal curve radius</td><td>1750 m (1˚)</td><td>As per existing alignment</td></tr>
<tr><td>Minimum horizontal curve radius</td><td>700 (2˚30')
Smaller radius is permitted with speed restriction</td><td>As per existing alignment</td></tr>
<tr><td>Maximum Jerk</td><td colspan="2">0.3 m/s^2 (preferred)
0.4 m/s^2 (absolute)</td></tr>
<tr><td>Desirable transition curve length, L (m).</td><td colspan="2">EQ1: $L_s = \frac{(E_u)V}{82.28}$ or
EQ2: $L_s = \frac{E_a}{1.34}$
If realigning existing tracks, replace EQ1 with EQ3
EQ3: $L_s = \frac{(E_u)V}{109.93}$
If 97 $kph < V \leq 201\ kph$, replace EQ2 with EQ4
EQ4: $L_s = \frac{E_a}{1.01}$</td></tr>
<tr><td>Minimum tangent length between reverse curves.</td><td colspan="2">72 m (preferred)
46 m (minimum)
30 m (absolute)</td></tr>
<tr><td>Minimum tangent length beyond ends of the platform (before horizontal or vertical curve)</td><td colspan="2">25 m (desirable)
15 m (absolute)</td></tr>
<tr><td>Equilibrium superelevation E_e (mm)</td><td colspan="2">$E_e = \frac{11.8(V^2)}{R}$</td></tr>
<tr><td>Maximum cant</td><td>100 mm (4 inches)</td><td>125 mm (5 inches)</td></tr>
<tr><td>Maximum cant deficiency</td><td colspan="2">76 mm (3 inches)</td></tr>
</table>

Table 6-2 Summary of Vertical Alignment Criteria

Description	Criteria for BDHR	Criteria for GCR
Maximum gradient (mainline and passing loops)	1.5 % (compensated) 2.0% (maximum length of 500m)	As per existing profile
Maximum gradient (sidings and yard tracks)	0.3% (compensated)	0.3% (compensated)
Preferred length of vertical curve, L (m)	$L = \frac{30 \times D}{R}$	
Minimum length of vertical curve, L (m)	$L = \frac{D \times V^2}{12.96 \times A}$	
Minimum distance between vertical curves	30 m (100 ft)	
Maximum vertical acceleration	0.2 m/s^2	
Gradient compensation	0.04 % per degree of curve	

7

Earthworks Criteria

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7. EARTHWORKS CRITERIA

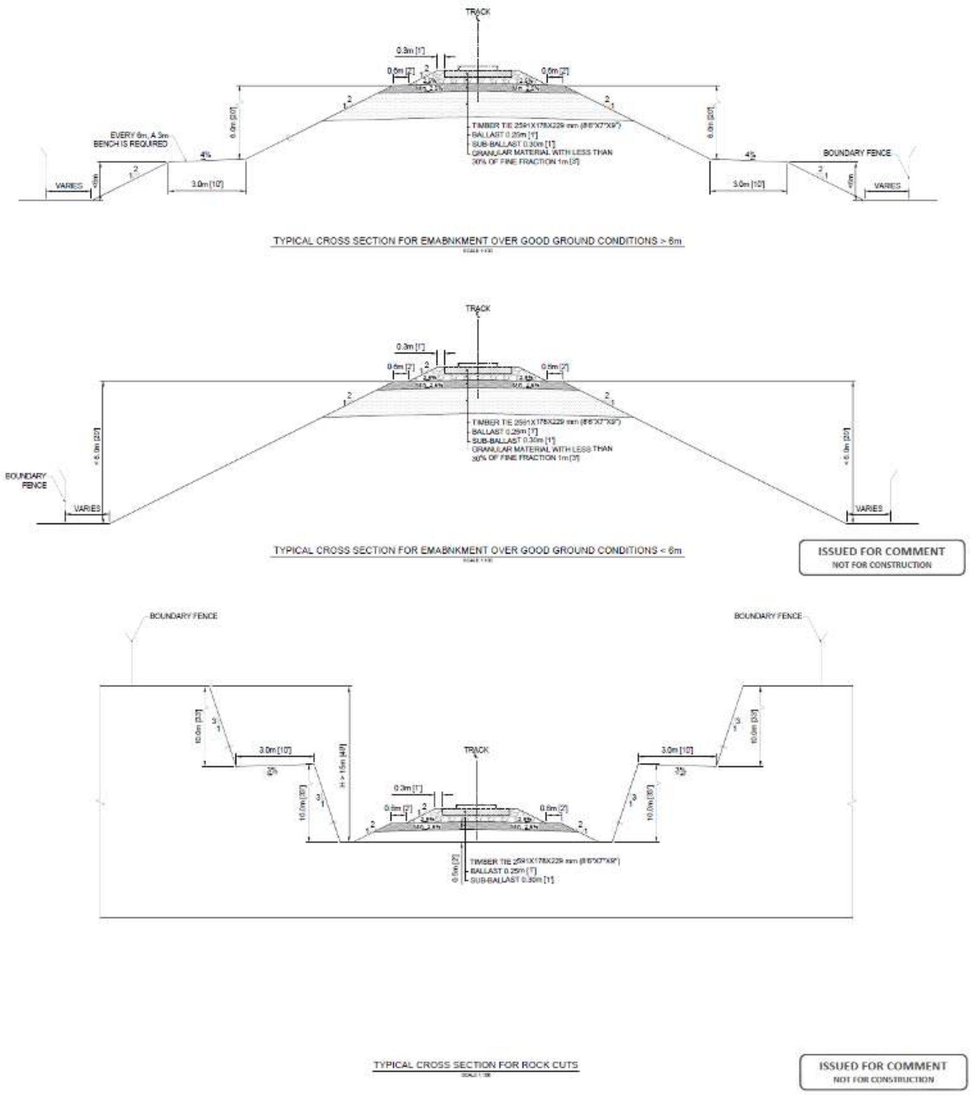

Figure 7-1: Typical Earthworks Cross Section

7.1 Embankment Cut

As per CN TS-2204, Industry Practices and AREMA MRE Chapter 1, Article 1.2.2, and according to our experience, the following criteria for cutting shall be used.

Table 7-1: Embankment Cutting Requirements

Item	Criteria
Typical cut backslopes	1 V: 2 H
Typical cut backslopes (solid rock – required for line drilling)	3 V: 1 H
Safety factor for slope stability	Static Permanent (long term) ≥1.5 Static Temporary (short term) ≥ 1.3 Seismic > 1.1
Benching	3m per 10m of height measured from the lowest point

* A geotechnical study must be completed for cuts slopes in different types of materials for detailed design.

7.2 Embankment Fill

As per AREMA MRE 1-1.2.3, the following criteria for fill shall be used.

Table 7-2: Embankment Fill Requirements

Item	Height of Fill	Criteria	Safety Factor
Fills	< 5 m (16 ft)	1V: 2H	Static Permanent ≥1.5 Static Temporary ≥ 1.3 Seismic > 1.1
	> 5 m (16 ft)	Geotechnical Study is Required.	
Note: Roadbed embankment is defined at top of subgrade.			

The fill side slopes will be determined on the basis of a detailed geotechnical study for the detailed design phase.

7.3 Stability Analysis

For stability analysis two stages shall be checked:

- Short term (total stress analysis) using undrained shear strength (su or cu).
- Long term (effective stress analysis) using drained strength parameters (c', ϕ').

In all loading conditions, the railway load shall be considered.

The parameters that will affect the factor of safety of slope stability analysis are :

- The geometry of the slope
- The type of the soils
- The unit weight of the slopes
- The ground water condition

- The soil strength parameters
- The external loads on the slope (i.e., train load)
- The compaction of the fill materials

The slope stability of the embankments under the earthquake condition shall be analyzed using the pseudo-static analysis.

7.4 Settlement Analysis

Settlement analysis should be carried out to evaluate vertical deformations for all embankments that can occur during and after the construction of the embankment for the following critical areas or cases:

- Approaches to bridge abutments
- Soft and organic soil layers beneath the embankment
- High embankments

Settlement calculations shall include immediate settlement, primary consolidation settlement and creep (i.e., for soft cohesive soils).

7.5 Liquefaction Assessment

Liquefaction is a phenomenon in which the shear stress with the soil will be rapidly increased by earthquake shaking, resulting in large surface settlements. The liquefaction evaluation shall be carried out using the "simplified" approach outlined in the Canadian Highway Bridge Design Code (CHBDC) and by Idriss and Boulanger (2008).

7.6 Ground Improvements

In complex and unfavorable geotechnical contexts, ground improvement may be required to improve the ground conditions and ensure the subgrade has adequate bearing capacity and meets the settlement criteria. The following contexts (amongst others) might require ground improvements:

- The compressible cohesive soils (e.g., Clay, Silty Clay, Clayey Silt)
- Very loose granular soils
- Organic soils (i.e., Peat soils)

The potential ground improvement techniques are dynamic compaction/replacement, stones columns, vibro-flotation, vertical drains, and rigid inclusions.

8

Track Criteria

8. TRACK CRITERIA

8.1 TRACK COMPONENTS

8.1.1 Rail

Various sizes of rail will be analyzed to determine the appropriate rail for use on the new railway. The best size and type of rail will balance the initial costs with longevity, and maintenance costs.

The choice of rail will be made based on the following criteria:

- Lifespan
- Resistance to rail breaks
- Maintenance costs
- Wear rate
- Cost
- Availability

CN’s SPC 3200 provides guidance for choosing the type of rail depending on annual MGT and degree of curvature.

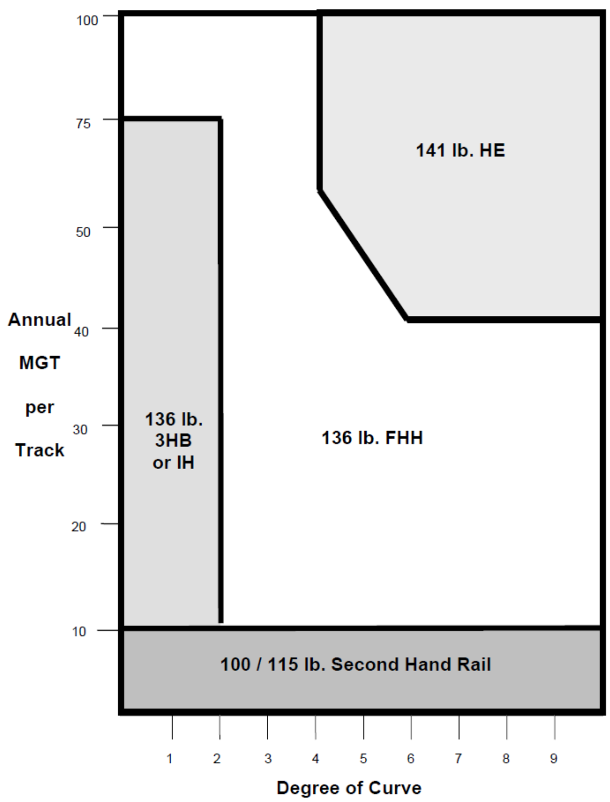

Figure 8-1: CN Guidance for Rail Selection

8.1.2 Ties

The following types of ties should be considered for use on the mainline and siding tracks:

- Hardwood
- Concrete

The following types of ties should be considered for use on the yard tracks:

- Hardwood
- Steel
- Concrete

The type of tie will be chosen to meet the operational requirements of the track. The tie must resist the vertical and horizontal forces will maintaining the alignment of the track. As well, ties will be evaluated based on the following criteria:

- Lifespan
- Maintenance costs
- Costs
- Availability

Tie spacing should be chosen based on subgrade strength, and depth of ballast and sub-ballast. Spacing should not be greater than 24 inches (0.6 m) and should not be less than 18.5 inches (0.47m).

8.1.3 Fasteners

Fasteners must be designed to maintain the gauge of the rails while transmitting torsional, lateral, longitudinal, and vertical forces to the ties. Elastic type fasteners, as opposed to rigid fasteners, are better suited to resist these different loads. As such, elastic type fasteners will be the preferred type of fastener for use on the new railway.

If rail spikes are used as the fastener system, they must be combined with rail anchors in order to resist longitudinal movement.

8.1.4 Turnouts

Turnouts used on mainline tracks and for mainline crossovers will be N°20 and must use the same rail weight as the mainline.

Turnouts used for yard and storage tracks will be N°8.

Turnouts connecting the mainline tracks to lead tracks in the yards will be at least N°10.

The unbalanced superelevation for turnouts shall not exceed 50 mm.

The type of frogs used on mainline turnouts should be either Spring (SPR) or Rail Bound Manganese (RBM) and switch ties used in turnouts must be made of hardwood.

8.1.5 Guard Rails

Guard rails must be provided on all bridges and arched culverts with an opening larger than 4.5m. The guard rails must be installed 15.2 m (50 ft) past the extremities of the bridge or culvert on which they are installed. Guard rails must also be installed in tunnels.

8.1.6 Derailers

Derails must be installed on both ends of tracks wherever there is a possibility that parked equipment could be moved by wind or gravity and obstruct the mainline or siding. Generally, derails must be installed where unattended rolling stock is regularly stored. The placement and use of derails will be as per Transport Canada’s Canadian Rail Operating Rules (CROR) most recent guidelines on derails.

8.1.7 Bumping Post

Bumping posts should be either mechanical or earthen type bumping posts.

Earthen bumping posts should be dimensioned as per CN’s typical Bumping Post Detail drawing.

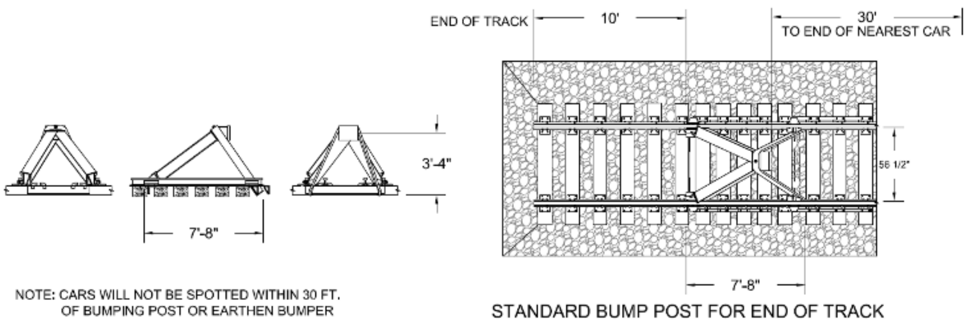

Figure 8-2: CN Typical Bumping Post

8.2 BALLAST

Ballast depth must be not less than 250 mm (10 inches) under the tie.

Ballast shoulder width must be not less than 300 mm (12 inches).

The pressure applied on the ballast by the ties must be controlled by the tie spacing. As per AREMA MRE Chapter 30, Article 1.3.6.1, the maximum recommended pressure on the ballast is 450 kPa (65 psi) or 585 kPa (85 psi) depending on the quality of the ballast. Kerr recommends limiting the pressure to 515 kPa (75 psi). For the purpose of this design, we will limit the pressure on the ballast to 515 kPa (75 psi).

8.3 SUB-BALLAST

Sub-ballast depth should be not less than 300 mm (12 inches).

Sub-ballast shoulder width should be not less than 600 mm (2 feet).

8.4 SUBGRADE

As per AREMA Chapter 16, Article 10.2.2.6, the maximum pressure on the well-compacted subgrade shall not exceed 172 kPa (25 psi). A geotechnical investigation will confirm the maximum allowable subgrade pressure.

8.5 PASSENGER PLATFORMS

Passenger platforms must respect the following dimensions.

Table 8-1: Passenger Platform Dimensions

Dimension	Requirement
Minimum platform length	TBD
Minimum low-level platforms	203 mm (8") Above the top of rail 1676 mm (5'-6") From the centreline of the adjacent track to edge of the platform
Minimum high-level platforms	1308 mm (4'-3-1/2") Above top of rail 1702 mm (5'-7") From the centreline of the adjacent track to edge of the platform
Minimum side platform width	3048 mm (10')
Minimum island Platform width	TBD

8.6 Level Crossings

Level crossing must be designed in accordance with Transport Canada Grade Crossing Regulations. The design of level crossings must be coordinated with the road designer to ensure that all requirements can be met.

Due to the large amount of gravel forestry roads that will be crossing the BDHR, some road crossings will have to be combined to reduce the total amount of level crossings and increase the safety. Sightline distances will be calculated as per Transport Canada's document "Determining Minimum Sightlines at Grade Crossings". The crossings with the largest sightlines and most desirable approach gradients will be kept and will allow access to the roads being cut off by the railway.

8.7 Summary of Track Criteria

Table 8-2: Summary of track criteria

Track Element	Criteria	
	Mainline (including sidings)	**Yard Tracks and Storage Tracks**
Rail	115 lb RE or larger To be re-evaluated based on operational requirements.	115 lb RE or larger To be re-evaluated based on operational requirements.
Joints	Welded CWR	Jointed
Ties	Hardwood	Hardwood
Tie spacing	535 mm (21 in) To be re-evaluated based on the type of tie and capacity of subgrade.	560 mm (22 in) To be re-evaluated based on the type of tie and capacity of subgrade.
Fasteners	Screw spikes	Screw spikes
Turnouts	Dual Motorized/Manual – AREMA No. 20	Dual Motorized/Manual or Manual – AREMA No. 8
Ballast shoulder width	300 mm (12 in) minimum	150 mm (6 in) minimum

Track Element	Criteria	
	Mainline (including sidings)	**Yard Tracks and Storage Tracks**
Depth of ballast under tie	250 mm (10 in) minimum To be re-evaluated based on the type of tie and capacity of the subgrade.	230 mm (9 in) minimum To be re-evaluated based on the type of tie and capacity of the subgrade.
Ballast shoulder slope	1V: 2H	1V: 2H
Depth of sub-ballast	300 mm (12 in) minimum To be re-evaluated based on geotechnical investigation.	300 mm (12 in) minimum To be re-evaluated based on geotechnical investigation.
Sub-ballast shoulder width	Minimum 0.6 m (2 feet) To be re-evaluated based on operational requirements.	Minimum 0.6 m (2 feet) To be re-evaluated based on operational requirements.
Slope of sub-ballast shoulder	1V: 2H	1V: 2H
Sub-ballast cross slope	2.5%	2.5%

9

Structures Criteria

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9. STRUCTURES CRITERIA

9.1 Design Forces

9.1.1 Design Loads

The dead load shall consist of the estimated weight of the structural member, plus that of the track, ballast, fill, and other portions of the structure supported thereon. The unit weight of materials comprising the dead load shall be assumed as follows:

- Reinforced Concrete 25kN/m^3
- Plain Concrete 25kN/m^3
- Structural Steel 78kN/m^3
- Wearing Coat 24kN/m^3
- Ballast 20kN/m^3
- Track rails, inside guardrails and fastenings 2kN/m
- Timber 10kN/m^3
- Soil 18kN/m^3

The superimposed dead loads of various elements shown on the typical sections shall be allowed for, using the design density stated above. The wearing coat, ballast, rails, steel or timber ties, fixings, ballast retainers and handrails are considered as super-imposed dead loads.

9.1.2 Railway Live Loads

Cooper E-80 live loading will be used for structures on the BDHR.

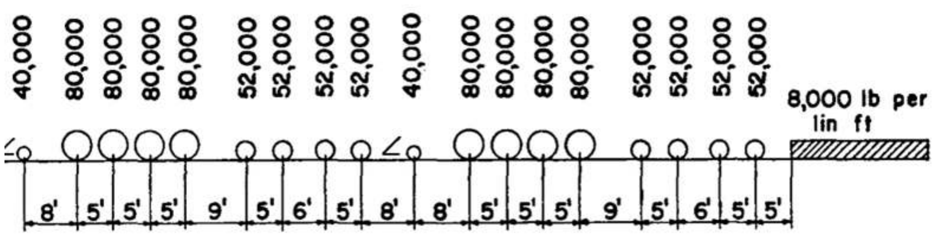

Figure 9-1: Cooper E-80 Loading

Cooper E-60 live loading will be used for structures on the Grevet-Chapais Railway.

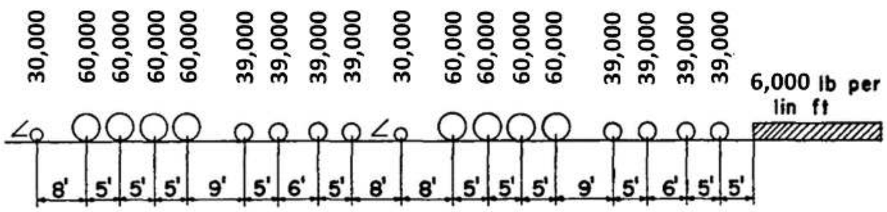

Figure 9-2: Cooper E60 Loading

9.1.3 Impact Load

Impact load, due to the vertical effects created by passage of locomotives and train loads, shall be applied vertically at top of each rail. Impact load expressed as a percentage of live load applied at each rail and depending on the span length of the structure shall be determined by the applicable formulas given in the AREMA Manual.

For concrete structures, these formulae are given in Ch. 8, Clause 2.2.3:

For $L \leq 4$ metres	$I = 60$
For 4 metres $< L \leq 39$ metres	$I = 125 / (L)^{1/2}$
For $L > 39$ metres	$I = 20$
Where:	L = Span length in (m)

For the steel structures, the formulae given in Ch. 15, Clause 1.3.5 shall be applied to rolling equipment without hammer blow (freight and passenger cars, and locomotives other than steam) to obtain the impact force (as a percentage of live load):

For $L < 80$ feet (24.4 m)	$I = 40 - 3L^2/1600$
For $L \geq 80$ feet (24.4 m)	$I = 16 + 600 / (L-30)$
Where:	L is the span length (in feet) as defined in AREMA Manual Ch.15, Clause 1.3.5.

Notes:

For existing concrete structures, reduction of impact may be allowed as follows: for speeds less than 65 km/h the impact shall be reduced in a straight-line variation from full effect at 65 km/h to 0.5 of the full effect at 15 km/h

For existing steel structures, for train speeds below 60 mph (96 km/h), for all spans carrying equipment without hammer blow, the values of the vertical effects of the impact equations shall be multiplied by the factor: $1 - 0.8/2500 \times (60 - S)^2 \geq 0.2$ where S = speed in mph

9.1.4 Wind Forces

In general, the wind forces shall be considered as a moving load acting in any horizontal direction. As a minimum, the bridge shall be designed for laterally and longitudinally applied wind forces defined in the following clauses of AREMA:

For concrete bridges, Chapter 2, Clause 2.2.3:

- On Live Load (Train): A wind load of 4.4 kN/m on the train shall be applied 2.450 m above the top of rail in a horizontal direction perpendicular to the centreline of the track.
- On Structure: The base wind load acting on the structure is assumed to be 2.16 kPa on the vertical projection of the structure applied at the center of gravity of the vertical projection in any horizontal direction.

For steel bridges, Chapter 15, Clauses 1.3.7 and 1.3.8:

- On Live Load (Train): A wind load of 4.4 kN/m on the train shall be applied 2.450 m above the top of rail in a horizontal direction perpendicular to the centreline of the track
- On Loaded Structure: lateral wind pressure shall be taken at 1.44 kPa normal to the following surfaces:
  - For girder spans, 1.5 times the vertical projection of the span.
  - For truss spans, the vertical projection of the span plus any portion of leeward trusses not shielded by the floor system.
  - For bridge piers and bents, the vertical projection of all windward and leeward columns and bracing.
- On Unloaded Structure:
  - The lateral wind force shall be taken as 2.4 kPa of surface as defined above.

9.1.5 Longitudinal Forces

Longitudinal forces due to braking and to traction are defined in Clause 22.3 of Chapter 8 and Clause 1.3.12 of AREMA, Chapter 15. The formulae give the values for the live load according to Cooper E-80 and corresponding to 36 t/axle load. For design loads other than E-80, these forces shall be scaled proportionally without changing the points of force application.

9.1.6 Earth Pressure

Earth pressure forces to be applied to the structure shall be determined in accordance with the provisions of AREMA Manual, Chapter 8, Part 5: Retaining Walls, Abutments and Piers.

9.1.7 Earthquake Forces

The objective of the seismic design is to secure safety for trains operating during an earthquake and to allow for the resumption of transportation as soon as possible after the earthquake stops.

The calculation shall be made using global coefficients that multiply the weight of structure. The seismic zone coefficient values (PGA) are given in Table section 4.3.

Each bridge location will be reviewed, and the appropriate value of Ground Acceleration will be determined. The Ground Acceleration used for any bridge shall be site specific.

The seismic design and structural detailing will be carried out according to AREMA Chapter 9.

9.1.8 Temperature Effects

The coefficient of expansion for steel and concrete shall be taken as 12×10^{-6} per degree Celsius. Temperature effects are to be considered only if any portion of the structure is not free to expand or contract under variation of temperature.

9.2 LOAD COMBINATIONS

As per AREMA MRE Chapter 8 Article 2.2.4, the following load combinations will be checked. The last column in this table indicates the allowable increase in the code-specified working stresses for each combination.

Table 9-1: Load Combinations

Group[1]	D+	LL+I	LF	CF	W	WL	OF	ICE	EQ	%
I	1	1		1						100
II	1				1					125
III	1	1	1	1	0.5	1				125
IV	1	1		1			1			125
V	1				1		1			140
VI	1	1	1	1	0.5	1	1			140
VII	1	1		1				1		140
VIII	1								1	150

Notes:

- D+ includes D (dead load), E (earth pressure), B (buoyancy) and SF (stream force)
- LL+I = live load plus impact load
- LF = longitudinal force (braking and traction)
- CF = centrifugal force
- W = wind on structure
- WL = wind on live load
- OF = walkway and snow loads
- ICE = ice loads
- EQ = seismic loads

9.2.1 Deflection

The deflection of the structure shall be computed for the live loading plus impact loading condition producing the maximum bending moment at mid-span for the simply supported spans. The structure shall be so designed that the computed vertical deflection shall not exceed 1/640 of the span length -centre to centre of bearings for simple spans.

9.3 BRIDGE TYPES AND DECKING

The following tables identify the design options for the bridge type and decking.

[1] These are different load combinations that AREMA has determined as the ones to study for determining the size and dimensions of a railway bridge. For example, Group 1 is the dead load, live load, and centrifugal load.

Table 9-2: Bridge Design Options

Item	Options	Comments
Bridge Type	Through Plate Girder	
	Deck Plate Girder	Preferred choice
	Box Girder	
	Trestle	Not applicable for this design
	Arch Truss	Not applicable for this design
	Through or Deck Truss	Not applicable for this design
Bridge Decking	Open Deck	Applicable only for Grevet-Chapais
	Ballast Deck	Preferred choice

9.4 Material Properties

9.4.1 Concrete

The principle concrete design characteristics are shown in Table 9-3 below

Table 9-3: Concrete Design Characteristic (based on cylinder testing)

Characteristics	Recommended Value
Minimum compressive strength f'_c (f_{cu}) in MPa Lean / Mass concrete Piles Footing, pile cap and piers Reinforced concrete spans Prestressed concrete	 15 (20) 25 (30) 30 (40) 30 (40) 35 (45)
Concrete density (kN/m^3)	24
Modulus of elasticity E_c (MPa)	$4700\sqrt{f'_c}$
Shear modulus G (MPa)	$\frac{Ec}{2(1+\upsilon)}$ Poisson's ratio may be assumed as y = 0.2

9.4.2 Reinforcing Steel

The principal design characteristics and minimum concrete cover of reinforcing bars are shown in the tables below.

Table 9-4: Rebar Design Characteristics

Characteristics	Recommended Value
Minimum yield strength f_c (MPa)	400
Modulus of elasticity Es (MPa)	200,000
Minimum nominal diameter (mm) • Primary reinforcement • Shear and stirrups	 16 10

Table 9-5 Design Concrete Cover

Characteristics	Recommended Minimum Cover (mm)
Concrete cast against and permanently exposed to earth	75
Concrete bridge slab: • Top reinforcement • Bottom reinforcement	50 40
Others: • Principal reinforcement • Stirrups, ties, and spirals	50 40
Precast concrete elements	35
Precast prestressed concrete: • Post-tensioning ducts	40 (but not less than half of duct diameter)

Modulus of Elasticity of Concrete, (Ec) (irrespective of concrete grade) =3.0x104 MPa.

Coefficient of thermal expansion or contraction= 12×10^{-6}.

9.4.3 Structural Steel

All structural steel shall be high tensile steel according to ASTM A588/A588M Grade 50W (weathering steel) or approved equivalent with the following characteristics:

- Tensile Strength = 485 MPa
- Yield Stress = 345 MPa
- Modulus of Elasticity = 200,000 MPa

All welding electrodes shall conform to AWS D1.5 or equivalent. Welding electrodes shall possess similar properties as the steel.

All bolts to be High Strength (HSFG) bolts conforming to ASTM A325M or approved equivalent. The coefficient of friction (mean slip coefficient) between two faces of connected steel will be considered not less than 0.33.

Anchor bolts shall conform to ASTM A307 or approved equivalent.

9.5 Substructure Design

Retaining walls constructed on the project site should be designed to resist lateral earth pressures. Earth pressure on abutments and retaining walls shall be considered granular backfill. The magnitude and distribution of the earth pressures will depend on the type and method of the placement of the backfill materials, the nature of soils behind the backfill, the magnitude of surcharge including construction loadings, the drainage conditions behind the walls, and the subsequent lateral movement of the structure. Seismic (earthquake) loading must also be considered in the design. The lateral earth pressures would increase under seismic loading conditions.

The coulombs equation shall be used for determination of the earth pressure coefficient with the following parameters of the backfill shown in the table below. The point of application of earth pressure due to fill shall be assumed at a height of 0.33h above the section under consideration.

The factor of safety against sliding at the base of the structure shall be at least 1.5.

Table 9-6: Earth Pressure Coefficients

Parameter Description	Parameter Value		
Material	Earth Fill	MG-112	MG-56
Unit Weight (kN/m3)	20	19	22
Coefficient of earth pressure at rest (k0)	0.5	0.47	0.36
Coefficient of active earth pressure (ka)	0.33	0.31	0.22
Angle of internal friction of back fill soil (f)	30 °	32 °	40 °

9.6 Culverts

AREAMA MRE Part 10, “Reinforced Concrete Culvert Pipe” and Part 4 “Culverts” will be used in the structural design of culverts on the BDRH and Grevet-Chapais Railway.

Table 9-7: Culvert Design Requirements

Item	Criteria
Type	Steel: Corrugated Pipe (CSP) or Bottomless Plate Arch Concrete: Pipe or Box Culvert (High Density Polyethylene Pipe not used for design but possible if it meets same resistance as CSP)
Concrete Culvert Construction	Where environmental conditions permit: Diameters ≤ 1.5m = Concrete Pipes Diameters > 1.5m = Concrete Boxes
Steel Culvert Construction	Where environmental conditions permit: Intermittent = CSP Permanent = Bottomless Plate Arch
Minimum Diameter of CSP	600mm
Minimum Cover of CSP	1,200mm
Minimum Thickness of CSP	2mm
CSP Foundation	Width: D/3, where D = diameter of CSP Thickness: 150mm to 450mm depending on the CSP diameter
Clearance between 2 CSP in parallel	1m (side by side)

10

Hydrology

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10. HYDROLOGY

This chapter sets out the hydrological and hydraulic design criteria for culvert, ditches and bridges, which are based on the standards required by, but not limited to, the Ministère des Transports et de la Mobilité durable du Québec (MTMD), the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs du Québec (MDDELCCFP), and AREMA.

10.1 RAINFALL DATA

The meteorological stations in closest proximity to the study area are Environment Canada's Chapais station (Climate ID: 7091299 Latitude: 49˚49' N; Longitude: 74˚59'W; Elevation: 381 m) and Matagami station (Climate ID: 7094639 Latitude: 49˚46'; Longitude: 77˚49'W; Elevation: 281 m). At Chapais station the average annual precipitation is 995.5 mm, with 684.4 mm of this amount falling as rain. At Matagami station the average annual precipitation is 906.72 mm, with 589 mm of this amount falling as rain.

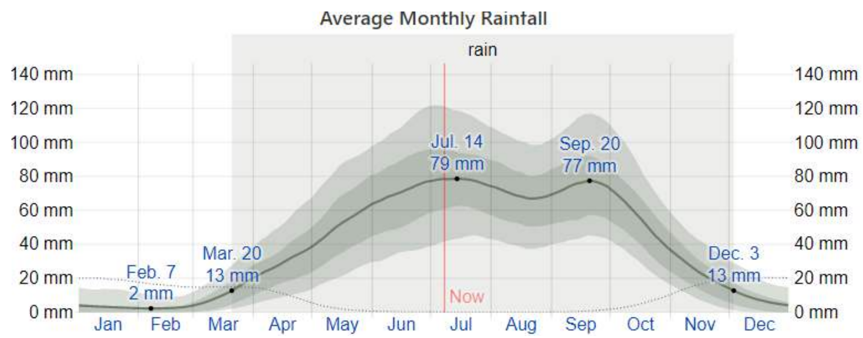

Figure 10-1: Monthly Average Rainfall at Chapais Station

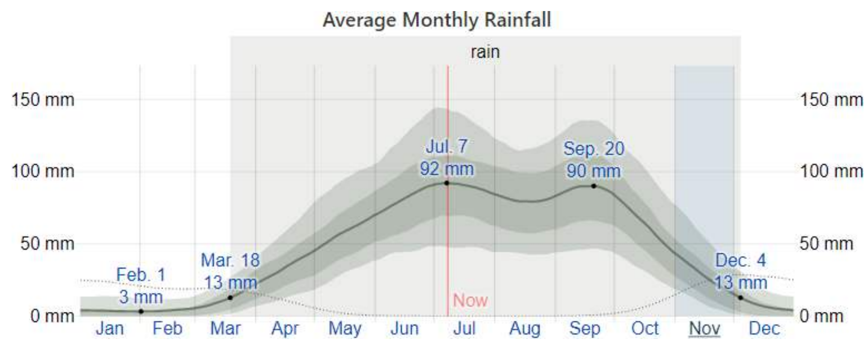

Figure 10-2: Monthly Average Rainfall at Matagami Station

An intensity-duration-frequency curve (IDF curve) is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence. The IDF curves and the rainfall intensities for various frequency of occurrence for the subject areas can be retrieved from Environment and Climate Change Canada. Rainfall intensity from a representative IDF curve is applicable when using the Rational Method for calculating the peak flow rate whereas the precipitation volume is applicable when using the SCS Method.

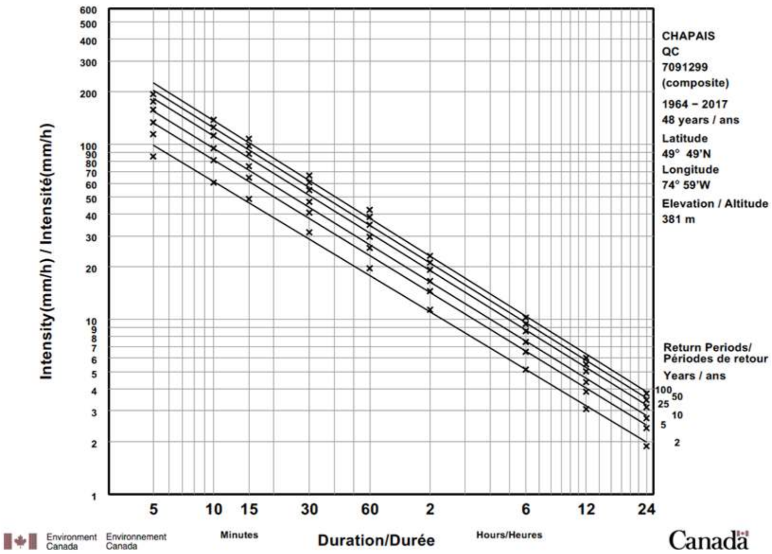

Figure 10-3: Rainfall Intensity-Duration-Frequency (IDF) at Chapais Station

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	85.4	114.4	133.7	158.0	176.0	193.9	48
	+/- 8.5	+/- 14.4	+/- 19.4	+/- 26.2	+/- 31.3	+/- 36.5	48
10 min	60.5	81.3	95.1	112.5	125.4	138.2	48
	+/- 6.1	+/- 10.3	+/- 13.9	+/- 18.8	+/- 22.4	+/- 26.1	48
15 min	48.8	64.6	75.0	88.2	98.0	107.7	48
	+/- 4.6	+/- 7.8	+/- 10.5	+/- 14.2	+/- 17.0	+/- 19.8	48
30 min	31.4	40.8	47.0	54.8	60.6	66.4	48
	+/- 2.7	+/- 4.6	+/- 6.3	+/- 8.4	+/- 10.1	+/- 11.8	48
1 h	19.6	25.6	29.6	34.7	38.5	42.2	48
	+/- 1.8	+/- 3.0	+/- 4.1	+/- 5.5	+/- 6.5	+/- 7.6	48
2 h	11.3	14.5	16.6	19.2	21.1	23.1	48
	+/- 0.9	+/- 1.6	+/- 2.1	+/- 2.8	+/- 3.4	+/- 3.9	48
6 h	5.2	6.5	7.4	8.6	9.4	10.2	48
	+/- 0.4	+/- 0.7	+/- 0.9	+/- 1.2	+/- 1.5	+/- 1.7	48
12 h	3.1	3.9	4.4	5.0	5.5	6.0	48
	+/- 0.2	+/- 0.4	+/- 0.5	+/- 0.7	+/- 0.9	+/- 1.0	48
24 h	1.9	2.4	2.7	3.1	3.5	3.8	48
	+/- 0.1	+/- 0.2	+/- 0.3	+/- 0.5	+/- 0.5	+/- 0.6	48

Figure 10-4: Return Period Rainfall Rates (mm/hr) at Chapais Station

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	7.1	9.5	11.1	13.2	14.7	16.2	48
10 min	10.1	13.6	15.8	18.7	20.9	23.0	48
15 min	12.2	16.1	18.8	22.1	24.5	26.9	48
30 min	15.7	20.4	23.5	27.4	30.3	33.2	48
1 h	19.6	25.6	29.6	34.7	38.5	42.2	48
2 h	22.7	28.9	33.1	38.4	42.3	46.1	48
6 h	31.0	39.1	44.5	51.3	56.4	61.4	48
12 h	36.8	46.3	52.5	60.5	66.3	72.2	48
24 h	45.2	57.3	65.3	75.4	82.9	90.4	48

Figure 10-5: Return Period Rainfall Amounts (mm) at Chapais Station

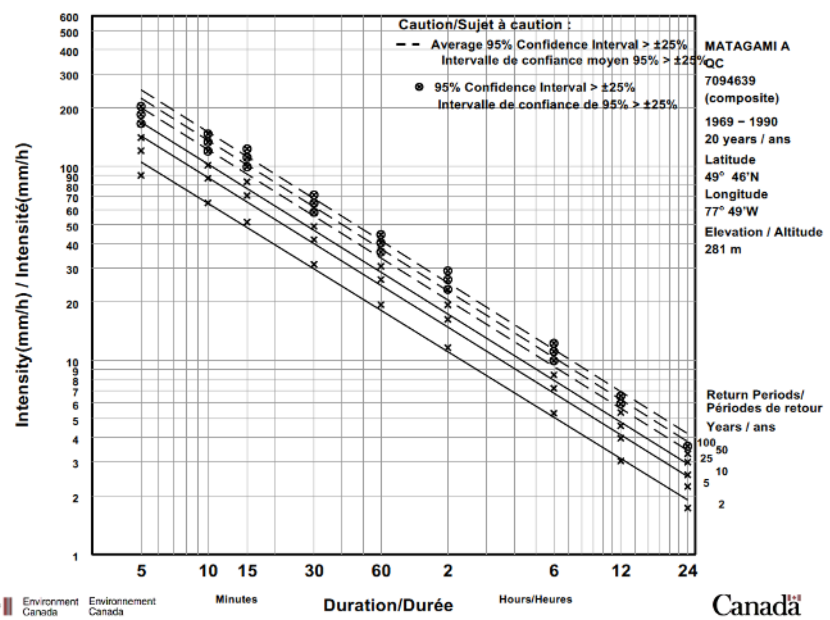

Figure 10-6; Rainfall Intensity-Duration-Frequency (IDF) at Matagami Station

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	89.9	120.4	140.7	166.2	185.2	204.0	20
	+/- 13.9	+/- 23.4	+/- 31.6	+/- 42.6	+/- 51.0	+/- 59.4	20
10 min	64.8	86.8	101.4	119.8	133.5	147.1	20
	+/- 10.0	+/- 16.9	+/- 22.8	+/- 30.8	+/- 36.8	+/- 42.9	20
15 min	51.6	70.7	83.4	99.4	111.2	123.0	20
	+/- 8.7	+/- 14.7	+/- 19.8	+/- 26.7	+/- 32.0	+/- 37.2	20
30 min	31.2	41.9	49.0	58.0	64.6	71.2	20
	+/- 4.9	+/- 8.2	+/- 11.1	+/- 14.9	+/- 17.9	+/- 20.8	20
1 h	19.4	26.1	30.5	36.1	40.3	44.4	20
	+/- 3.1	+/- 5.2	+/- 7.0	+/- 9.4	+/- 11.2	+/- 13.1	20
2 h	11.6	16.2	19.3	23.2	26.1	28.9	20
	+/- 2.1	+/- 3.6	+/- 4.8	+/- 6.5	+/- 7.7	+/- 9.0	20
6 h	5.3	7.2	8.4	9.9	11.1	12.2	20
	+/- 0.8	+/- 1.4	+/- 1.9	+/- 2.6	+/- 3.1	+/- 3.6	20
12 h	3.0	4.0	4.6	5.4	6.0	6.5	20
	+/- 0.4	+/- 0.7	+/- 1.0	+/- 1.3	+/- 1.6	+/- 1.8	20
24 h	1.7	2.2	2.6	3.0	3.3	3.6	21
	+/- 0.2	+/- 0.4	+/- 0.5	+/- 0.7	+/- 0.8	+/- 1.0	21

Figure 10-7: Return Period Rainfall Rates (mm/hr) at Matagami Station

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Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	7.5	10.0	11.7	13.9	15.4	17.0	20
10 min	10.8	14.5	16.9	20.0	22.3	24.5	20
15 min	12.9	17.7	20.8	24.8	27.8	30.8	20
30 min	15.6	21.0	24.5	29.0	32.3	35.6	20
1 h	19.4	26.1	30.5	36.1	40.3	44.4	20
2 h	23.2	32.5	38.6	46.4	52.1	57.8	20
6 h	31.9	43.0	50.4	59.7	66.5	73.4	20
12 h	36.3	47.6	55.1	64.5	71.6	78.5	20
24 h	41.5	53.6	61.5	71.6	79.1	86.5	21

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Figure 10-8: Return Period Rainfall Amounts (mm) at Matagami Station

Effects of climate change on the above rainfall amounts are then factored to account for climate change by a government recommended factor (currently 10%).

10.2 Topographical Data

Surface runoff is greatly influenced by topography, the soil conditions, and the land use. The geographic areas of study (BDH Railway and Grevet-Chapais Railway) is located in the Canadian subarctic region where peak runoff period occurs in the spring. This region is dotted with thousands of lakes, streams, and swamps. Although the soil in the area is relatively saturated – resulting in more surface water- runoff. However, the runoff slows down due to relatively flat topography and the influence of lakes and swamps.

Digital topographic maps produced by National Resources Canada (NRCan) conform to the National Topographic System (NTS) of Canada. They are available in two standard scales: 1:50 000 and 1:250 000. The 1:250 000 scale maps will be used for watershed delineations, the calculation of the surface area of lakes and swamps in each watershed, the calculation of the catchment slope and the flow path for each of the watersheds. The Google imagery was used to identify the location and the width of the major watercourses. In addition to the topographical data, the soil type according to its hydrological characteristics was used for this hydrological study based on the soil map at Chapais.

Catchment slope (85/10 Method) Calculation:

$$S_w = 100\left[\frac{\Delta h - h_f}{0.75(L - L_f)}\right]$$

Where:

Δh = different in elevation (m) between the 85% points and the 10% point obtained from contours

Hf = sum of heights of rapids and waterfalls between 10% and 85% points (m)

L= total length of the main channel including the undefined flow path to head of the basin (m)

Lf = sum of lengths of rapids and waterfalls up to 10% of L (m)

Table 10-1 Drainage Calculations and Hydrologic Method

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Item	Criteria
Design Rainfall	For Culverts: • 25 Year Rainfall at Matagami Station and Chapais Station and • 100 Year Rainfall at Matagami Station and Chapais Station for verification For Bridges: • 100 Year Rainfall Data at Matagami Station and Chapais Station
Watershed ≤ 25km^2 Regular Crossings	Rational Method: Q (m^3/s) = 0.00275 x C_p x I x A_b Where: Q: Peak flow (m^3/s), C_p: Runoff coefficient, I: Rainfall intensity (mm/hr), A_b: Watershed surface area (ha)
Watershed > 25km^2 Regular Crossings	Soil Conservation Service (SCS) Curve Number Method: $Q_T = \frac{0.2083 \times S \times P_c}{0.5D + 0.6T_c}$ $P_C = \frac{(X_T - 0.2E)^2}{(X_T + 0.8E)}$ $E = (\frac{25400}{CN}) - 254$ Where: CN: Curve number, E: Potential retentions (mm), X_T: 24-hour rainfall corresponding to the design return period (mm), Q_T: Peak runoff in T years of design return period (m^3/s), Pc: Direct surface runoff (mm), S: Watershed area (Km^2), Tc: Catchment time (hr), D: The duration of excessive rainfall (Assume D=0.5Tc)
Navigable Crossings	Design with 2-year return period rainfall

Item	Criteria
Other Considerations[3]	Time of concentration: • For C > 0.4: Tc = 0.057 x L x A-0.2 x S-0.1 • For C < 0.4: Tc = 3.26 (1.1 – C) x $L^{0.5}$ x $S^{-0.33}$ (C < 0.4) Where: C = Runoff coefficient L = Flow path distance (m) A = Catchment area (ha) S = Flow path slope (%) Note: • Minimum time of concentration = 10 min. • Influence of Lakes & Swamps: FL • Rainfall intensity correction coefficient for the time of concentration (tc) greater than 60 mins: Fi = 17.07 x tc-0.693 • Climate Change factors: See Tables below

Table 10-2: 2080s Climate Change at Chapais

T (years)	2		5		10		20		25		50		100	
5 min	8.19	15.2%	10.94	14.7%	13.3	19.4%	15.97	25.9%	16.84	28.0%	19.83	35.2%	23.21	43.6%
10 min	11.66	15.7%	15.79	16.5%	19.16	20.9%	23.07	27.8%	24.31	29.7%	28.2	34.9%	32.52	41.1%
15 min	14.3	17.3%	19.1	18.3%	22.79	21.5%	27.1	27.5%	28.35	28.6%	31.98	30.5%	36.19	34.4%
30 min	19.21	22.2%	24.81	21.7%	28.69	22.1%	32.62	23.3%	33.75	23.1%	37.12	22.5%	40.68	22.6%
1 h	23.78	21.6%	31.02	21.1%	36.22	22.2%	41.39	23.6%	43.09	24.1%	47.82	24.3%	52.41	24.2%
2 h	28	23.5%	35.39	22.2%	40.27	21.6%	45.05	21.5%	46.34	20.8%	50.37	19.2%	54.59	18.4%
6 h	38.1	23.1%	47.52	21.5%	53.89	21.1%	60.38	21.5%	62.14	21.1%	67.63	19.9%	73.64	19.9%
12 h	45.02	22.3%	56	21.0%	63.79	21.4%	71.76	22.5%	74	22.4%	80.85	21.9%	88.26	22.3%
24 h	55.57	23.0%	69.57	21.5%	79.06	21.1%	88.71	21.5%	91.34	21.1%	99.48	19.9%	108.42	19.9%

Table 10-3: 2080s Climate Change at Matagami

T (years)	2		5		10		20		25		50		100	
5 min	8.49	15.2%	11.75	17.0%	14.27	19.9%	16.42	19.0%	17.04	18.6%	19.46	19.4%	21.98	20.2%
10 min	11.97	15.2%	16.23	17.1%	19.87	19.9%	23.34	19.0%	24.41	18.6%	28.73	19.4%	33.66	20.2%
15 min	14.19	15.3%	19.63	17.1%	24.34	19.9%	28.91	19.0%	30.31	18.5%	36.03	19.4%	42.59	20.2%
30 min	17.78	15.2%	24.54	17.1%	29.65	19.9%	33.94	19.0%	35.13	18.5%	39.86	19.4%	44.7	20.1%
1 h	21.85	15.2%	30.21	17.1%	36.76	19.9%	42.44	19.0%	44.08	18.6%	50.55	19.4%	57.37	20.1%
2 h	25.5	15.2%	36.09	17.1%	45.35	19.9%	54.52	19.0%	57.38	18.6%	68.93	19.4%	82.31	20.2%
6 h	35.59	15.2%	48.6	17.1%	59.44	19.9%	69.44	19.0%	72.47	18.6%	84.54	19.4%	97.91	20.2%
12 h	40.46	15.2%	53.99	17.1%	65.42	19.9%	75.99	19.0%	79.2	18.5%	92.16	19.4%	106.66	20.2%
24 h	46.55	15.2%	61.3	17.1%	73.59	19.9%	84.66	19.0%	87.98	18.5%	101.4	19.4%	116.21	20.2%

Table 10-4: Runoff Coefficient for Various Types of Runoff Surface[4]

Runoff Surface Type	Runoff Coefficient
Railway yard	0.20 – 0.35
Light industrial area	0.50 – 0.80
Heavy industrial area	0.60 – 0.90
Asphalt	0.50 – 0.70
Gravel surfaces	0.60 – 0.65
Ballast (25-year rainfall event)	0.66
Ballast (100-year rainfall event)	0.84
Lawn and grassed area	0.35

The Design Flood is used to determine the required hydraulic capacity of the structures. Considering the proposed railway culverts and bridges have a service life of up to 50 years, the Design Flood is based on the 100-year flood return period as there is roughly a 40% chance this level will be exceeded during the service life of the structure.

$$R = \left[1 - \left(1 - \frac{1}{T}\right)^{Z}\right] \times 100$$

Where:

RR = Annual exceedance probability, %

TT = Flood return period, year

ZZ = Service life, year

10.3 DITCHES

There are various types of ditch such as Interceptor (Crest) ditch, embarquement toe ditch, and trackside ditch. All the proposed ditches will be trapezoidal open channel. Ditch hydraulics takes the form of open channel flow. The hydraulic capacity of a ditch depends on its dimensions, slope, and roughness coefficient. Followed by hydrological analysis to determine the design discharge the ditch should be designed to convey, the hydraulic analysis is to determine the hydraulic requirements of the ditch to adequately conveying the design discharge.

The capacity of a ditch can be determined by using Manning's equation:

$$Q = A \times R^{2/3} \times S^{0.5} \times n^{-1}$$

Where:

Q = Capacity (m3/s)
A = Ditch cross-sectional area (m2)
R = Hydraulic radius
S = Slope of the ditch
N = Roughness coefficient

Table 10-5 :Trackside Ditch Design Requirements from AREMA MRE 1-1.2.4.2.e

Description	Criteria
Minimum depth measured from the edge of the subgrade line	24 in (600 mm)
Minimum base width, for ditch on earth materials	36 in (900 mm)
Minimum gradient, for ditch on earth materials to minimize sedimentation	0.25%
Design Flow	25-year flood

Table 10-6: Roughness Coefficient for Various Types of Ditch Lining

Lining Type	Roughness Coefficient
Concrete	0.011 – 0.015
Earth	0.016 – 0.020
Gravel	0.023 – 0.036
Vegetal Lining	0.030 – 0.500

Table 10-7: Maximum Permissible Velocities for Various Types of Ditch Lining

Lining Type	Velocity
Grass covered	6 ft/s or 1.8 m/s
Stones (100 – 150mm)	8 – 10 ft/s or 2.5 – 3.0 m/s
Boulders (250mm)	16.5 ft/s or 5.0 m/s
Hard packed rock	20 ft/s or 6.0 m/s
Asphalt	10 ft/s or 3.0 m/s
Concrete	20 ft/s or 6.0 m/s

10.4 CULVERTS

Culvert hydraulics takes the form of both pressure flow and open channel flow. A hydraulic analysis determines the hydraulic requirements of the culvert to adequately convey the design discharge. These requirements determine the size, shape, slope, inlet and outlet treatments of the culvert. Culvert hydraulics analysis will be carried out with the HY-8 Culvert Hydraulic Analysis Program, which is software developed by the United States Federal Highway Administration (FHWA) and used by the Ministère des Transports et de la Mobilité durable du Québec (MTMD) and the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs du Québec (MDDELCCFP) for drainage management.

The proposed culverts crossing BDH railway track as well as the existing culverts crossing Grevet-Chapais railway track will need to be designed or re-designed to ensure that their hydraulic capacity will be able to accommodate the increased rainfall resulting from climate change.

Table 10-8: Minimum Design Requirements for Culvert

Item	Criteria
Type of Culvert	Steel: • Corrugated Pipe (CSP) Culvert: Diameter ranges from 0.6m to 2.0m. • Bottomless Structural Plate Bolt-a-Plate Culvert: Span ranges from 2m to 10m. • Bottomless Structural Plate Super-Cor Culvert: Span ranges from 10m to 25m Span.
Design Flow	• A 25-year flood without static head at the entrance (a maximum headwater to culvert diameter/rise ratio (HW/D) of 1.0). • A 100-year flood with maximum 2 ft headwater below base of rail at the entrance or results in a HW/D not exceeding 1.5, whichever is less.
Minimum Diameter of Pipe Culvert[6]	• 24 in (600 mm) for main line track. • 18 in (450 mm) for other tracks.
Minimum Height of Cover[7]	Minimum 12 in (300mm) between the top of the CSP culvert to the bottom of ties (1200mm based on CN Standards).
Minimum Permissible Spacing between Culverts in Parallel[8]	• 12 in. (0.3 m) (For 24 in diameter culverts and smaller). • 0.5D (For 24 in - 72 in diameter culverts). • 36 in (0.9 m) (For 72 in and larger diameter culvert). • where D = diameter of culverts.
Design Considerations for Fish Passage[9]	Bottomless Structural Plate Culvert to be used. If CSP Culvert be used, then, 1) The bottom of CSP buried below riverbed by 10% of its diameter 2) Min. 200mm depth of water flowing at the bottom of a CSP 3) Maximum drop at the outlet of a CSP = 300mm 4) Permissible Flow velocity in culvert: For culvert length ≤ 25m: 1.2m/s For culvert length > 25m: 0.9m/s 5) If width of waterway is reduced by culvert by 20-50% For the culvert length ≤ 25m: 1.0 % max slope of culvert For the culvert length > 25m: 0.5 % max slope of culvert
Minimum Thickness of CSP Culvert	2mm
CSP Foundation[10]	• Width: D/3, where D = diameter of CSP • Thickness: 150mm to 450mm depending on the CSP diameter

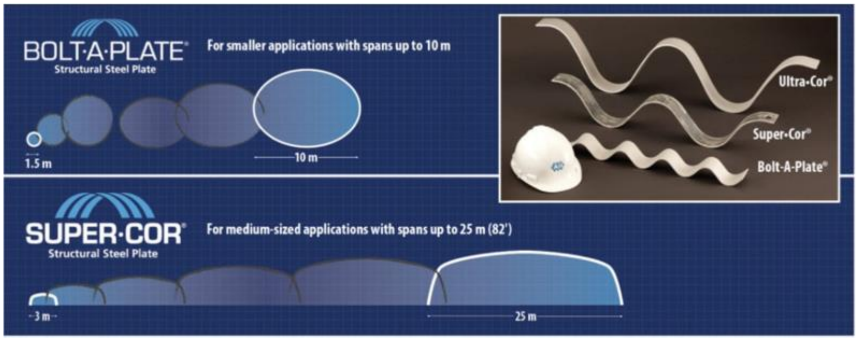

Figure 10-9 Types of Structural Steel Plate Culvert

Table 10-9: Rip-Rap Sizes for Erosion Protection

Rip-Rap Type	Thickness	Rip-Rap Size	Maximum Permissible Velocity
1	12 in 300 mm	8 – 0 in 200 – 0 mm	6.5 ft/s 2.0 m/s
2	12 in 300 mm	8 – 4 in 200 – 100 mm	7.5 ft/s 2.3 m/s
3	20 in 500 mm	12 – 8 in 300 – 200 mm	9.2 ft/s 2.8 m/s
4	28 in 700 mm	16 –12 in 400 – 300 mm	10.5 ft/s 3.2 m/s
5	32 in 800 mm	20 – 12 in 500 – 300 mm	11.2 ft/s 3.4 m/s

10.5 Effects of Beaver Dams on Subaortic Wetland Runoff

Beaver dams can alter runoff in subarctic wetlands temporarily, spatially, and to varying degrees depending on the geometry, type, and class of beaver dam. In general, the more recently built and well-maintained dams have the greatest effects causing the impounded water to outflow the stream banks and divert to the surrounding wetland whereas, the dams in disrepair impound little water and divert no water to the wetland. During low flow, the overflow and gap flow type dams divert much water to the wetland while the underflow and through flow type dams do not. At high flow, the gap flow and the overflow type dams continue to divert water to the wetland as do the underflow type. In addition, basins with beaver dams have an enhanced evaporation flux, decreased outflow, decreased groundwater flux, and an increased storage with respect to the basins without beaver dams.

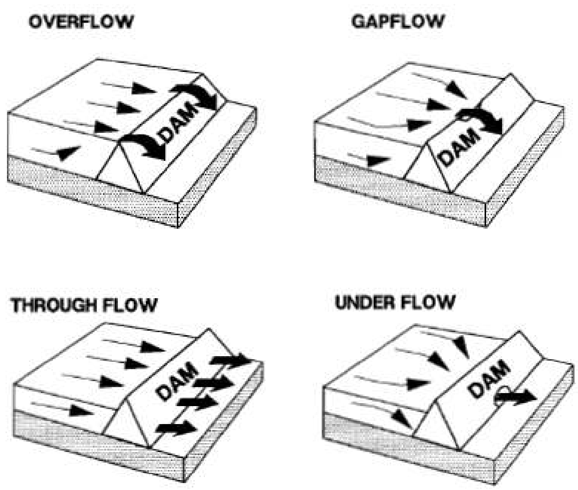

Figure 10-10 Types of beaver dams

11

Signals and Communication

11. SIGNALING AND COMMUNICATION

11.1 TERMINOLOGY

In order to clarify the terminology used in this section, this paragraph provides a review of the state-of-the-art train control system technologies in Canada. The signaling systems described below are defined in detail in Transport Canada report TP 13105E.

Definitions:

Block: A length of the track of defined limits, the use of which by train or engine is governed by block signals, cab signals, or both.

Block signal: A fixed signal at the entrance to a block to govern a train or engine entering or using that block.

Supervision: The movement of trains or engines supervised by dispatchers at the Operations Control Centre (OCC), who will issue instructions as may be required.

Balise: A passive transponders which transmits via radio its exact location to passing trains.

Dual control switch: A switch equipped for powered operations, also equipped for hand operation. Except as required by the rule, a dual-controlled switch must not be placed in "hand" position without permission from the OCC or signalman.

The following train control methods are described below:

Non-signaled territory: A line governed by COCR rule.

Commenté [MH2]: EN uses COCR, Is it CROR? As in Canadian Rail Operating Rules?

- Dispatchers issue movement authorities and manage clearances and permits according to rail operating rules. In advanced non-signaled systems (CMBS/CAMBS/OCS), dispatchers are assisted by a computer software located in the OCC to monitor train movements. This software provides protection against train conflicts and eliminates human errors at the dispatcher level.
- In this method the dispatchers rely on location information given by the train driver at specific mileposts to locate trains. Similarly, the Dispatcher relies on information from the Track Maintenance Foreman to protect maintenance of way personnel and vehicles.

Signaled territory - Automatic Block Signal System (ABS): A series of consecutive blocks which are governed by block signals, cab signals, or both, in which ABS rules apply.

- The signals in ABS are actuated by the block occupancy by a train or engine, or by other conditions affecting the use of the block. When signals in ABS are withdrawn from service, trains and engines will be governed by train orders, GBO, or special instructions.
- The line is equipped with track circuits to detect the track occupancy status at certain blocks. Depending on the track circuit technology, the block length ranges from 2 to 10 km. Only certain sections of the line are divided into blocks, generally at stations and sidings.
- When a train or maintenance of way vehicle is detected in a block, the track circuit sends its information to an interlocking system which controls signals and allows the dispatcher to command switches and set routes, authorizing train movements and preventing train meets in the block.

Signaled territory - Centralized Traffic Control System (CTC): A system in which CTC rules apply.

- Where CTC is designated in the timetable or special instructions, trains and engines will be governed by block signals, cab signals, or both, and with reference to both opposing and following trains and engines on the same track.
- The rail line is equipped with track circuits installed along the entire line to detect the block occupancy. The block length ranges from 2 to 5 km, depending on various parameters including train load, authorized speed, and maximum stopping distance. Dispatchers located at the OCC set train routes, control train movements and switch positions over the entire line. Wayside signals or in-cab signals provide indications and information of the status of the tracks ahead to the train.
- Trains are given access to a block only after the train ahead has left the block, or the following one, based on operation rules. Track circuits send their information to an interlocking system which controls signals and allows the dispatcher to command switches and set routes. Train movements and speeds are dictated by indication from signals installed along the tracks or displayed in the driver cab. These signals have several aspects and are often elaborate. Train drivers shall strictly adhere to signal indications at all times. CTC lines can also be equipped with an automatic train protection (ATP) system to enforce speed limits and apply emergency braking (if necessary), thus enhancing safety of operations.

Signaled territory - Moving block: This system relies on data communications between trains and the OCC to authorize train movements.

- The line is not divided into blocks. Dispatchers located at the OCC set train routes, control train movements and switch positions over the entire line. The train calculates its position based on in-cab odometers and balises installed along the tracks and sends it in real time to the OCC.
- Based on actual position of all trains, software installed in the OCC determines the safe train distances based on their length, actual speed and direction, the track geometry, safe braking distances and stopping characteristics. An interlocking system controls and command switches based on the train routes set by the dispatcher. This principle of operations is denominated as moving blocks, as opposed to fixed blocks used with ABS and CTC methods.
- Train movements and speeds are dictated by information displayed in the driver cab according to data communications with the OCC. Train drivers adhere to in-cab indications at all times and trains can be equipped with an ATP system to enforce speed limits and apply emergency braking (if necessary), thus enhancing safety of operations. This system is able to support high traffic and reduce waiting times, thus increasing the efficiency of train operations.

None of these technologies solely relies on GPS tracking to determine train positions, since this technology is neither a safe nor accurate enough for train operations. Meanwhile many systems use GPS to complement track circuits and odometer systems, providing dispatchers with additional non-vital train positioning information.

The table below lists out the options and characteristics of the telecommunications components to be developed in the Feasibility Study.

Table 11-1: Signaling System Components

Component	Options	Characteristics
Train Control System	Non-signaled system (Manual or computer-assisted train orders or train order system via radio)	System makes operations slower & more difficult. Safety of train movements depends on the ability of the system to avoid human errors and inaccurate decisions at the dispatcher level.
	ABS signaling system	System adapts to the number of trains per day.
	CTC signaling system with wayside signals	Requires equipping railway line with heavy infrastructure consisting of signals & track circuits. Suitable for high-volume traffic.
	CTC signaling system with in-cab signaling	Requires equipping whole line with track circuits & all rolling stock & MOW vehicles with on-board computers. Suitable for high-volume traffic.
	Moving block signaling system	Requires equipping all trains & MOW vehicles. Prevents other users who are not equipped from using the mainline. Suitable for high-volume traffic.
Switch Control	Manual control of switches.	Requires human intervention at each switch, reducing operation fluidity.
	Dual Control switches controlled and locked from the OCC.	System adapts to needs of railway operation. Ensures smooth movement & operation. Requires installation of motorized switches with cold-air blowers, wayside signals & local track circuits to prevent movement of switches.
End-of-Train Device	Used by operator to ensure train integrity.	Industry standard.
Traffic Monitoring System	Monitoring of rolling stock movements via GPS.	Real-time display of rolling stock & MOW vehicle positions in the OCC is not a reliable system, however, it provides non-vital information to dispatchers to supplement track-circuit occupancy or odometer systems.
	Track circuits	Real-time display of block occupancy in the OCC.
Safety Equipment	Hot box detectors	Locations to be determined as per industry practices. *
	Rail pull-apart detectors	Track circuits permit detection of broken rails but do not detect all types of rail breaks e.g. broken heads.
	Wheel impact load detectors (WILD)	Locations to be determined with full compliance with AAR*.
	Dragging equipment detectors	To be installed with hotbox/wheel detectors. *
	Weigh-in-motion Scale (WIM)	To identify irregular loading of wagons. **
	Rock fall / avalanche detector (intrusion alarm)	Locations to be determined as per industry practices e.g., tunnel entrances. * The detectors will be located at deep cuts where geotechnical results indicate a higher risk of rockslide or slope instability.

Component	Options	Characteristics
	Acoustic Bearing Detection System	To identify potential wheel bearing deterioration in advance of Hot Box Detector
Equipment Identification	AEI Tag Readers	Facilitates identification of specific wagons.
Rail/Road Crossings	Railway crossing signs	Cross-arms
	Active crossing without barrier	Cross product ≥ 1,000
	Active crossing with barrier	Cross product > 50,000
(*) An AEI reader connected to the detector will allow identification of the wagon with a defective component. The detector will be connected to a VHF mobile which will broadcast the information of any defective component to the locomotive engineer and to the dispatcher. A data message will also be sent.		
(**) Weigh in motion detectors will be connected to an AEI reader and the weigh in motion system will be designed to allow identification of overloaded cars and / or distorted loading of cars at one end or one side. WIM detectors will send the info by data message to the loading supervisor.		

Some of the Safety Equipment detectors listed above could be consolidated into a Supersite detector. A Supersite is a comprehensive multi-sensor monitoring system for the detection and measurement of bearings and rolling wheel surface defects. The Supersite system comprises of Bearing Acoustic Monitor, Wheel Condition Monitor, Vehicle / Bogie Geometry, Tracking, Vehicle Weights and Wheel Profile, with data integrated via software to provide a total trackside intelligence system.

11.2 TELECOMMUNICATIONS

The telecommunication system is required to provide a communication link at all times between the dispatcher, train crews, and maintenance personnel.

This system must meet two objectives:

- Cover all the requirements of the railway operation,
- Ensure the safety of personnel at all locations, including tunnels.

The operator must submit a radio frequency request to the CRTC. This request will include the number of radio channels required, which is dependent upon the number of train and MOW crews.

If fiber optic cable is selected as the railway's transmission backbone, a part of the cable could serve as a back-up telecommunication system at FLNA. This would provide a means for emergency transmission in case there is a malfunction of the dedicated, primary telecommunication system at FLNA.

The table below lists out the options and characteristics of the telecommunications components to be developed in the Feasibility Study.

Table 11-2: Component Options and Characteristics

Component	Options	Characteristics
Primary Transmission Backbone	Fiber optic cable installed along ROW	Reliability, resilience & excellent technical performance. System adaptable to railway operational requirements.
		Buried cable or aerial cable on utility poles.
		Cable laid during track construction.
		Single cable: fiber count min. 24 fibers.
	Microwave	Requires construction of towers to connect sites. Less reliable & sensitive to weather conditions.
Back-Up Transmission Backbone	Fiber optic cable installed along ROW	Ensures full redundancy.
	Microwave	Ensures full redundancy.
	Satellite phones	Limited system, as satellite transponders would be required for locations with no signals i.e. tunnels.
Transmission Technology	SONET	> 100 Mbps per direction
	Ethernet	> 100 Mbps per direction
Radio Technology	Dedicated mobile phone network: GSM-R, TETRA or PTC	Complex system more adaptable to metro and high-density railways.
	Cellular network	Not available on Right of Way (ROW).
	Satellite communication	Low bandwidth system. Direct visibility between terminals & satellite is required. Service in tunnels to be analyzed.
	Digital VHF Network	• System adaptable to railway operational requirements with provision of several radio channels and frequencies. VHF network will be robust based on appropriate equipment redundancy. • Analog VHF is not considered due to foreseen short-term obsolescence of the technology.
Land-Based Radio Infrastructure	Aerial environment	Towers, antennas & waveguides placed close to ROW.
	In tunnels	Radiating (leaky) cables. Redundancy required.
Satellite Infrastructure	Aerial environment	Nil
	In tunnels	To be investigated.
Radio Availability	Aerial, within min. of 200m from ROW	Radio coverage study to be performed.
	Inside tunnels, within 10m from tunnel entrances.	Radio coverage study to be performed.

11.3 BUNGALOWS AND POWER SUPPLY

Signaling and telecom equipment must be installed in bungalows that will be maintained to a stable temperature, compatible with the operation of electronic equipment. These bungalows must have their own back-up power supply.

Table 11-3: Requirements for Signaling Bungalows

Component	Options	Characteristics
Equipment Storage	Heating, AC, Ventilation	Mandatory
	Dimensions	Maximum 8' X 8'
	Location	Away from radio towers to avoid damage from falling ice.
	Security	Protected against vandalism and theft.
Electrical Power Sources	Principle power supply without external source	Diesel generator
	Principle power supply with external source	Power transformer
	Voltages supplied	To be analyzed per industry standards & practices.
	Back-up power supply without external source	Back-up diesel generator identical to main, equipped with automatic switch-over mechanism.
	Back-up power with external power source	Back-up diesel generator with automatic switch-over mechanism.
	Fuel Tanks	• Protected against intrusion. • Sized to ensure 6-month supply in all seasons. • Dedicated wagon for providing fuel to fuel tanks. • If external power supply not available, both generators equipped with identical tanks.

12

Road Geometry

Commenté [MH3]: Table of contents and title below uses Access Roads

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12. ACCESS ROADS

12.1 INTRODUCTION

Access road are defined by roads within the property of the railway and used exclusively by authorized personnel. Access road elements include the roadway, shoulders, embankments, ditches and cuttings. These elements are within the access road right-of-way and are shown in the following figure.

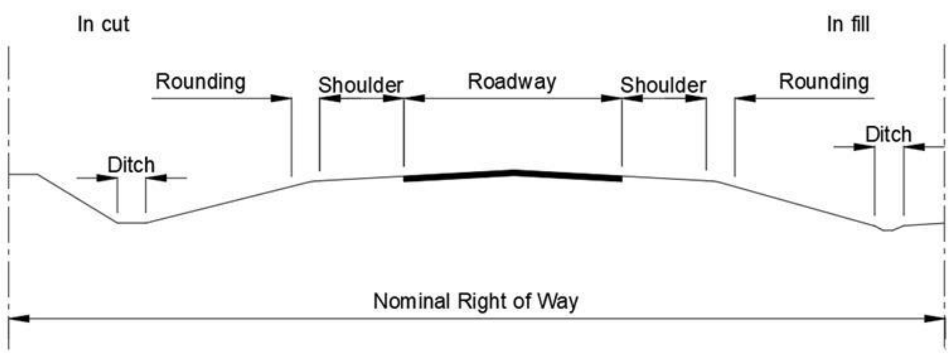

Figure 12-1: Access Road Cross-section

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12.2 ROAD STRUCTURE

During roadway construction, the first step is earthworks, namely excavation and backfill. Backfill is the part of the earthworks executed with the material from the cuttings, excavations, ditches or borrow pits and placed under the infrastructure line according to the road profile.

During the work, the excavated material can be reused as fill according to the following characteristics

- Road grading
- Natural water content
- Limit of liquidity and plasticity
- Organic matter content

Regarding the slopes of cut or fill slopes, the tables of the MTQ volume II will be used to ensure that the slopes are not too steep.

- Cut slopes: Table 1.4-1 of Volume II, Chapter 1 p. 2
- Embankment slope: table 1.5-1 of volume II, chapter 1, p.2

A geotechnical study will have to be done to determine the parameters of the soils in place, to know the thickness of the topsoil and the depth of the rock.

Regarding the pavement structure, the design criteria will be established according to the standards in the **MTMD's Volume II, Chapter II and the MTQ's pavement design software entitled Chaussée 2**.

The road structure will consist of:

- MG-112: minimum thickness of 600 mm
- MG-20: minimum thickness of 300 mm

These thicknesses will have to be validated in the geotechnical study because if the soils in place have a low bearing capacity, then an increase in the thickness of the granular layers will be calculated. In addition, due to the high percentage of heavy trucks that will travel on these access roads (during construction), a calculation will then be produced according to **table 2.5-4 of MTQ Volume II, Chapter 2**.

For the sectors where the roads will be built in a rock cut, the pavement structure will then be established according to **MTQ Volume II, Chapter 2, section 2.5.2.**

For the cross-section of access roads, the design will be established according to the design criteria of MTQ Volume I. When designing access roads, the following points will be analyzed

- Profile alignment;
- Sight distance;
- Curve reversal;
- Flat intersections;
- Low traffic flow road.

Regarding the design of culverts less than 3 m in diameter that will be installed under access roads, the design criteria will be established according to the standards in **MTQ Volume III, Chapter 4 as well as the guidelines for watercourse crossings in Quebec with or without fish**.

Culvert selection will be based on the following considerations;

- Hydraulic, to ensure proper drainage and free passage of fish;
- Geotechnical and structural;
- Environmental;
- Geometric (according to the profile of the road);
- Economic (to minimize construction and maintenance costs);

The design of culverts should also be based on a 50+ year service life.

With respect to restraint systems (guardrails at the roadway), the design criteria will be established according to MTQ Volume VIII. The selection of restraint systems is based on the following parameters

- Targeted safety performance and restraint capacity;
- The particularities of each site;
- The characteristics of the restraint systems;
- The facilities;
- Long-term capital and maintenance costs

13. BUILDINGS INTRODUCTION

13.1 PURPOSE AND SCOPE

The Phase 1 development plan includes the construction of:

- Passenger train stations at 4 locations: Matagami, Waskaganish, Waswanipi, Chapais.
- Maintenance of way building and bulk handling buildings in Waskaganish
- Maintenance of way building at Matagami
- Maintenance of way & train building and bulk handling buildings in Chapais

This section describes the criteria relating to Architecture, MEP and Structures of these buildings and should be read as a complement to other sections of this document.

13.2 ABBREVIATIONS

Table 13-1: Abbreviations

Acronyms	Abbreviation
MOW	Maintenance of Way
BOH	Back of House
MEP	Mechanical, Electrical & Plumbing
HVAC	Heating/ Ventilation / Air-conditioning

13.3 CODES AND STANDARDS

13.3.1 Hierarchy of standards

The following hierarchy should apply:

- Provincial and Canadian statuary codes.
- Relevant designs standards.
- Other referenced guidance documents or areas of expertise identified for this project.

13.3.2 General codes and standards

Applicable codes and standards are as follow:

- CCQ, NBC Canada 2015 mod. Qc, NECB Canada 2015 mod. Qc, NPC 2015 mod. Qc, CSA C22.10-18, CSA B651-18, CSQ, NFCC 2010 mod. Qc, NFPA 130-2020, RQMT, RSST, TRANSPORT ACT

13.3.3 Architectural

Composition

These stations (Matagami, Waskaganish, Waswanipi, Chapais) might be organized as per below shemes:

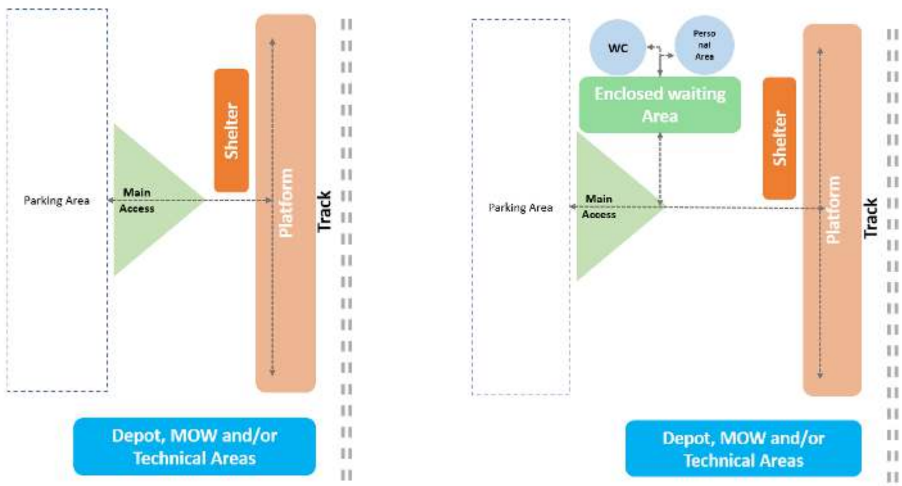

Figure 13-1: Option: Train Platform + Shelter and parking area / Option: Train Platform + Shelter; Parking Area; and Enclosed Waiting Area on the side.

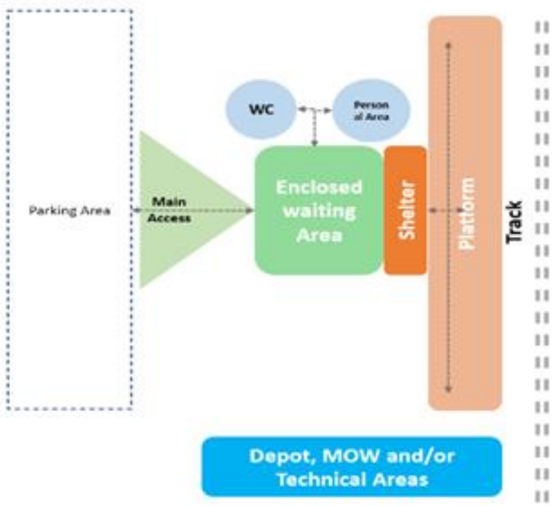

Figure 13-2: Option: Train Platform + Shelter connected to an enclosed waiting area+ Parking Area; and Other Buildings

As required by the operation and maintenance requirements of each facility.

Sizing & Circulation

Stations:

- **Planning & Sizing**: Stations need to be planned and sized to meet long term forecasts for passenger flows and changing demographic of users.

13.4 MEP

13.4.1 Mechanical

13.4.1.1 HVAC

Internal environmental conditions should be defined during summer and winter seasons.
In summary, the internal conditions to be designed for should be as follows until otherwise specified during the development of the design:

Table 13-2: HVAC Internal Conditions Summary

Space	Heating (Winter Season)	Cooling (summer season)	Ventilation
Indoor Station Space (As required)	15°C	N/A	3°C Delta from the external temperature in summer (Max. ext temp is 30°C)
Electrical Rooms	15 °C max	N/A	Temp. + 5 °C (Max.+ 35 °C
Maintenance of Way and other workshops	15 °C max	N/A	Temp. + 5 °C (Max. + 35 °C
Offices	23°C (20-50 % H.R)	25°C (20-50 % H.R)	N/A
All spaces	All spaces should be protected against freeze and in compliance with operation and maintenance requirements.		

13.4.1.2 General Mechanical

In addition, process mechanical systems for the Rail facilities and buildings include the following: Locomotive Fuelling, Compressed air, Fluid storage, distribution, and dispensing systems.

Process mechanical systems to be provided to serve the intended use for each functional work area.

13.4.2 Plumbing systems

13.4.2.1 Sanitary Drainage

The sanitary drainage in buildings must be sized considering the following requirements:

- Sanitary water must be sized considering the types and number of sanitary equipment (washbasins, toilets, etc.) provided in each facility.
- Drainage and above-ground sanitary vent of 80mm and more: class 4000 cast iron.
- Drainage and above-ground sanitary vent of 65mm or less: DWV type copper.
- Minimum diameter of drainage fittings and pipes: 40 mm.
- The vent piping must be insulated on the last 3 metres inside on the heated part.
- The horizontal drainage and vent piping must have a slope in the direction of flow.
- Design drainage systems so that there are no reverse slopes and/or low points.

13.4.2.2 Storm Water Drainage

The storm drainage network must be planned according to the configuration of the building.

Storm drainage piping must meet the following requirements:

- Rainwater with a rainfall intensity according to Environment and Climate Change Canada.
- Above-ground rain drainage of 80 mm or more: class 4000 cast iron;
- Above-ground rain drainage of 50 mm or less: DWV copper;
- PVC piping is allowed for buried portions, however, refer to local requirements for the use of PVC piping.
- All storm drainage piping must be insulated. All exposed piping inside the building must be covered with a liner consisting of a washable pre-finished PVC molded sheath.
- Each roof basin will be provided with at least one storm drain and one emergency drain.

- The piping layout will be installed in such a way as to be concealed
- The hydraulic load in litres from a roof or paved surface is the maximum 15 min rainfall determined in conformance with Subsection 1.1.3. of Division B of NBC.

13.4.2.3 Domestic water supply

The water inlet pipe of the building must be equipped with a backflow prevention device, insulation valves, water meter, sleeve and all accessories required for a complete and functional installation.

Domestic water system piping installed inside buildings must meet the following requirements:

External piping:

- L-type copper with 95/5 welded joints
- Stainless steel schedule40 with welded joints.

Buried piping:

- Copper type K with silver welded joint (piping up to 80 mm);
- Ductile iron with mechanical seals (piping 100 mm and more).

All domestic cold water and domestic hot water piping must be insulated. All exposed piping inside the building must be covered with a liner consisting of a washable pre-finished PVC molded sheath.

13.4.3 Firefighting systems

The construction of a building must meet the requirements of the Quebec Construction Code. The design and installation of portable fire extinguishers shall follow the requirements of NFPA 10.

13.4.3.1 Water inlets

Sprinkler water inlets will be combined with domestic water.

The size of the underground pipe and the validation of the need for the installation of a fire pump will have to be validated with hydraulic calculations according to the most demanding system.

Depending on the nature of the uses, the surface area and the height of the building, a fire pump shall be presumed. However, fire hydrant flow tests will need to be performed on the water system's master pipes and compared to the demands of different sprinkler systems to validate whether a fire pump is required.

13.4.3.2 Automatic sprinkler

In future buildings the installation and design of the required water sprinkler systems will need to meet the requirements of the CCQ and NFPA 13.

The building shall be equipped with fire pipes. The design of the fire pipe network must follow the requirements of the NFPA 14 standard and the CCQ. In general, the 21/2" discharge sockets will be installed in the exit stairwells. If a fire pump is required to meet the demands of different sprinkler systems, the design of the fire pipe network should be based on a demand of 30 L/s at a pressure of 690 kPa at the furthest discharge socket.

13.5 ELECTRICAL SYSTEMS

All input data for the electrical design should comply with the general requirement identified in this report including Environment Climatic Conditions and Power Supply Characteristics.

13.5.1.1 Electrical Power

Table 13-3: Requirements for Electrical Power Source

Component	Options	Characteristics
Electrical Power Sources	Principle power supply without external source	Diesel generator
	Principle power supply with external source	Power transformer
	Voltages supplied	To be analyzed per industry standards & practices.
	Back-up power supply without external source	Back-up diesel generator identical to main, equipped with automatic switch-over mechanism.
	Back-up power with external power source	Back-up diesel generator with automatic switch-over mechanism.
	Fuel Tanks	• Protected against intrusion. • Sized to ensure 6-month supply in all seasons. • Dedicated wagon for providing fuel to fuel tanks. • If external power supply not available, both generators equipped with identical tanks.

13.5.1.2 Lighting

Lighting for the different areas of the buildings must be designed to meet the lighting level, in accordance with the program, the CCQ, the recommendations of the IES, and NFPA for emergency lighting.

If any contradiction between the values of the program and those of the standards and recommendations, the highest value shall prevail unless agreed otherwise during the design development.

All building lighting will be LED type. The lighting can be divided into four parts: Normal lighting, Outdoor lighting, Emergency lighting

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13.5.1.2.1 Normal lighting

The following table shows the level of illumination required in the different areas.

Table 13-4: Level of illumination per Area – Normal Lighting

Areas	Horizontal (lux)	Vertical (lux)
stairs	150	150
elevator shaft	30	-
technical room	200	-
storage room	100	-
offices	500	
toilet	150	-

Areas	Horizontal (lux)	Vertical (lux)
internal waiting areas	200	120
external platform	50	-
parking	50	-
maintenance workshop	300	
inspection pits		300
maintenance tracks	200	
loading dock	200	

Outdoor lighting

The outdoor lighting will be powered by the panels located in the technical rooms. A minimum horizontal lighting level is 50 lux.

Emergency lighting

The emergency lighting system shall ensure that it maintains a lighting level of at least equal to those in the table below.

Table 13-5: Level of illumination per Area – Emergency Lighting

Areas	Horizontal (lux)
Stairs	10
Elevator shaft	-
Technical Room	50
Storage Room	25
offices	50
Toilet	50
Internal waiting areas	25
External Platform	10
Parking	10
Maintenance workshop	50
Inspection pits	50
Maintenance tracks	50
Loading dock	50

Exit signs

Signage signs are placed in the appropriate places, according to the Quebec Construction Code. These signs consist of pictograms in accordance with CSA-C22.2 No. 141-10. All signs are connected to the uninterruptible power supply network.

14. STRUCTURES

This chapter acts as a reference/guide for the Structural design of the buildings associated with "La Grande Alliance" Project.

14.1 CLIMATIC CONDITION

The structures of the buildings must be designed to withstand the specific weather conditions of the locations related to the Grand Alliance project.

According to the NBC 2015 Appendix C tables: C-2 and C-3.

14.2 STRUCTURAL DESIGN LIFE

To ensure a sufficient level of quality for operation, the buildings will be designed and constructed for the following service life:

Element	Description	Design life (years)
Buildings' Structure	Walls, foundations, slabs, roofs, posts…	50

14.3 TECHNICAL REQUIREMENTS

All building general Structural technical requirements should be in accordance with the code and standards, as well as per the general structural requirements in the above sections.

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