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REPORT

Township of Wainfleet

Roadside Safety Study:
Guide Rail and Unprotected Hazard
Inventory, and Condition and Risk Assessment

October 2017

CANADA'S BEST MANAGED COMPANIES
Platinum member

Executive Summary

1 INTRODUCTION AND METHODOLOGY

In 2017, the Township of Wainfleet initiated the inventory and assessment of roadside protection systems (herein referred to as guide rails) and roadside hazards (herein referred to as unprotected hazards) alongside approximately 260 kilometres of township roadways excluding numbered highways. Associated Engineering (Ont.) Ltd. was retained by the Township of Wainfleet to inventory the existing guide rails and complete a detailed condition and risk assessment. During the inventory of existing guide rails, unprotected hazards were also documented and tracked within the inventory.

The primary purpose of the assessment was to confirm the location, type, and condition of existing guide rails (in terms of type, end treatments, length, condition, etc.) and existing unprotected hazards. For each guide rail and unprotected hazard, a set of recommended remediation measures was identified in order to address any noted deficiencies. In addition to the inventory and condition assessment, a risk assessment was undertaken and a risk score was calculated to develop a means of prioritization amongst the different guide rails and unprotected hazards.

2 ANALYSIS AND FINDINGS

The assessment includes the identification and review of unprotected hazards along approximately 260 kilometres of roadways selected for review within the Township of Wainfleet. In total, 40 guide rails were inventoried which consisted of 31 standalone guide rails and 9 system guide rails. The following was noted:

- The most frequent type of guide rail inventoried along the roadways within the Township of Wainfleet were steel-beam guide rails (26); representing approximately 65 percent of all guide rails inventoried;
- Approximately three-quarters of the total length of guide rails inventoried were steel-beam guide rails spanning approximately 1,526 metres;
- Approximately one-tenth of the guide rails inventoried were three-cable guide rails and one-tenth were thrie-beam guide rails, spanning approximately 197 and 193 metres, respectively; and
- SoftStop or equivalent end treatments were the most prevalent inventoried at 8 installations for approaches while a total of 15 guide rails had no approach end treatment installed.

The inventory identified 108 roadside hazards including both those protected and unprotected. The following was noted:

- A majority of the hazards had no form of roadside protection (68) while a lesser number (40) were protected; and

- The most frequently observed type of hazard were fixed objects, of which 32 were identified, followed by box-culverts, embankments, and watercourses at 23, 23, and 19 instances, respectively.

The following was noted in the condition assessment of the guiderails:

- A slight majority of the guide rails had hazard markers (51%) and while only minimal (18%) had snow plow markers;
- In terms of mounting height, almost three-quarters of the guide rails were at the correct mounting height (68%);
- A majority of the guide rails had an adequate plumb angle (90%);
- In terms of overall design conformance, approximately one-third (35%) of the guide rails had an adequate design conformance (meeting requirements for having adequate system transitions, rail-lapping, deflection area, run-out area, shoulder design, shoulder stability, and approach/departure length);
- 65 percent of the **rails** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement;
- 65 percent of the **posts** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement;
- 64 percent of the **block-outs** reviewed (applicable to box-beam, entrance or intersecting roadway, steel-beam, steel-beam with channel, and thrie-beam installations only) had a condition rating of 4 or 5 indicating a favourable condition while the remaining 36 percent had a condition rating of 3 or less indicating the need for replacement; and
- Approximately one-third (32%) and one-half (50%) of the guide rails reviewed were determined to have an adequate approach or departure length for protecting motorists from a roadside hazard, respectively.

The guide rails and unprotected hazards inventoried were assigned a risk score based on the roadway AADT, the length of the guide rail or hazard, the condition of the system or its ability to provide protection from the adjacent hazard. ***The Township of Wainfleet may wish to use the risk score as a means of prioritizing remediation amongst the different guide rails and/or unprotected hazards*.**

Remediation measures and associated costs were identified for each of the unprotected hazards determined to warrant protection and each of the guide rails determined to be inadequate. The following was noted:

- For the unprotected hazards, a guide rail length ranging from 26 to 50 metres was recommended for installation;
- For the guide rails determined to be inadequate based on length of need, an extension was recommended, the majority of which were under 25 metres in length;

- The most common remediation measures recommended were the installation of new guide rail (53 cases), the replacement of old guide rail with new guide rail (24 cases), and minor treatments (22 cases); and
- The costliest remediation measure recommended was the replacement of an existing guide rail with a new guide rail system, averaging $16,070 per replacement. The second costliest remediation measure recommended was the installation of a new guide rail system, averaging $15,520 per installation.

3 COMMON ROADSIDE SAFETY ISSUES

The following were common roadside safety issues encountered over the course of the field investigation:

- **Unprotected Hazards** - where elimination, relocation or making the hazard traversable/crashworthy was not practical, and the extent of the hazard was amenable to shielding throughout its length, a guide rail installation was recommended;
- **Inadequately Protected Hazards** - where a hazard was present in the minimum roadside clear zone and the system proved to be obsolescent, in poor condition, and/or insufficient length to adequately shield the hazard;
- **Design Conformance Issues -** common issues with design conformance included: clear zone issues involving fixed object hazards located within the run-out area beyond gating-type end treatments, use of eccentric loaders on roads with design speeds greater than 80 kilometres per hour, and barrier curbs located in front of a guide rail system;
- **Access Conflicts -** in situations where an intersecting roadway, driveway or field access precludes the provision of a run of guide rail sufficient to meet length of need requirements; consideration should be given to providing a driveway return; and
- **Drainage Ditches** - large, water-filled drainage ditches, some of which run for several kilometres, are present within the roadside clear zone. The provision of roadside protection along the entire length is difficult to justify. Increased delineation of the roadway edge is recommended to clearly define the extent of the roadway, and the hazard area beyond, allowing road users to make decisions in support of their own safety.

4 LIFE-CYCLE REPLACEMENT COSTS

The Township of Wainfleet wishes to be pro-active in incorporating life-cycle replacement costs into its capital budget on a yearly basis in keeping with asset management best-practices. Asset management best-practices typically involve the following:

- Asset inventories and condition assessments;
- Determination of useful asset-life;
- Valuation of assets on the basis of replacement costs;
- Determination of annual maintenance investment to maintain the condition of current assets (replacement cost divided by useful asset-life to determine annual investment needs); and
- Determination of investment needed to eliminate any backlog of outstanding deficiencies.

In applying this high-level asset management approach to roadside safety systems in the Township of Wainfleet, the following assumptions were applied:

- The useful asset-life for all roadside safety systems is 30 years unless three- cable guide rail then it is 20 years;
- Where remediation measures were identified, the Ministry of Transportation Ontario HiCO System unit costs for installations and removals were assumed to be adequate to determine the overall replacement value of the existing inventory;
- Should a new guide rail be identified for installation, steel-beam or steel-beam with channel was the preferred installation type and was often an upgrade from current conditions;
- Should a new approaching or leaving end treatment be recommended, the extruder was the default installation approach and was often an upgrade from current conditions; and
- The addition of object markers on the approaching and leaving ends of all systems was required, where often none had been provided.

In applying asset management best-practices, this assignment accomplished the following tasks:

- Complete a comprehensive inventory, and condition and risk assessment of existing roadside safety assets to determine number of assets and to characterize any and all deficiencies associated with these systems based upon prevailing standards; and
- Complete a comprehensive inventory of unshielded roadside hazards within the clear zone.

The replacement cost of the existing inventory was determined to be approximately **$392,000**. Using a 30-year useful asset-life, this suggests an annual maintenance requirement of approximately $13,000 to maintain the status-quo for the 260 kilometres of roadway reviewed.

When remedial measures to address deficiencies associated with existing systems were priced and summed with the remedial measures required to address unshielded hazards, the combined backlog of deficiencies was found to total approximately **$1.29 million.**

While initially appearing counter-intuitive, as the remedial cost exceeds the replacement cost of the entire fleet, this finding is consistent with the following observations:

- Many elements of the existing fleet are either approaching or at the limit of their expected service life, and thus in need of complete replacement;
- Many existing system elements are fundamentally deficient in terms of existing standards applicable to length of need, approaching and/or leaving end treatments, transitions, and delineation; and
- Where replacement is identified as a required remedial measure, often less-expensive (considering capital cost only) three-cable guide rails are recommended for replacement by more-expensive (again, considering capital costs only) steel-beam guide rails.

Thus, while the cost of eliminating the deficiency backlog may appear excessive, relative to the estimated value of the inventory as a whole, backlog elimination accomplishes numerous objectives, including:

- Replacement of all deficient systems with compliant systems offering comprehensive shielding, superior crash performance, enhanced maintainability, and lower overall life-cycle costs (albeit with higher initial capital costs). This accomplishment will add significantly to the overall size (in terms of linear metres of guide rail, and numbers of end treatments) of the inventory; and
- Elimination of numerous unshielded hazards through the provision of shielding, further adding to the overall size of the inventory.

5 CONCLUSIONS AND RECOMMENDATIONS

In 2017, the Township of Wainfleet initiated the inventory and assessment of roadside protection systems (herein referred to as guide rails) and roadside hazards (herein referred to as unprotected hazards) alongside approximately 260 kilometres of municipal and township roadways. Associated Engineering (Ont.) Ltd. was retained by the Township of Wainfleet to inventory the existing guide rails and complete a detailed condition and risk assessment. During the inventory of existing guide rails, unprotected hazards were also documented and tracked within the inventory.

The primary purpose was to confirm the location, type, and condition of existing guide rails (in terms of type, end treatments, length, condition, etc.) and existing unprotected hazards. For each guide rail and unprotected hazard, a set of recommended remediation measures was identified in order to address any noted deficiencies. In addition to the inventory and condition assessment, a risk assessment was undertaken and a risk score was calculated to develop a means of prioritization amongst the different guide rails and unprotected hazards.

As a result of the assignment, the Township of Wainfleet has received a detailed georeferenced inventory of all of the guide rails and unprotected hazards situated alongside municipal or township roadways. Furthermore, a condition and risk assessment including recommended remediation measures with their associated costs has been provided. Overall, the roadside objects layer will provide the Township of Wainfleet the necessary asset management framework required to determine life-cycle costs and develop budgets for capital improvements involving roadside safety systems.

6 NEXT STEPS

This report encompasses data collected over the course of the assignment; with all the data being collected in July of 2017. As this data ages, the accuracy of the database will deteriorate as the Township of Wainfleet proceeds with implementation of the location specific recommendations in this report in addition to road reconstruction projects.

Since this roadside objects layer will primarily be used for asset management and capital planning decisions it is important to keep the data as up-to-date as possible so that informed decisions can be made about the allocation of capital funding.

Within the roadside objects layer, the data can be subdivided into several categories: guide rail inventory and hazard inventory, condition assessment, risk assessment, remediation measures, and associated costs. The Municipality should maintain the currency of the dataset and the following sub-section discusses several possible strategies.

Guide Rail Inventory and Hazard Inventory

Through the Municipality's capital works programs and projects, any new installations or extensions of guide rail will be explicitly tracked with detailed design and/or record drawings. In addition, maintenance activities should be tracked. The Township has two (2) options for updating the dataset:

- **In-House:** municipal staff will be trained by Associated Engineering on protocols for updating the roadside objects layer and the necessary attributes to update for an ongoing basis).
- **Out-Source:** municipal staff will provide all drawings and work orders to Associated Engineering (for an ongoing basis) and Associated Engineering staff will update the roadside objects layer on behalf of the Township.

Condition Assessment

Aside from the inventory information describing the geometry and composition of the guide rail and/or hazard, the condition assessment should be updated approximately every (5) years to address the potential degradation of the asset and update the remaining service life. It is proposed that Associated Engineering train township staff to carry out the condition assessments and update the roadside objects layer.

Risk Assessment, Remediation Measures and Associated Costs

In addition to updating the inventory and condition assessment information, the derived fields such as risk scores, remediation measures, and total remediation costs will need to be updated to maintain an accurate and complete dataset for future prioritization and capital planning. Updates to the assets through completed remediation will reduce risk scores, for example. Reviewing remaining work to be undertaken, in the context of the adjusted risk scores and the current balance of remedial work to be completed (along with the associated costs), should be done on an annual basis. It is proposed that Associated Engineering be retained annually to complete these updates.

Updates to Asset Registry

When the Municipality implements any of the proposed remediation measures, certain actions will be required in order to accurately track the assets:

- **Minor Treatments:** minor treatments such as installing hazard markers, snow plow markers, delineation strips, installing approach/departure end treatments, or addressing system transitions. In the asset registry, the existing asset should be updated with the necessary information since the majority of the guide rail remains unaltered; the service life would not be extended.
- **Install Guide Rail:** a new guide rail is installed to provide protection from a currently unprotected hazard. In the asset registry, a new asset should be created with the necessary information and the existing asset (tracking the unprotected hazard) should be deleted.
- **Extend Guide Rail:** an existing guide rail is extended to provide the necessary length of need to provide protection from a partially protected hazard. In the asset registry, the existing asset should be updated with the necessary information since the majority of the guide rail remains unaltered; the service life would not be extended as only the extension and end treatments would be new.
- **Replace Guide Rail:** an existing guide rail is removed and a new guide rail is installed to address significant deficiencies and/or length of need requirements. In the asset registry, a new asset should be created with the necessary information and the existing asset (tracking the deficient guide rail) should be deleted.
- **Remove Guide Rail:** an existing guide rail is removed since there is not a roadside hazard situated within the minimum clear zone. In the asset registry, the existing asset (tracking the unnecessary guide rail) should be deleted.
- **Remove Unprotected Hazards:** an unprotected hazard that is made traversable or removed. The existing asset (tracking the unprotected hazard) should be deleted.

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1 Introduction and Methodology

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As a result of the assignment, the Township of Wainfleet has received a detailed georeferenced inventory of all of the guide rails and unprotected hazards situated alongside township roadways. Furthermore, a condition and risk assessment including recommended remediation measures with their associated costs has been provided. Overall, the roadside objects layer will provide the Township of Wainfleet with the necessary asset management framework required to determine life-cycle costs and develop budgets for capital improvements involving roadside safety systems.

The following subsection provides an outline of the data collection and methodology utilized during the roadside safety assessment/guide rail and unprotected hazard inventory, and condition and risk assessment.

1.1 DATA COLLECTION AND ASSEMBLY

In order to effectively conduct the inventory, and condition and risk assessment, the various data sources as described below were obtained from the Township of Wainfleet, the Regional Municipality of Niagara, or through open data sources:

- Geographic Information System (GIS) layers;
- Aerial/Orthographic photography; and
- Historic traffic volume data.

Through a combination of data provided by the Township of Wainfleet and various open data sources, road segment centrelines were extracted and used to identify the attributes associated with the road segment adjacent to a guide rail or unprotected hazard.

The orthographic photography was used as a further means of verifying the location of guide rails and unprotected hazards throughout the various phases of the assignment.

In order to approximate the average annual daily traffic (AADT) volumes for the roadways within the study area, the Township of Wainfleet provided rural roadway traffic volume maps containing automated traffic recorder (ATR) counts during 2015 and 2016 as well as traffic volume spreadsheets. In addition, fifty (50) roadway sections, where recent data was not available, were selected for the collection of new traffic volume data via Ontario Traffic Inc. The ATR data was assumed to be a reasonable estimate of the AADT volumes pertaining to each section of roadway and appended to the single line road network (SLRN) layer. For roadway sections without traffic volumes provided, an average traffic volume from roadways of similar types had been employed.

1.2 DEVELOPMENT OF DATA COLLECTION INTERFACE

Prior to collecting the condition and risk assessment data, a detailed data dictionary was developed identifying the guide rail and unprotected hazard attributes required to adequately assess the condition of any existing guide rails or lack thereof. Within the data dictionary provided in **Appendix A**, the various attributes required for assessing the condition and associated risk of a guide rail or unprotected hazard were identified, defined, and described in terms of the attribute's optionality, data type, potential values, and data sources where applicable. In order to improve the efficiency of the data collection efforts, reduce the potential for data entry error, and minimize the post-processing requirements, a data collection interface with direct integration into GIS was developed utilizing the data dictionary and the data described in **Section 1.1** as a framework. The data collection interface was developed to provide field automation and validation and has been divided into six (6) categories as displayed in **Figure 1-1**.

As a result, a detailed dataset pertaining to the guide rails and unprotected hazards within the Township of Wainfleet had been captured and stored. This dataset will form the basis for a new roadside objects layer within the Township of Wainfleet's GIS.

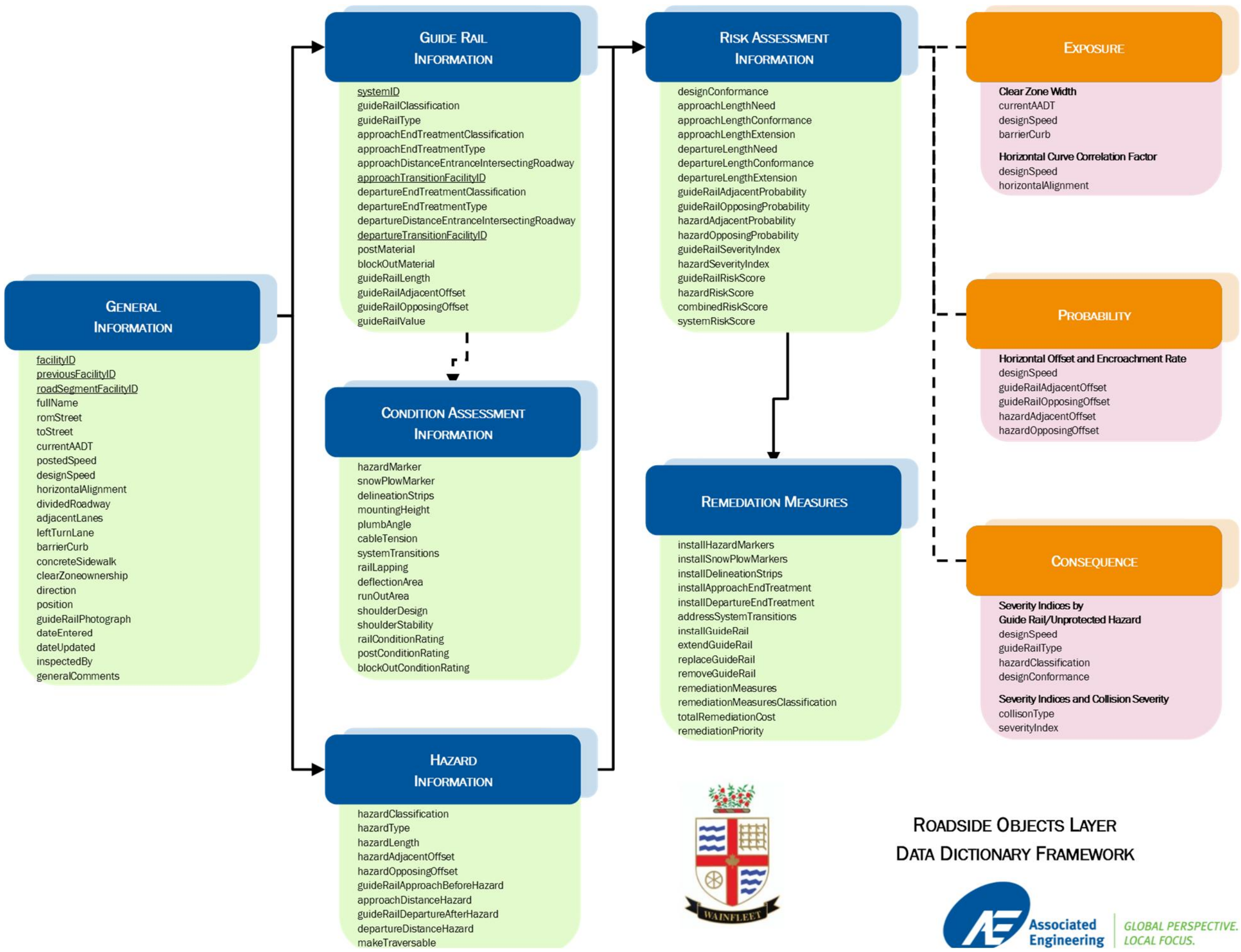


Figure 1-1
Roadside Objects Layer: Data Dictionary Framework

1.2.1 Guide Rail Information

In the case of an existing guide rail, each individual guide rail may act as part of a compound guide rail system or act as a standalone guide rail system. For a compound guide rail system, each guide rail component (differentiated by the classification and type of guide rail) was associated with the compound guide rail system identifier; one system may have multiple components while one component must have one system. Within these compound guide rail systems, the first guide rail component in the system was denoted as the system approach component and the last guide rail component in the system was denoted as the system departure component. By relating each guide rail component by the compound guide rail system identifier, the overall length of the compound guide rail system can be compared to that of the length of need in relation to the hazard in which the guide rail system is protecting. In order to plot the guide rail components within the roadside objects layer, orthographic photography was used and GIS utilized to draw the guide rail at the time of the assessment.

For each guide rail, the approach and departure have a form of end treatment applied. In the event of a lack of end treatment, the values were “Not Applicable”. As presented, there is an option to indicate that an end treatment can be installed at an entrance or intersecting roadway. In some instances, a guide rail may be limited in length due to a conflict with an upstream or downstream entrance or intersecting roadway. Should a conflict exist and the length of need is not met, alternative treatments will need to be recommended. Lastly, the post material and block-out material (where applicable) were documented for information purposes only.

1.2.2 Hazard Information

Whether assessing an existing guide rail or an unprotected hazard, several aspects are required to identify the presence, type, and geometry of a hazard. Similar to guide rails and end treatments, hazards were classified based on the general type of hazard. It is noted that a hazard is not necessarily present should there be a guide rail; this could represent a guide rail that should be removed or a compound guide rail system whereby the hazard is directly protected via another guide rail component within the system. When there is a guide rail and a hazard present, the hazard is indirectly defined through comparison of the approach and departure points of the guide rail in relation to the approach and departure points of the hazard. In the same manner as the guide rail, orthographic photography was used and GIS utilized to draw any unprotected hazards at the time of the assessment.

1.2.3 Condition Assessment Information

The guide rail system was evaluated in terms of its potential to operate as intended, providing the desired level of safety in the event of a collision in addition to conforming to applicable standards. Guide rails were assessed in terms of hazard markers, snow plow markers, delineation strips, mounting height, plumb angle, cable tension, system transitions, rail-lapping, deflection area, run-out area, shoulder design, and shoulder stability. The condition of the rail, posts, and block-outs were also assessed based on a five-point scale.

1.2.4 Risk Assessment Information

When evaluating the risk of a guide rail or unprotected hazard, the exposure, probability, consequence model was used. Each of the risk elements were used and applied to each guide rail or unprotected hazard to determine a guide rail risk score or hazard risk score. In the event that a guide rail was not in adequate condition, the hazard risk score was added to the guide rail risk score since it would not adequately protect errant vehicles. In the event that a guide rail was inadequate in length, the required length of the guide rail (required to protect the hazard) was calculated (as further explained below). The actual measured length of the guide rail system expressed as a percentage of the required length was then multiplied by the hazard risk score to account for the portion of the roadside hazard that was unprotected.

Exposure Information

In order to quantify the risk of a guide rail or unprotected hazard, the exposure was determined through three (3) key factors: frequency of roadside encroachment, traffic volume, and the length of the guide rail or unprotected hazard. Exposure is a measure of the number of vehicles expected to encroach onto the roadside. It is a function of the roadway's traffic volume and the length of a guide rail or unprotected hazard. As the traffic volume or the length of guide rail or unprotected hazard increases, the exposure to the guide rail or unprotected hazard also increases resulting in a higher number of expected roadway departures within the conflict area. As indicated in the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide*[1], roadside encroachments occur at a rate of 0.0003 encroachments per kilometre per year per vehicle per day for a single direction of travel. The AADT attributed to each of the roads under investigation (as described in **Section 1.1**) was used to determine the number of vehicles travelling past the guide rail or unprotected hazard. The length of the guide rail or unprotected hazard (in metres) was determined through field measurement at the time of the assessment. The exposure component to the risk score calculation is presented below:

$$Risk\ Score_{Exposure} = 0.0003\ encroachments/kilometre/year/vehicle/day \times (x_{AADT}\ vehicles/day \div 2) \times (x_{length} metres \div 1000\ metres/kilometre)$$

Probability Information

In addition to the exposure component, it is important to describe the likelihood of a collision with a guide rail or an unprotected hazard in the event of a roadway departure. The probability of colliding with a guide rail or unprotected hazard is a function of the design speed (assumed to be 10 kilometres per hour above the posted speed limit) and the extent of lateral encroachment or horizontal offset as discussed and calculated[1]. The design speed was calculated as 10 kilometres per hour above the posted speed limit as noted during the field assessment. The horizontal offset will be based on two scenarios: adjacent lane roadway departure, and opposing lane roadway departure. Since the adjacent lane will always be in closer proximity to the guide rail or unprotected hazard, the probability of a collision will always be higher should

[1] American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide*, 2011.

the vehicle leave the roadway. The horizontal offset of the adjacent lane will be estimated in 0.5 metre increments from the edge of the travelled lane to the guide rail or the unprotected hazard. To determine the horizontal offset of the opposing lane, a standard lane width was assumed to be 3.50 metres. This lane width was added to the estimated offset of the guide rail or unprotected hazard on the opposite side of the roadway.

Given the horizontal offsets, the probability of collision with a guide rail or unprotected hazard would be negligible if it were located outside of the roadway's clear zone defined by the Ministry of Transportation Ontario in the *Roadside Safety Manual*[2]. The clear zone was determined based on the roadway's design speed and AADT. If situated along a horizontal curve, the clear zone was increased by a conservative factor of 1.50 based on horizontal curve correlation factors as documented in the Transportation Association of Canada *Geometric Design Guide*[3] to accommodate the additional recovery space required.

Should the guide rail or unprotected hazard be located within the clear zone, the probability of colliding with it would increase as the design speed increases or the horizontal offset decreases. In essence, the higher the vehicle speed or the closer the roadside object, the likelier it is to be struck in the event of roadway departure. To determine the probability of collision, the adjacent and opposing lanes were reviewed independently due to their different horizontal offsets. The probability of collision was assessed based on the design speed and the horizontal offset in 0.5 metre increments for both the adjacent and opposing lanes using encroachment rates. The probability component to the risk score calculation is presented below:

$$Risk\ Score_{Probability} = x_{adjacent\ lane\ probability} + x_{opposing\ lane\ probability}$$

Consequence Information

After understanding the exposure and the probability of collision with a guide rail or unprotected hazard, the consequence of colliding with the roadside object is best determined by the severity of the collision. The severity of a collision is based on several factors such as the design speed, type of guide rail or unprotected hazard, and the general conformance to standards to provide a certain degree of safety. Associated with each severity index are the probabilities pertaining to the severity of collision: property damage only, non-fatal injury, and fatality. As the severity index increases, the probability of a more severe collision resulting in a fatality is increased. For instance, a severity index of 0.5 may be assigned a probability of 100% for a property damage only collision while a severity index of 10 may be assigned a probability of 100% for a fatality collision as discussed in the *Roadside Design Guide*[1]. Adapted severity indices were used for the purposes of this roadside safety study. To assess the severity of an individual guide rail or unprotected hazard, these severity indices were associated with various roadside objects in conjunction with the design speed; these values have been excerpted from the *Roadside Design Guide*[1].

[2] Ministry of Transportation Ontario (MTO), *Roadside Safety Manual*, 1993.
[3] Transportation Associated of Canada (TAC), *Geometric Design Guide for Canadian Roads*, 2017.

For the purposes of this study, it has been assumed that:

- Guide-posts act in the same manner as three-cable;
- Box-beam and high-tension cable act in the same manner as steel-beam; and
- Entrance or intersecting roadways, thrie-beam, and concrete act in the same manner as steel-beam with channel.

When assessing the consequence within the risk score, the relative weighting of each collision severity level needs to be assessed to emphasize the higher societal cost associated with fatality collisions over non-fatal injury collisions and property damage only collisions. The relative costs are a factor of 1 for property damage only collisions, a factor of 10 for non-fatal injury collisions, and a factor of 1,967 for fatality collisions as derived from the most recent societal cost values applicable in Ontario[4]. The consequence component to the risk score calculation is presented below:

$$Risk\ Score_{Consequence} = (1 \times prob^{property\ damage\ only}) + (10 \times prob^{non-fatal\ injury}) + (1{,}967 \times prob^{fatality})$$

Combined Risk Score

After assessing risk in terms of exposure, probability, and consequence, a total combined risk score for each guide rail or unprotected hazard was calculated as follows:

$$Risk\ Score_{Combined} = Risk\ Score_{Exposure} \times Risk\ Score_{Probability} \times Risk\ Score_{Consequence}$$

Based on the results of the condition assessment and length of need calculations, the hazard risk score may be added to the guide rail risk score and prorated based on one of the two following scenarios:

- The hazard risk score was added to the guide rail risk score based on the length of the guide rail divided by the length of the guide rail system should the condition of the guide rail fall below a condition rating of 4; or
- The hazard risk score was added to the guide rail risk score based on the length of extension of the guide rail divided by the length of the guide rail system should the guide rail be too short to fully protect against the hazard.

It is noted that if the guide rail was in good condition and was long enough to fully protect against the hazard, then the hazard risk score would be negligible (zero) as the guide rail is considered to provide the necessary protection from the hazard.

1.2.5 Remediation Information

Based upon the condition of the guide rail or lack thereof, remediation measures were recommended during the assessment and have been divided into five (5) types of remediation: minor treatments, install, extend,

[4] Ministry of Transportation Ontario, *Analysis and Estimates of the Social Cost for Motor Vehicle Collisions in Ontario*, 2007.

replace, or remove. It has been assumed that if a system should be repaired, it will be more cost-effective to remove the damaged section and install a new guide rail. In situations where guide rails are installed as a compound system leading up to a concrete bridge or structure, the length of the guide rail was assessed based on its system identifier and the overall length of the compound guide rails through post-processing of the data. Overall, the remediation costs were based on individual guide rails or unprotected hazards and can be summarized by system. Remediation measures and suggested associated unit costs obtained from the Ministry of Transportation Ontario's Highway Costing (HiCo) System are presented in **Table 1-1**.

Table 1-1
Remediation Measures and HiCo System Unit Costs

No.	Installation Cost	Cost/Unit
1	Install Hazard Markers	$200.00
2	Install Snow Plow Markers	$200.00
3	Install Delineation Strips	$200.00
4	Install Approach End Treatment	$5,100.00
5	Install Departure End Treatment	$5,100.00
6	Install System Transitions	$5,100.00
7	Install Guide-Post	$20.00
8	Install Three-Cable	$34.00
9	Install Box-Beam	$305.00
10	Install Entrance or Intersecting Roadway	$82.00
11	Install High-Tension Cable	$51.00
12	Install Steel-Beam	$82.00
13	Install Steel-Beam with Channel	$96.00
14	Install Thrie-Beam	$510.00
15	Install Concrete	$190.00
16	Extend Guide-Post	$20.00
17	Extend Three-Cable	$34.00
18	Extend Box-Beam	$305.00
19	Extend Entrance or Intersecting Roadway	$82.00
20	Extend High-Tension Cable	$51.00
21	Extend Steel-Beam	$82.00

No.	Installation Cost	Cost/Unit
22	Extend Steel-Beam with Channel	$96.00
23	Extend Thrie-Beam	$510.00
24	Extend Concrete	$190.00
25	Remove Guide-Post	$3.00
26	Remove Three-Cable	$5.75
27	Remove Box-Beam	$17.00
28	Remove Entrance or Intersecting Roadway	$9.00
29	Remove High-Tension Cable	$8.65
30	Remove Steel-Beam	$9.25
31	Remove Steel-Beam with Channel	$12.00
32	Remove Thrie-Beam	$17.00
33	Remove Concrete	$88.00

1.2.6 Graphical User Interface

Based on the aforementioned information categories, a Graphical User Interface (GUI) was prepared with the background logic and data validation to streamline the data collection process. The GUI was integrated with Manifold System, a GIS software application, and implemented on a tablet to allow for digital data collection during the data collection.

2 Analysis and Findings

The following sections present the analysis and findings of the guide rail inventory, and condition and risk assessment. The assessment includes the identification and review of unprotected hazards along approximately 260 kilometres of roadways selected for review within the Township of Wainfleet. In total, 40 guide rails were inventoried and assessed which consisted of 31 standalone guide rails and 9 system guide rails. Throughout the duration of this section within the figures presented, guide rails and their corresponding end treatments will be referred to with the naming conventions presented in **Table 2-1**. Additional analysis is provided in **Appendix B** pertaining to the guide rail inventory, and condition and risk assessment.

Table 2-1
Roadside Safety Systems and End Treatments Naming Convention

Roadside Safety System	End Treatment
• Guide-Post (GP) • Three-Cable (TC) • Box-Beam (BB) • Entrance or Intersecting Roadway (ENT) • High-Tension Cable (HTC) • Steel-Beam (SB) • Steel-Beam with Channel (SBWC) • Thrie-Beam (TB); • Concrete (CONC)	• Three-Cable Turned-Down (TCTD) • Steel-Beam Turned-Down (SBTD) • Breakaway Cable Terminal (BCT) • Crash Attenuator (CAT) • Eccentric Loader (ECL) • Entrance or Intersecting Roadway (ENT) • Extruder (EXT) • SoftStop or Equivalent (SOFT) • Proper Transition (Proper TRS) • Improper Transition (Improper TRS) • Not Applicable (NA)

2.1 GUIDE RAIL INVENTORY

Figure 2-1 presents the number of guide rails by type. As illustrated, the most frequent type of guide rail inventoried along the roadways within the Township of Wainfleet were steel-beam guide rails (26); representing approximately 65 percent of all guide rails inventoried.

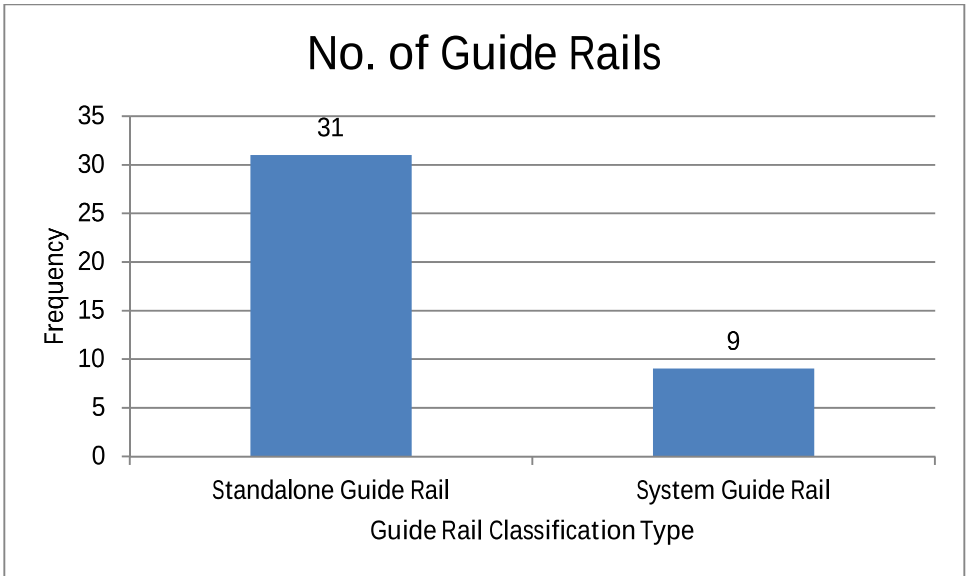


Figure 2-1
Number of Guide Rails by Type

Figure 2-2 presents the total length of guide rails by type. As illustrated, approximately three-quarters of the total length of guide rails inventoried were steel-beam guide rails spanning approximately 1,526 metres. Approximately one-tenth of the guide rails inventoried were three-cable guide rails and one-tenth were thrie-beam guide rails, spanning approximately 197 and 193 metres, respectively.

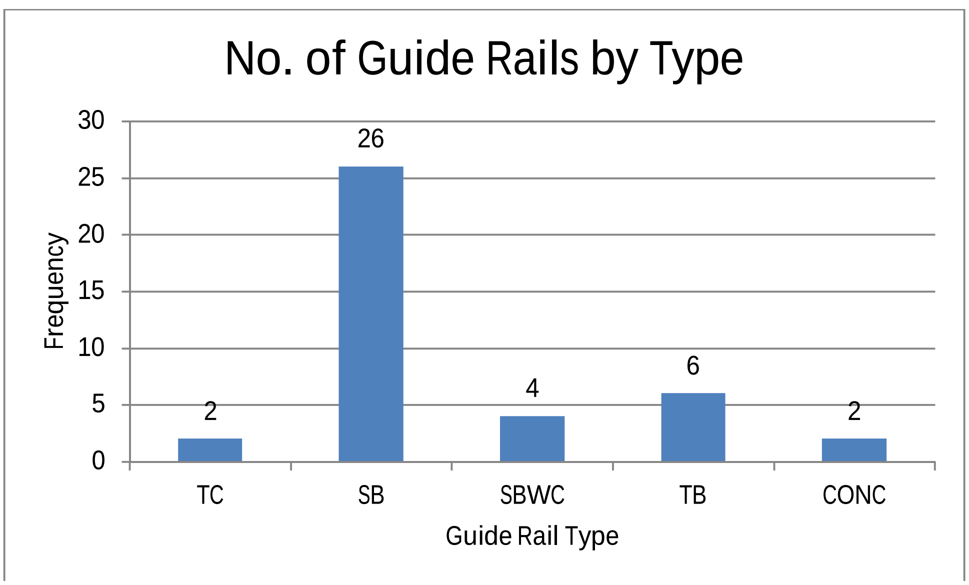


Figure 2-2
Total Length of Guide Rails by Type

Figure 2-3 presents the average length of guide rails by type. On average, three-cable guide rails were the longest at approximately 99 metres in length per guide rail while steel-beam guide rails were second spanning approximately 59 metres in length per guide rail.

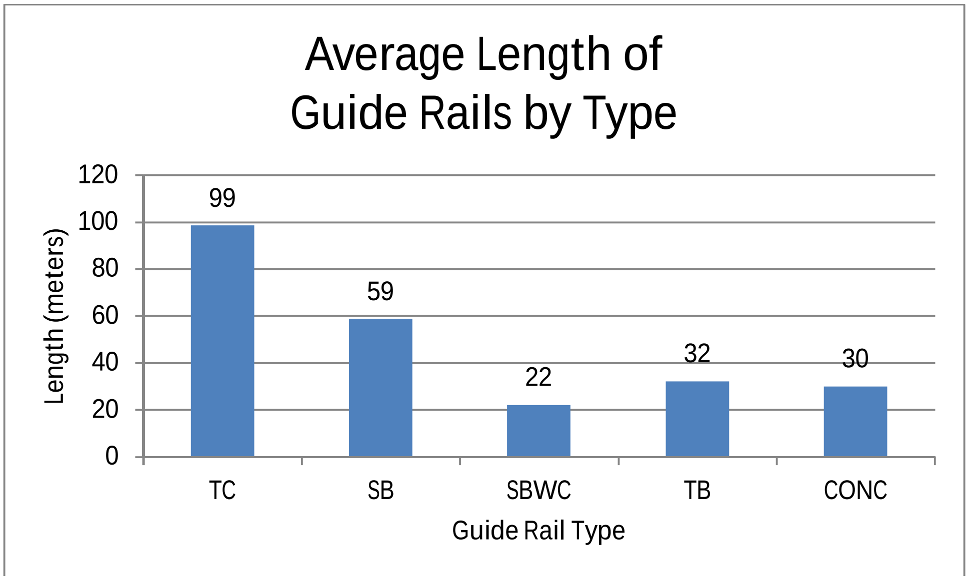


Figure 2-3
Average Length of Guide Rails by Type

Figure 2-4 presents the number of guide rail approach end treatments by type; similar statistics were observed for guide rail departure end treatments. In summary, SoftStop or equivalent end treatments were the most prevalent inventoried at 8 installations for approaches while a total of 15 guide rails had no approach end treatment installed.

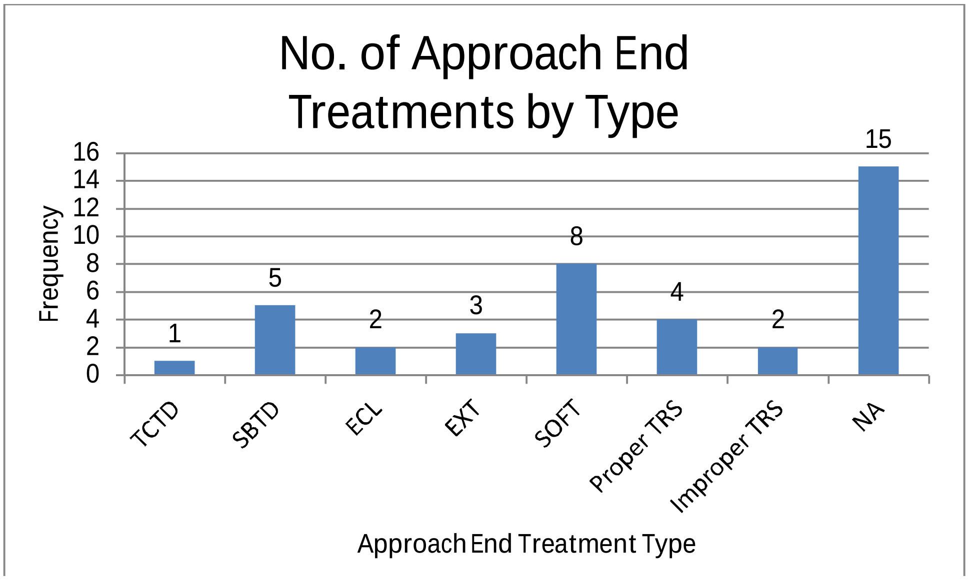


Figure 2-4
Number of Guide Rail Approach End Treatments by Type

2.2 HAZARD INVENTORY

In total, the inventory identified 108 roadside hazards including both those protected and unprotected; **Figure 2-5** presents the number of hazards by protection. As illustrated, a majority of the hazards had no form of roadside protection (68) while a lesser number (40) were protected.

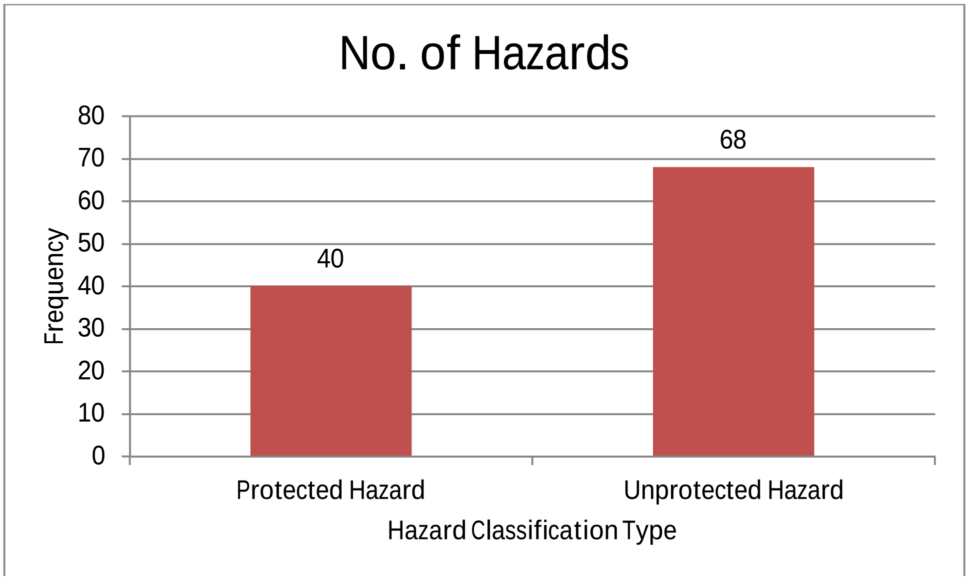


Figure 2-5
Number of Hazards by Protection

Of these 108 hazards, **Figure 2-6** presents the number of hazards by type. The most frequently observed type of hazard were fixed objects, of which 32 were identified, followed by box-culverts, embankments, and watercourses at 23, 23, and 19 instances, respectively.

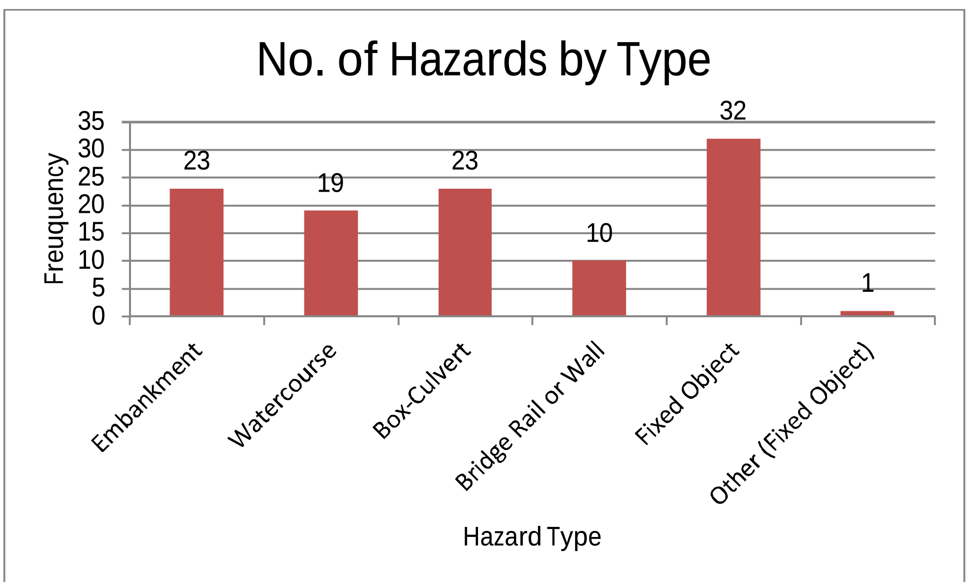


Figure 2-6
Number of Hazards by Type

2.3 CONDITION ASSESSMENT

Table 2-2 presents the summary statistics of the condition of the guide rails inventoried in terms of the presence of hazard markers, snow plow markers, mounting height, plumb angle, and design conformance. A slight majority of the guide rails had hazard markers (51%) and while only minimal (18%) had snow plow markers. In terms of mounting height, almost three-quarters of the guide rails were at the correct mounting height (68%). A majority of the guide rails had an adequate plumb angle (90%). In terms of overall design conformance, approximately one-third (35%) of the guide rails had an adequate design conformance (meeting requirements for having adequate system transitions, rail-lapping, deflection area, run-out area, shoulder design, shoulder stability, and approach/departure length).

Table 2-2
Condition Assessment Summary Statistics

Condition Category	Percent Adequate	Percent Inadequate
Hazard Marker	51	49
Snow Plow Marker	18	82
Mounting Height	68	32
Plumb Angle	90	10
Design Conformance	35	65

The condition of the rail, posts, and block-outs were assessed and given a rating based on a scale of 1 to 5. The rail, posts, and block-out condition results are presented in **Figure 2-7**, **Figure 2-8**, and **Figure 2-9**, respectively with the following notable observations:

- As a whole, 65 percent of the **rails** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement;
- As a whole, 65 percent of the **posts** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement; and
- As a whole, 64 percent of the **block-outs** reviewed (applicable to box-beam, entrance or intersecting roadway, steel-beam, steel-beam with channel, and thrie-beam installations only) had a condition rating of 4 or 5 indicating a favourable condition while the remaining 36 percent had a condition rating of 3 or less indicating the need for replacement.

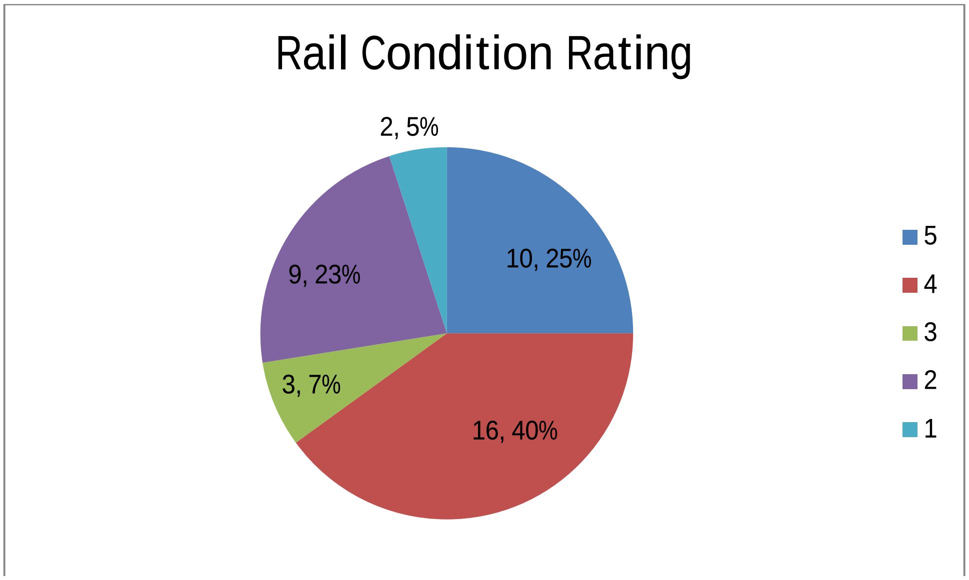


Figure 2-7
Rail Condition Rating

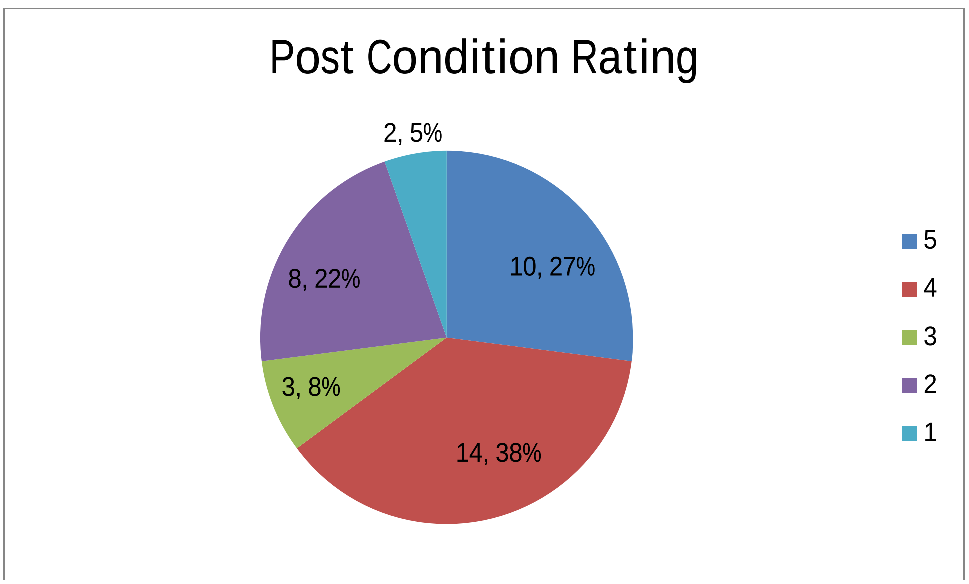


Figure 2-8
Post Condition Rating

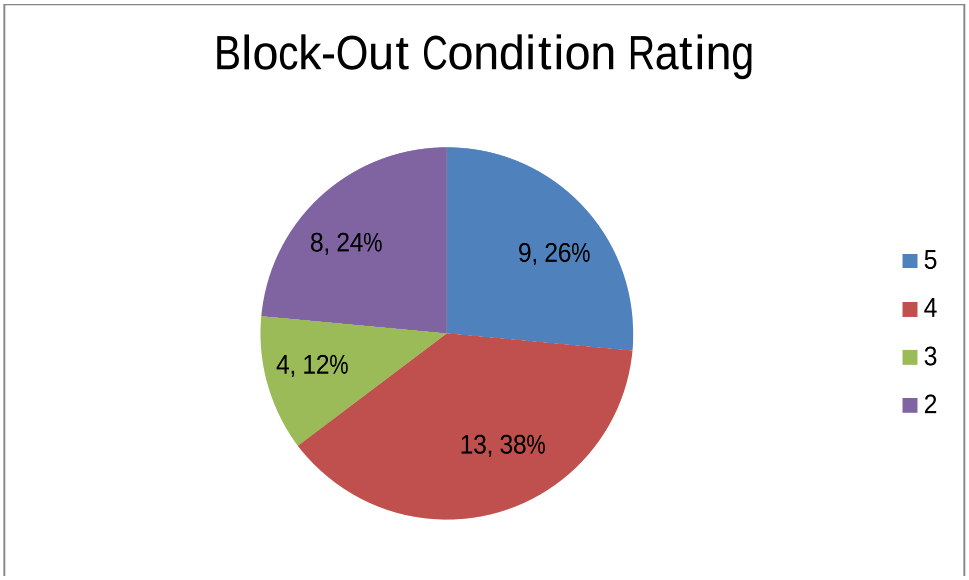


Figure 2-9
Block-Out Condition Rating

In comparison with the Transportation Associated of Canada's *Geometric Design Guide for Canadian Roads*[3], the approach and departure lengths were reviewed for their conformance to the required lengths of need. **Figure 2-10** presents the approach length conformance while **Figure 2-11** presents the departure length conformance. Approximately one-third (32%) and one-half (50%) of the guide rails reviewed were determined to have an adequate approach or departure length for protecting motorists from a roadside hazard, respectively.

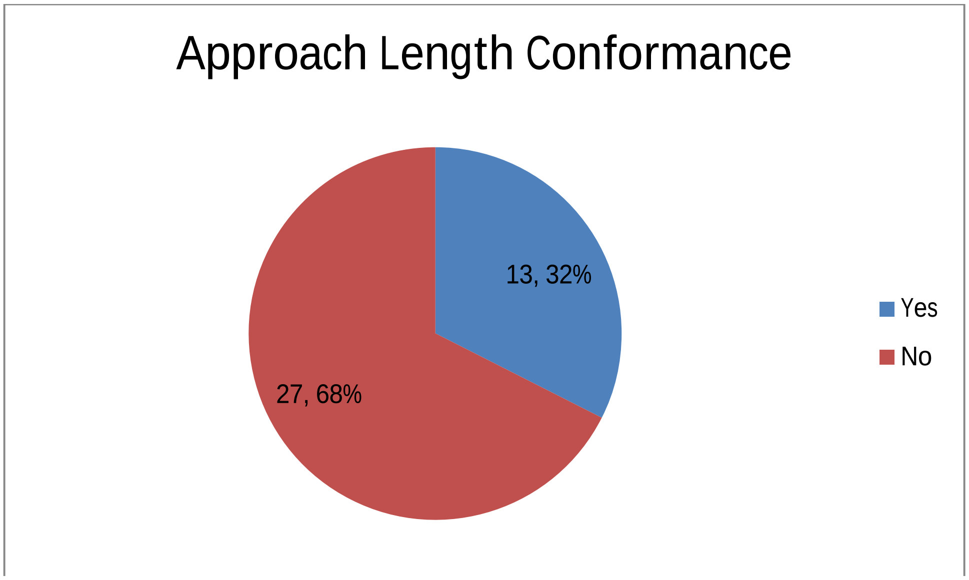


Figure 2-10
Approach Length Conformance

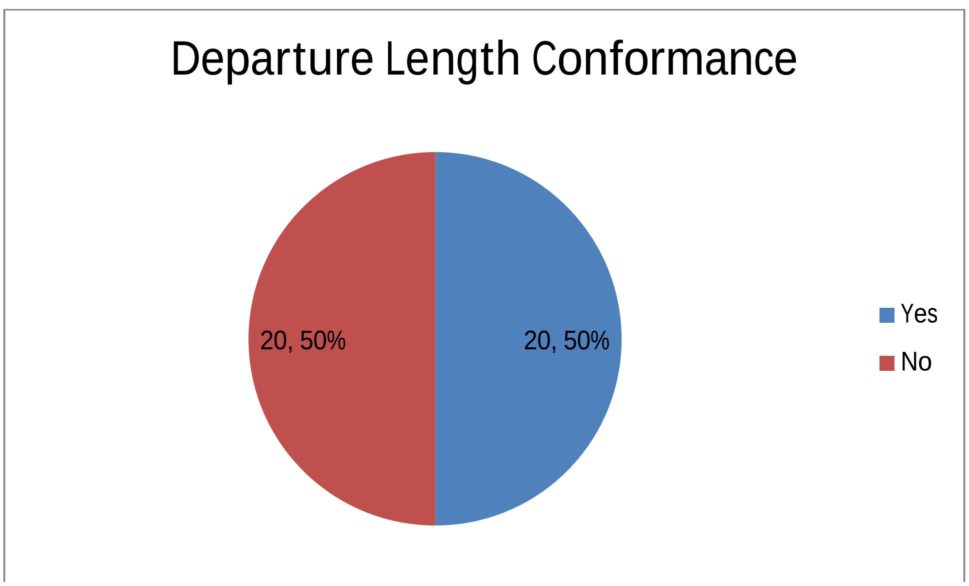


Figure 2-11
Departure Length Conformance

2.4 RISK ASSESSMENT

Based on the methodology discussed in **Section 1.2.4**, the guide rails and unprotected hazards inventoried were assigned a risk score. **Table 2-3** presents the top five (5) guide rails with the highest ranked risk score and **Table 2-4** presents the top five (5) unprotected hazards with the highest risk score; the high risk scores may be attributed to a number of factors including the roadway's AADT, the length of the guide rail, and the condition of the system or its ability to provide protection from the adjacent hazard. A summary of the sorted system risk scores is presented in **Figure 2-12**.

***The Township of Wainfleet may wish to use the risk score as a means of prioritizing remediation amongst the different guide rails and/or unprotected hazards*.**

Table 2-3
Highest Risk Guide Rails

Rank	Roadway	From/To	Description	Issue	Risk Score
1	Lakeshore Road	Side Road 18 to Station Road	Three-Cable	Poor Condition	15.246
2	Philips Road	R.R. 27 to R.R. 23	Steel Beam	Poor Condition	4.120
3	Hewitt Road	Lambert Road to R.R. 27	Steel Beam	Poor Condition	3.989
4	Lakeshore Road	Crescent Heights to Bessey Road	Steel Beam to Three-Cable to Steel Beam	Inadequate Transition Design and Poor Condtion of Three-Cable	3.905
5	Feeder Road East	Dixie Road to Feeder Road West	Steel Beam	Inadequate Approach Length	3.565

Table 2-4
Highest Risk Unprotected Hazards

Rank	Roadway	From/To	Hazard Classification	Hazard Type	Risk Score
1	Priestman Road	Highway 3 to Concession 5	Fixed Object	Utility Poles	2.888
2	Priestman Road	Highway 3 to Concession 5	Embankment	Watercourse	0.514
3	Concession 1	Minor Road to Burkett Road	Fixed Object	Box-Culvert	0.506
4	Priestman Road	Highway 3 to Concession 5	Embankment	Watercourse	0.469
5	Malowany Road	Garringer Road to Feeder Road East	Fixed Object	Bridge Rail	0.384

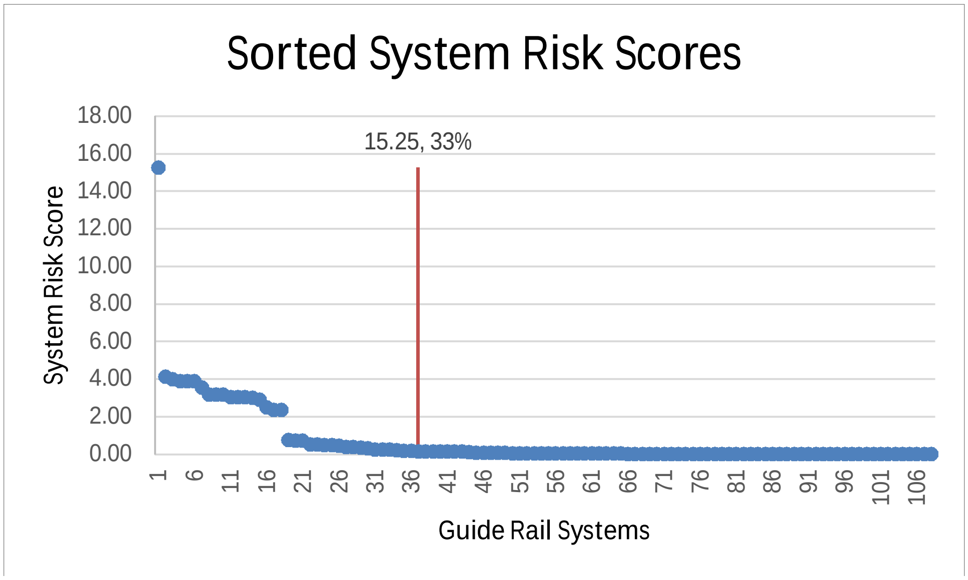


Figure 2-12
Sorted System Risk Scores

2.5 REMEDIATION MEASURES AND ASSOCIATED COSTS

For any unprotected hazard determined to warrant protection by means of a guide rail, the length of guide rail was determined based on the length of need. **Figure 2-13** presents a histogram of the length of the guide rail recommended to be installed at all unprotected hazards based on the length of need recommended in the Transportation Association of Canada's *Geometric Design Guide for Canadian Roads*[3]. Typically, a guide rail length ranging from 26 to 50 metres was recommended for installation.

Where a guide rail is already installed but is of insufficient length, the length of guide rail extension was determined based on the length of need as well. **Figure 2-14** presents a histogram of the length of the guide rail extension recommended where the length of need was determined to be inadequate based on the length of need recommended in the Transportation Association of Canada's *Geometric Design Guide for Canadian Roads*[3]. The majority of the extensions were under 25 metres in length; 4 being under 25 metres, 1 between 26 and 50 metres, and 2 between 51 and 75 metres.

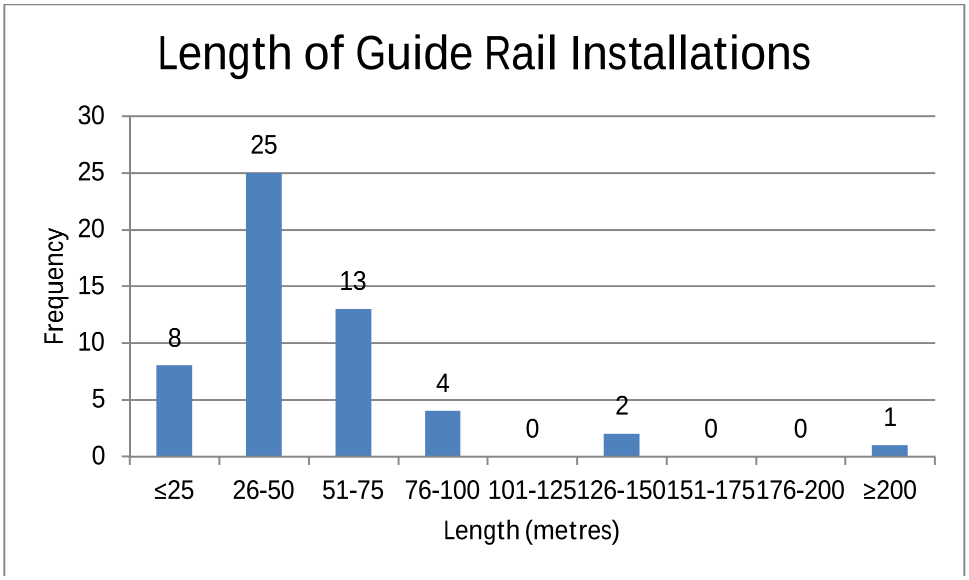


Figure 2-13
Length of Guide Rail Installation

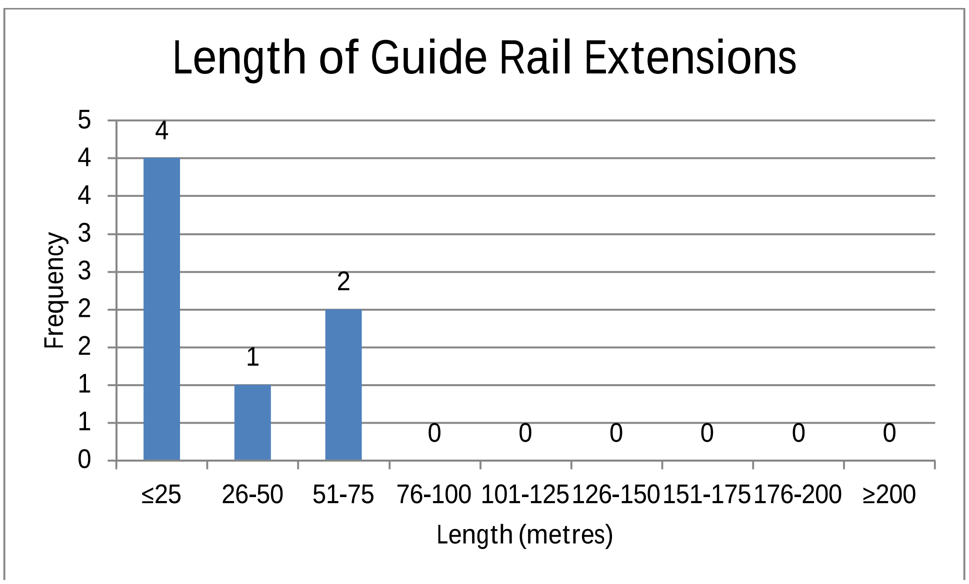


Figure 2-14
Length of Guide Rail Extension

Figure 2-15 presents the most common remediation measures recommended as a result of the inventory and condition and risk assessment. By far, the most common remediation measures recommended were the installation of new guide rail (53 cases), the replacement of old guide rail with new guide rail (24 cases), and minor treatments (22 cases). Less common remediation measures included extending a guide rail, or removing a guide rail.

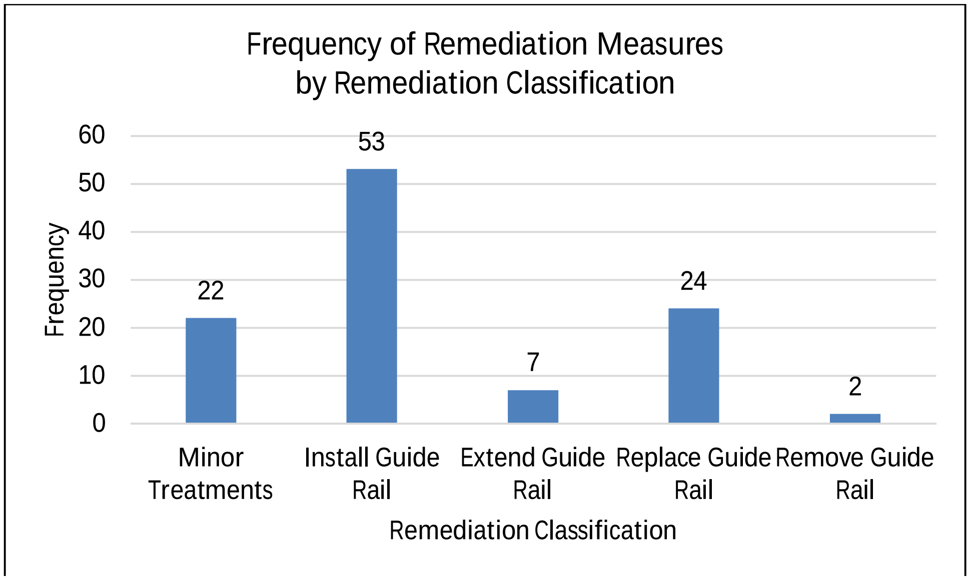


Figure 2-15
Frequency of Common Remediation Measures

Figure 2-16 presents the average cost associated with the common remediation measures recommended. The costliest remediation measure recommended was the replacement of an existing guide rail with a new guide rail system, averaging $16,070 per replacement. The second costliest remediation measure recommended was the installation of a new guide rail system, averaging $15,520 per installation.

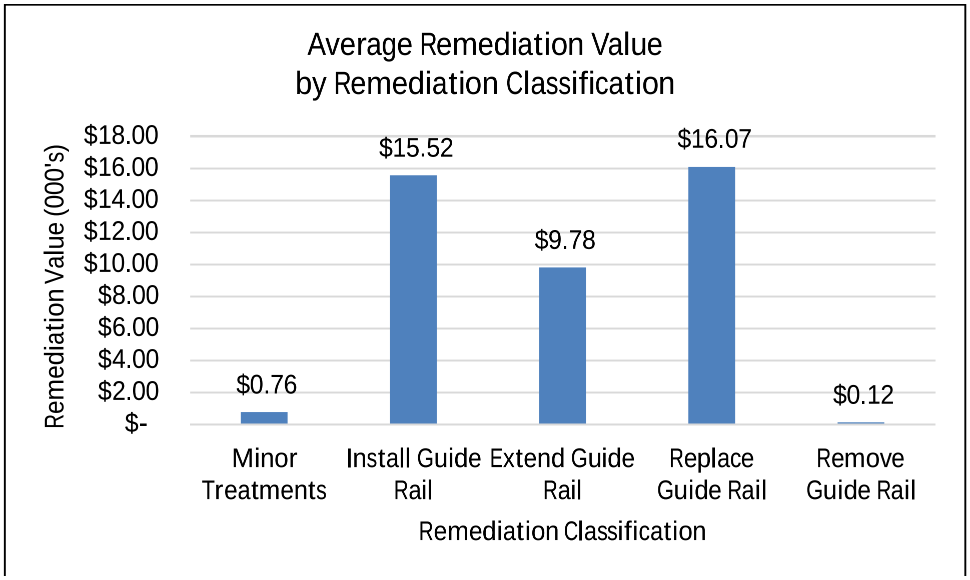


Figure 2-16
Average Cost of Common Remediation Measures

A file containing the entire roadside objects layer, as collected and assessed through this assignment has been provided as a Microsoft Excel Workbook with the geometry information stored as a string in Well Known Binary (WKB) format. Shapefiles have also been prepared with a separate file for points, polylines, and areas, as required.

3 Common Roadside Safety Issues

The following section of the report outlines common roadside safety issues identified over the course of the guide rail inventory and condition and risk assessment in addition to the review of potential unprotected hazards.

3.1 UNPROTECTED HAZARDS

Unprotected hazards located within the minimum roadside clear zone were inventoried and assessed based upon their linear (along the roadway) and lateral (at right-angles to the roadway) extent, to determine the length of need for roadside protection to adequately shield road users from the hazard. Where elimination, relocation or making the hazard traversable/crashworthy was not practical, and the extent of the hazard was amenable to shielding throughout its length, a guide rail installation was recommended.

Steel-beam guide rail, with or without channel, was the treatment of choice due to the effectiveness and life-cycle economics of this system. One example of an unprotected hazard was found on Mill Race Road between Buliung Road and Church Street, as shown in **Figure 3-1**. In this instance, the recommended installation length was 56 metres.

Figure 3-1
Fully-Unprotected Hazard (Mill Race Road)

The approaching end of this new system would be in the minimum roadside clear zone; therefore, a suitable end treatment was recommended. The end treatment of choice in conjunction with steel-beam guide rail was the guide rail SoftStop, based upon its effectiveness at design speeds up to 100 kilometres per hour, its ability to be retrofitted without grading modifications to the roadway shoulder or ditch/drainage design in most applications, and in consideration of the advantages of guide rail fleet standardization. The departure treatment would not be considered within the clear zone and therefore a whale tail end treatment can be used.

To ensure that the approaching and leaving ends of the system are clearly visible to road users and winter maintenance staff, a final recommendation was made to install Wa-33 Object Markers (left or right as applicable) directly in front of the system for both directions of travel. Currently, there is one double-sided object marker on the upstream side of the hazard; there should also be a double-sided marker on the far side of the hazard. There should also be consideration for the installation of snow plow markers and delineation strips to further assist drivers.

Utility poles were also frequently within the clear zone on some roads such as along Preistman Road, shown **Figure 3-2**. Since installing a guide rail or series of guide rails along the total length of the road where the utility poles are present is impractical from a cost perspective, it is recommended that delineation in the form of hazard markers be installed to warn vehicles of the roadside hazards.

Figure 3-2
Fully-Unprotected Hazard (Preistman Road)

3.2 INADEQUATELY PROTECTED HAZARDS

Many locations were identified where: a hazard was present within the minimum roadside clear zone; and roadside protection in the form of guide rail was provided, but the system proved to be obsolescent, in poor condition, and/or of insufficient length to adequately shield the hazard from both directions of travel. One example of a system that is inadequate to protect a hazard is located on Cement Road between Highway 3 and Lakeshore Road and is shown in **Figure 3-3**. In this instance, 16 metres of steel-beam guide rail, in poor condition, and of insufficient length, is present.

Figure 3-3
Partially Protected Hazard (Cement Road)

To upgrade the roadside protection to current standards, and to adequately shield the hazard, simply extending the steel-beam guide rail is impractical. In this instance, the recommendations are to: remove the 16 metres of steel-beam guide rail; replace it with 50 metres of steel-beam guide rail; install energy attenuating end treatments on the approach and departure ends of the system; and provide object markers, snow plow markers, and delineation strips visible to approaching traffic from both directions of travel. Over time, this upgraded form of roadside protection will adequately shield road users from the hazard without introducing other risks into the roadside, while being less-costly and longer-lived to maintain.

3.3 DESIGN CONFORMANCE ISSUES

Adequacy issues identified were not limited to steel-beam guide rail. Length of need issues, protection of approaching and leaving ends, and clear zone issues involving fixed object hazards located within the run-out area behind gating-type end treatments, were also identified.

In the examples shown in **Figure 3-4** and **Figure 3-5** located along Lakeshore Road between Dillon Road and Centre Road, and along Mill Race Road, respectively, several problems exist. Firstly, as presented in **Figure 3-4,** the system does not provide adequate protection from the hazard (embankment) and does not transition from steel-beam to three-cable guide rail appropriately. This could lead to a vehicle leaving the roadway and rolling down the embankment on the far side.

In **Figure 3-5**, there is issues with the transition as well as with the approach and departure lengths. Firstly, the transition itself should not exist as the guide rail should be wrapped around the radius of the curve as a continuous guide rail rather than installed in two linear sections. Secondly, the approach length is inadequate to protect vehicles from the large box culvert if they do leave the roadway. The same is true of the adjacent guiderail on the other side of the road.

It should be noted that when installing either gating style end treatments, the systems are designed to eliminate the spearing threat of a stiff and upright steel-beam approach end, either by bending the beam in the case of the eccentric loader, or by flattening/extruding the beam in the case of the extruder of SoftStop. When struck at an angle however, both systems are designed to yield and allow the errant vehicle to pass through the system without any attempt to attenuate its speed. In such instances, a run-out area free of fixed object hazards alongside and behind the end treatment is essential.

In this instance, the water hazard and embankment would be located within the run-out area and a vehicle colliding with the end treatment would likely continue to run into the water. Unfortunately, due to the geometric constraints it won't be possible to provide this run-out area. However, delineation will help drivers remain alert to the hazard and result in less roadway departures.

Figure 3-4
Design Conformance Issues (Lakeshore Road)

Figure 3-5
Design Conformance Issues (Mill Race Road)

3.4 ACCESS CONFLICTS

Intersecting roadways, driveways, and field accesses may preclude the provision of a run of guide rail sufficient to meet length of need requirements and to prevent an errant vehicle from outflanking the system and reaching the hazard. In such instances, a special form of end treatment, known as a driveway return, is employed. The driveway return provides protection around a small radius and perpendicular to the roadway. Its approach end may either employ an extruder (generally reserved for public roadway approaches), or it may be flared and buried or may be left upright (driveways and field entrances).

The radius and the perpendicular portion of the system preclude outflanking, and transition seamlessly to the steel-beam guide rail running parallel to the roadway. Posts in the radius are drilled to weaken them, allowing them to break away in a head-on impact. The steel-beam then acts like a crash cushion, going into tension and restraining the errant vehicle.

In extreme cases, such as where an intersecting roadway or driveway is present immediately upstream of a fixed object hazard such as a bridge parapet, and the driveway return cannot be accommodated, other treatments which address the fixed object threat only (e.g., crash cushions such Quad-Trend may be considered). However, these solutions are costly, and do not address outflanking. Access relocation should be considered as a more cost-effective alternative, where feasible.

In the example shown in **Figure 3-6** located along Hewitt Road between Lambert Road and Regional Road 27, a driveway return with an object marker is recommended to replace the current end treatment.

Figure 3-6
Access Conflict on Approach End (Hewitt Road)

3.5 DRAINAGE DITCHES

Large, water-filled agricultural irrigation ditches, extending for several kilometres along Feeder Road and Clarendon Street, are present within the roadside clear zone, adjacent to several rural roads within the Township of Wainfleet. These watercourses pose a submergence hazard throughout their length. However, the provision of roadside protection throughout is difficult to justify given that the roadways are generally straight and flat, and the traffic volumes upon them are relatively low.

Applying best-practices, options include: shielding road users from the hazard by means of a low-cost guide rail (e.g. three-cable); road edge delineation to assist road users in selecting an appropriate speed and path so as to remain on the roadway; or a reduction in the posted speed limit to reduce the likelihood of roadway departures.

Collision histories in similar situations suggest that roadway departures involving these features are infrequent, and rarely if ever result in vehicle submergence. Shielding road users from such extensive hazards would be expensive. Three-cable guide rail, which deflects up to three metres on impact, may not prevent vehicles from reaching the hazard. A reduced speed limit would likely achieve poor compliance and prove ineffective, as most road users would fail to perceive the connection between it and roadside threat.

Delineation, to help keep road users on the road, is both effective, and cost-efficient. Options include one or more of the following: painted edge lines; partially-paved shoulders; edge line rumble strips; permanent retro-reflective pavement markers; and post-mounted delineation. Any or all of these treatments could be considered in order to clearly define the extent of the roadway, and the hazard area beyond, allowing road users to make decisions in support of their own safety. On this basis, a delineation treatment is recommended.

4 Life-Cycle Replacement Costs

The Township of Wainfleet wishes to be pro-active in incorporating life-cycle replacement costs into its capital budget on a yearly basis in keeping with asset management best-practices. Asset management best-practices typically involve the following:

- Asset inventories and condition assessments;
- Determination of useful asset-life;
- Valuation of assets on the basis of replacement costs;
- Determination of annual maintenance investment to maintain the condition of current assets (replacement cost divided by useful asset-life to determine annual investment needs); and
- Determination of investment needed to eliminate any backlog of outstanding deficiencies.

In applying this high-level asset management approach to roadside safety systems in the Township of Wainfleet, the following assumptions were applied:

- The useful asset-life for all roadside safety systems is 30 years unless three- cable guide rail then it is 20 years;
- Where remediation measures were identified, the Ministry of Transportation Ontario HiCO System unit costs for installations and removals were assumed to be adequate to determine the overall replacement value of the existing inventory;
- Should a new guide rail be identified for installation, steel-beam or steel-beam with channel was the preferred installation type and was often an upgrade from current conditions;
- Should a new approaching or leaving end treatment be recommended, the extruder was the default installation approach and was often an upgrade from current conditions; and
- The addition of object markers on the approaching and leaving ends of all systems was required, where often none had been provided.

In applying asset management best-practices, this assignment accomplished the following tasks:

- Complete a comprehensive inventory, and condition and risk assessment of existing roadside safety assets to determine number of assets and to characterize any and all deficiencies associated with these systems based upon prevailing standards; and
- Complete a comprehensive inventory of unshielded roadside hazards within the clear zone.

As presented in **Figure 4-1** the replacement cost of the existing inventory was determined to be approximately **$392,000**. Using a 30-year useful asset-life, this suggests an annual maintenance requirement of approximately $13,000 to maintain the status-quo for the 260 kilometres of roadway reviewed.

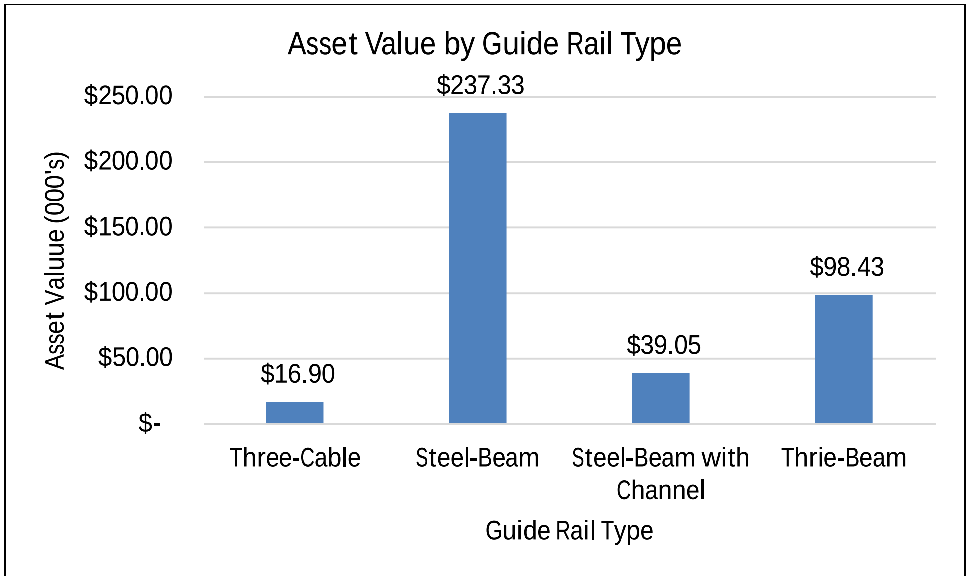


Figure 4-1
Asset Value by Guide Rail Type

When remedial measures to address deficiencies associated with existing systems were priced and summed with the remedial measures required to address unshielded hazards, the combined backlog of deficiencies was found to total approximately **$1.29 million**, as summarized in **Figure 4-2.**

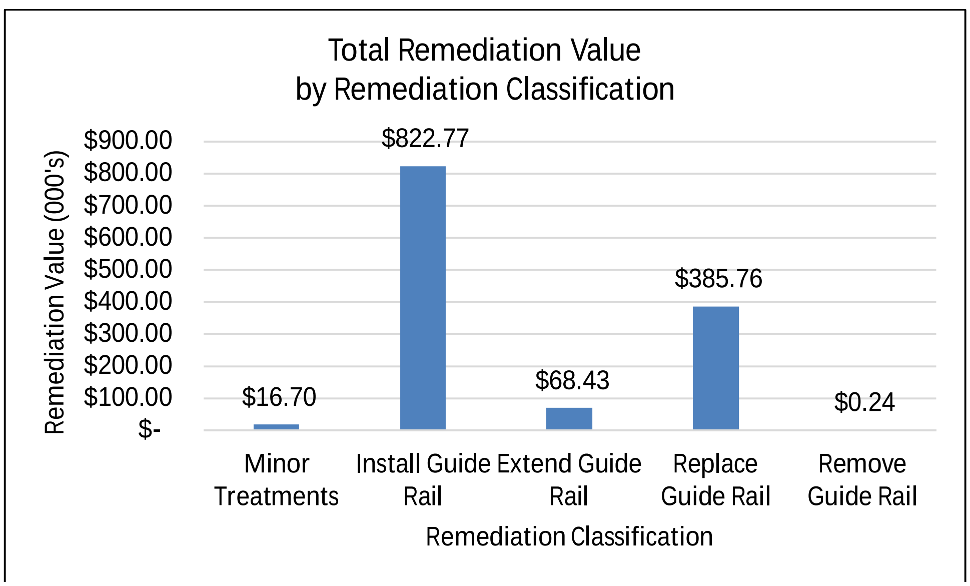


Figure 4-2
Estimated Value of Recommended Remedial Measures

While initially appearing counter-intuitive, as the remedial cost exceeds the replacement cost of the entire fleet, this finding is consistent with the following observations:

- Many elements of the existing fleet are either approaching or at the limit of their expected service life, and thus in need of complete replacement;
- Many existing system elements are fundamentally deficient in terms of existing standards applicable to length of need, approaching and/or leaving end treatments, transitions, and delineation; and
- Where replacement is identified as a required remedial measure, often less-expensive (considering capital cost only) three-cable guide rails are recommended for replacement by more-expensive (again, considering capital costs only) steel-beam guide rails.

Thus, while the cost of eliminating the deficiency backlog may appear excessive, relative to the estimated value of the inventory as a whole, backlog elimination accomplishes numerous objectives, including:

- Replacement of all deficient systems with compliant systems offering comprehensive shielding, superior crash performance, enhanced maintainability, and lower overall life-cycle costs (albeit with higher initial capital costs). This accomplishment will add significantly to the overall size (in terms of linear metres of guide rail, and numbers of end treatments) of the inventory; and
- Elimination of numerous unshielded hazards through the provision of shielding, further adding to the overall size of the inventory.

5 Conclusions and Recommendations

In 2017, the Township of Wainfleet initiated the inventory and assessment of roadside protection systems (herein referred to as guide rails) and roadside hazards (herein referred to as unprotected hazards) alongside approximately 260 kilometres of municipal and township roadways. Associated Engineering (Ont.) Ltd. was retained by the Township of Wainfleet to inventory the existing guide rails and complete a detailed condition and risk assessment. During the inventory of existing guide rails, unprotected hazards were also documented and tracked within the inventory.

The primary purpose was to confirm the location, type, and condition of existing guide rails (in terms of type, end treatments, length, condition, etc.) and existing unprotected hazards. For each guide rail and unprotected hazard, a set of recommended remediation measures was identified in order to address any noted deficiencies. In addition to the inventory and condition assessment, a risk assessment was undertaken and a risk score was calculated to develop a means of prioritization amongst the different guide rails and unprotected hazards.

As a result of the assignment, the Township of Wainfleet has received a detailed georeferenced inventory of all of the guide rails and unprotected hazards situated alongside municipal or township roadways. Furthermore, a condition and risk assessment including recommended remediation measures with their associated costs has been provided. Overall, the roadside objects layer will provide the Township of Wainfleet the necessary asset management framework required to determine life-cycle costs and develop budgets for capital improvements involving roadside safety systems.

5.1 ANALYSIS AND FINDINGS

On the basis of the review, 40 guide rails were inventoried and assessed which consisted of 31 standalone guide rails and 9 system guide rails. The following was noted:

- A majority of the guide rails inventoried along the roadways within the Township of Wainfleet were steel-beam guide rails (26); representing 65 percent of all guide rails inventoried;
- Approximately three-quarters of the total length of guide rails inventoried were steel-beam guide rails spanning approximately 1,526 metres;
- SoftStop or equivalent end treatments were the most prevalent inventoried at 8 installations for approaches while a total of 15 guide rails had no approach end treatment installed;
- Approximately two-thirds the guide rails were at the correct mounting height (68%);
- As a whole, 65 percent of the **rails** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement;
- As a whole, 65 percent of the **posts** reviewed had a condition rating of 4 or 5 indicating a favourable condition while the remaining 35 percent had a condition rating of 3 or less indicating the need for replacement; and

- As a whole, 64 percent of the **block-outs** reviewed (applicable to box-beam, entrance or intersecting roadway, steel-beam, steel-beam with channel, and thrie-beam installations only) had a condition rating of 4 or 5 indicating a favourable condition while the remaining 36 percent had a condition rating of 3 or less indicating the need for replacement.
- Approximately two-thirds (68%) of the guide rails reviewed were determined to have an inadequate approach length for protecting motorists from a roadside hazard; and
- In terms of risk score, systems with a higher risk score tended to be those on higher volume roadways and were systems that were generally in poor condition and/or inadequate length to adequate shield motorists from a hazard.

In total, the inventory identified 108 roadside hazards including both those protected and unprotected. A majority of the hazards had no form of roadside protection (68) while a lesser number (40) were protected. Of these 108 hazards, the most frequently observed type of hazard were fixed objects, of which 32 were identified, followed by box-culverts, embankments, and watercourses at 23, 23, and 19 instances, respectively. In terms of risk score, unprotected hazards with a higher risk score tended to be instances located on roadways with higher volumes in which the hazard was in close proximity to the travelled roadway.

5.2 REMEDIATION MEASURES AND ASSOCIATED COSTS

The most common remediation measure recommended was the installation of new guiderail system (53 cases). Less common remediation measures included installing minor improvements (hazard markers, snowplough markers, etc), extending a guide rail, replacing a guide rail, or removing a guide rail.

The costliest remediation measure recommended was the replacement of an existing guide rail with a new guide rail system, averaging $16,070 per replacement. The second costliest remediation measure recommended was the installation of a new guide rail system, averaging $15,520 per installation.

5.3 COMMON ROADSIDE SAFETY ISSUES

The following common issues were noted as a result of the guide rail inventory, condition and risk assessment, and assessment of unprotected hazards:

- **Unprotected Hazards** - where elimination, relocation or making the hazard traversable/crashworthy was not practical, and the extent of the hazard was amenable to shielding throughout its length, a guide rail installation was recommended;
- **Inadequately Protected Hazards** - where a hazard was present in the minimum roadside clear zone and the system proved to be obsolescent, in poor condition, and/or insufficient length to adequately shield the hazard;
- **Design Conformance Issues** - common issues with design conformance included: clear zone issues involving fixed object hazards located within the run-out area beyond gating-type end treatments, use of eccentric loaders on roads with design speeds greater than 80 kilometres per hour, and barrier curbs located in front of a guide rail system;

- **Access Conflicts** - in situations where an intersecting roadway, driveway or field access precludes the provision of a run of guide rail sufficient to meet length of need requirements; consideration should be given to providing a driveway return; and
- **Drainage Ditches** - large, water-filled drainage ditches, some of which run for several kilometres, are present within the roadside clear zone. The provision of roadside protection along the entire length is difficult to justify. Increased delineation of the roadway edge is recommended to clearly define the extent of the roadway, and the hazard area beyond, allowing road users to make decisions in support of their own safety.

5.4 LIFE-CYCLE REPLACEMENT COSTS

The Township of Wainfleet wishes to be pro-active in incorporating life-cycle replacement costs into its capital budget on a yearly basis in keeping with asset management best-practices. The replacement cost of the existing inventory was determined to be approximately **$392 thousand**. Using a 30-year useful asset-life, this suggests an annual maintenance requirement of approximately $13,000 to maintain the status-quo for the 260 kilometres of roadway reviewed. When remedial measures to address deficiencies associated with existing systems were priced and summed with the remedial measures required to address unshielded hazards, the combined backlog of deficiencies was found to total approximately **$1.29 million**.

While initially appearing counter-intuitive, as the remedial cost exceeds the replacement cost of the entire fleet, this finding is consistent with the following observations:

- Many elements of the existing fleet are either approaching or at the limit of their expected service life, and thus in need of complete replacement;
- Many existing system elements are fundamentally deficient in terms of existing standards applicable to length of need, approaching and/or leaving end treatments, transitions, and delineation; and
- Where replacement is identified as a required remedial measure, often less-expensive (considering capital cost only) three-cable guide rails are recommended for replacement by more-expensive (again, considering capital costs only) steel-beam guide rails.

Thus, while the cost of eliminating the deficiency backlog may appear excessive, relative to the estimated value of the inventory as a whole, backlog elimination accomplishes numerous objectives, including:

- Replacement of all deficient systems with compliant systems offering comprehensive shielding, superior crash performance, enhanced maintainability, and lower overall life-cycle costs (albeit with higher initial capital costs). This accomplishment will add significantly to the overall size (in terms of linear metres of guide rail, and numbers of end treatments) of the inventory; and
- Elimination of numerous unshielded hazards through the provision of shielding, further adding to the overall size of the inventory.

6 Next Steps

This report encompasses data collected over the course of the assignment; with all the data being collected in July of 2017. As this data ages, the accuracy of the database will deteriorate as the Township of Wainfleet proceeds with implementation of the location specific recommendations in this report in addition to road reconstruction projects.

Since this roadside objects layer will primarily be used for asset management and capital planning decisions it is important to keep the data as up-to-date as possible so that informed decisions can be made about the allocation of capital funding.

Within the roadside objects layer, the data can be subdivided into several categories: guide rail inventory and hazard inventory, condition assessment, risk assessment, remediation measures, and associated costs. The Municipality should maintain the currency of the dataset and the following sub-section discusses several possible strategies.

Guide Rail Inventory and Hazard Inventory

Through the Municipality's capital works programs and projects, any new installations or extensions of guide rail will be explicitly tracked with detailed design and/or record drawings. In addition, maintenance activities should be tracked. The Township has two (2) options for updating the dataset:

- **In-House:** municipal staff will be trained by Associated Engineering on protocols for updating the roadside objects layer and the necessary attributes to update for an ongoing basis).
- **Out-Source:** municipal staff will provide all drawings and work orders to Associated Engineering (for an ongoing basis) and Associated Engineering staff will update the roadside objects layer on behalf of the Township.

Condition Assessment

Aside from the inventory information describing the geometry and composition of the guide rail and/or hazard, the condition assessment should be updated approximately every (5) years to address the potential degradation of the asset and update the remaining service life. It is proposed that Associated Engineering train township staff to carry out the condition assessments and update the roadside objects layer.

Risk Assessment, Remediation Measures and Associated Costs

In addition to updating the inventory and condition assessment information, the derived fields such as risk scores, remediation measures, and total remediation costs will need to be updated to maintain an accurate and complete dataset for future prioritization and capital planning. Updates to the assets through completed remediation will reduce risk scores, for example. Reviewing remaining work to be undertaken, in the context of the adjusted risk scores and the current balance of remedial work to be completed (along with the associated costs), should be done on an annual basis. It is proposed that Associated Engineering be retained annually to complete these updates.

Updates to Asset Registry

When the Municipality implements any of the proposed remediation measures, certain actions will be required in order to accurately track the assets:

- **Minor Treatments:** minor treatments such as installing hazard markers, snow plow markers, delineation strips, installing approach/departure end treatments, or addressing system transitions. In the asset registry, the existing asset should be updated with the necessary information since the majority of the guide rail remains unaltered; the service life would not be extended.
- **Install Guide Rail:** a new guide rail is installed to provide protection from a currently unprotected hazard. In the asset registry, a new asset should be created with the necessary information and the existing asset (tracking the unprotected hazard) should be deleted.
- **Extend Guide Rail:** an existing guide rail is extended to provide the necessary length of need to provide protection from a partially protected hazard. In the asset registry, the existing asset should be updated with the necessary information since the majority of the guide rail remains unaltered; the service life would not be extended as only the extension and end treatments would be new.
- **Replace Guide Rail:** an existing guide rail is removed and a new guide rail is installed to address significant deficiencies and/or length of need requirements. In the asset registry, a new asset should be created with the necessary information and the existing asset (tracking the deficient guide rail) should be deleted.
- **Remove Guide Rail:** an existing guide rail is removed since there is not a roadside hazard situated within the minimum clear zone. In the asset registry, the existing asset (tracking the unnecessary guide rail) should be deleted.
- **Remove Unprotected Hazards:** an unprotected hazard that is made traversable or removed. The existing asset (tracking the unprotected hazard) should be deleted.

Closure

This report was prepared for the Township of Wainfleet to summarize the approach and methodology, analysis and findings, and conclusions and recommendations from the roadside safety study conducted to inventory and assess roadside safety systems and roadside hazards alongside the Township's roadways.

The services provided by Associated Engineering (Ont.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (Ont.) Ltd.

Jeff Suggett, M.Sc.
Project Manager

Jordan Frost, P.Eng.
Project Engineer

PERMIT STAMP

Appendix A – Roadside Objects Layer Data Dictionary

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Issue Date:	August 22, 2017	**File:**	A.01.02
Previous Issue Date	Not Applicable		
To:	Richard Nan		
From:	Jordan Frost, P.Eng.		
Client:	Township of Wainfleet		
Project Name	Roadside Safety Study		
Project No.	2017-5109.000		
Subject:	Roadside Objects Layer Data Dictionary		

ROADSIDE OBJECTS LAYER DATA DICTIONARY

TABLE OF CONTENTS

1 GENERAL INFORMATION

facilityID

facilityID uniquely identifies each guide rail/unprotected hazard in the roadside objects layer and was automatically assigned at the time of the assessment

previousFacilityID

previousFacilityID uniquely identifies each guide rail/unprotected hazard in the roadside objects layer and was previously assigned by the Township of Wainfleet

roadSegmentFacilityID

roadSegmentFacilityID corresponds with the *objectID* in the single line road network (SLRN) layer provided by the Township of Wainfleet and denotes the unique identifier of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment

fullName

fullName corresponds with the *street_name* in the singe line road network (SLRN) layer provided by the Township of Wainfleet and denotes the full name of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment

fromStreet

fromStreet corresponds with the *limit1* in the single line road network (SLRN) layer provided by the Township of Wainfleet and is a non-directional attribute denoting the intersecting street at the approaching end of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment

toStreet

toStreet corresponds with the *limit2* in the single line road network (SLRN) layer provided by the Township of Wainfleet and is a non-directional attribute denoting the intersecting street at the departing end of the roadway adjacent to the corresponding guide rail/unprotected hazard and was automatically appended at the time of the assessment

currentAADT

currentAADT corresponds with the *currentAADT* derived from various data sources appended to the single line road network layer (SLRN) provided by the Township of Wainfleet and denotes the non-directional average annual daily traffic (AADT) volume of the roadway adjacent to the guide rail/unprotected hazard and was automatically appended at the time of the assessment

postedSpeed

postedSpeed is a integer data type representing the posted speed limit (in kilometres per hour) of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

note: where posted speed limits were not present, a statutory speed limit of 80 kilometres per hour was assumed

designSpeed

designSpeed is a integer data type representing the design speed limit (in kilometres per hour) of the roadway adjacent to the guide rail/unprotected hazard and was calculated at the time of the assessment using *postedSpeed*

$$designSpeed = postedSpeed + 10$$

horizontalAlignment

horizontalAlignment is a “yes” or “no” indicator of whether or not a horizontal curve is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

dividedRoadway

dividedRoadway is a “yes” or “no” indicator of whether or not a physical median is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

adjacentLanes

adjacentLanes is a integer data type representing the number of adjacent lanes of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

leftTurnLane

leftTurnLane is a “yes” or “no” indicator of whether or not a two-way/continuous left-turn lane is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

barrierCurb

barrierCurb is a “yes” or “no” indicator of whether or not a barrier curb is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

concreteSidewalk

concreteSidewalk is a “yes” or “no” indicator of whether or not a concrete sidewalk is present on the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

clearZone

clearZone is a floating-point double data type representing the clear zone of the roadway adjacent to the guide rail/unprotected hazard and was determined at the time of the assessment using *currentAADT*, *designSpeed*, *horizontalAlignment*, and *barrierCurb*, and with the *Roadside Safety Manual*[1]

$$IF\ horizontalAlignment = Yes\ THEN\ horizontalCurveCorrelationFactor = 1.50$$

$$IF\ horizontalAlignment = No\ THEN\ horizontalCurveCorrelationFactor = 1.00$$

$$clearZone = clearZone \times horizontalCurveCorrelationFactor$$

Table 1-1
Clear Zone Widths

Design Speed (kilometres per hour)	Clear Zone Width (metres)			
	A	B		
	AADT ≥ 6000	AADT ≥ 1500	AADT ≥ 750	AADT < 750
120	10.0	8.0	7.0	6.0
110	9.0	7.0	6.0	5.0
100	7.0	6.0	5.0	4.0
90	6.0	5.0	4.0	4.0
80	5.0	4.0	4.0	4.0
70	4.0	3.0	3.0	3.0
≤ 60	3.0	3.0	3.0	3.0
≤ 60 + Barrier Curb	0.5	0.5	0.5	0.5

[1] Ministry of Transportation Ontario, *Roadside Safety Manual*, 1993.

Table 1-2
Horizontal Curve Correlation Factors

Radius (metres)	Horizontal Curve Correlation Factor Design Speed (kilometres per hour)						
	≤ 60	**70**	**80**	**90**	**100**	**110**	**120**
1000	1.00	1.00	1.00	1.00	1.00	1.00	1.00
900	1.07	1.09	1.11	1.15	1.19	1.24	1.31
800	1.08	1.10	1.13	1.17	1.23	1.28	1.34
700	1.09	1.12	1.15	1.20	1.25	1.32	1.43
600	1.10	1.14	1.17	1.23	1.29	1.37	1.46
500	1.11	1.16	1.22	1.27	1.35	1.44	-
400	1.14	1.19	1.27	1.35	1.42	-	-
350	1.17	1.23	1.31	1.39	-	-	-
300	1.20	1.27	1.35	1.46	-	-	-
250	1.22	1.32	1.42	-	-	-	-
220	1.25	1.35	-	-	-	-	-
200	1.29	1.40	-	-	-	-	-
180	1.32	1.45	-	-	-	-	-
150	1.35	-	-	-	-	-	-
120	1.40	-	-	-	-	-	-
100	1.50	-	-	-	-	-	-
50	1.75	-	-	-	-	-	-

ownership

ownership is a string data type representing the jurisdictional ownership and responsibility to manage the guide rail/unprotected hazard and was entered at the time of the assessment:

values: municipality, province, private

direction

direction is a string data type representing the direction of the guide rail/unprotected hazard in relation to the direction of travel of the nearest lane of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

values: north, northeast, east, southeast, south, southwest, west, northwest

position

position is a string data type representing the position of the guide rail/unprotected hazard in relation to the nearest lane of the roadway adjacent to the guide rail/unprotected hazard and was entered at the time of the assessment

values: left, right

guideRailPhotograph

guideRailPhotograph is a string data type representing the filename of the photograph of the guide rail and was entered at the time of the assessment

dateEntered

dateEntered is a date data type representing the date in which the guide rail/unprotected hazard was first entered in the roadside objects layer and was automatically entered at the time of the assessment

$dateEntered = today()$

dateUpdated

dateUpdated is a date data type representing the date in which the guide rail/unprotected hazard was last updated in the roadside objects layer and was automatically entered at the time of the assessment using a default date

$dateUpdated = 01/01/1900$

inspectedBy

inspectedBy is a string data type representing those responsible for the inventory, condition assessment, and/or risk assessment of the guide rail/unprotected hazard and was automatically entered at the time of the assessment

generalComments

generalComments is a string data type representing additional comments pertaining to the guide rail/unprotected hazard and was entered at the time of the assessment

2 GUIDE RAIL INFORMATION

systemID

systemID uniquely identifies each guide rail/unprotected hazard system in the roadside objects layer and was automatically assigned at the time of the assessment

guideRailClassification

guideRailClassification is a string data type representing the classification of the guide rail and was entered at the time of the assessment

values: flexible, semi-rigid, rigid, not applicable

guideRailType

guideRailType is a string data type representing the type of the guide rail and was entered at the time of the assessment

values: guide-post, three-cable, box-beam, entrance or intersecting roadway, high-tension cable, steel-beam, steel-beam with channel, thrie-beam, concrete, not applicable

approachEndTreatmentClassification

approachEndTreatmentClassification is a string data type representing the classification of the guide rail approach end treatment and was entered at the time of the assessment

values: tapered-down, stand-up non-energy absorbing, stand-up energy absorbing, system transition, not applicable

approachEndTreatmentType

approachEndTreatmentType is a string data type representing the type of the guide rail approach end treatment and was entered at the time of the assessment

values: three-cable turned-down, steel-beam turned-down, concrete turned-down, breakaway cable terminal, crash attenuator, eccentric loader, entrance or intersecting roadway, extruder, softstop or equivalent, proper transition, improper transition, not applicable

approachDistanceEntranceIntersectingRoadway

approachDistanceEntranceIntersectingRoadway is a integer data type representing the approximate distance to the nearest upstream entrance or intersecting roadway which may limit the available space required for installation or extension of the guide rail and was entered at the time of the assessment *note:* if the upstream conflict is outside the bounds for installation or extension, a default value of 999 metres is used

approachTransitionFacilityID

approachTransitionFacilityID corresponds with the *facilityID* in the roadside objects layer and denotes the unique identifier or the guide rail which occurs sequentially before the current guide rail within respective guide rail system and was automatically entered at the time of the assessment

departureEndTreatmentClassification

departureEndTreatmentClassification is a string data type representing the classification of the guide rail departure end treatment and was entered at the time of the assessment

values: tapered-down, stand-up non-energy absorbing, stand-up energy absorbing, system transition, not applicable

departureEndTreatmentType

departureEndTreatmentType is a string data type representing the type of the guide rail departure end treatment and was entered at the time of the assessment

values: three-cable turned-down, steel-beam turned-down, concrete turned-down, breakaway cable terminal, crash attenuator, eccentric loader, entrance or intersecting roadway, extruder, softstop or equivalent, proper transition, improper transition, not applicable

departureDistanceEntranceIntersectingRoadway

departureDistanceEntranceIntersectingRoadway is a integer data type representing the approximate distance to the nearest downstream entrance or intersecting roadway which may limit the available space required for installation or extension of the guide rail and was entered at the time of the assessment

note: if the downstream conflict is outside the bounds for installation or extension, a default value of 999 metres is used

departureTransitionFacilityID

departureTransitionFacilityID corresponds with the *facilityID* in the roadside objects layer and denotes the unique identifier or the guide rail which occurs sequentially after the current guide rail within respective guide rail system and was automatically entered at the time of the assessment

postMaterial

postMaterial is a string data type representing the guide rail post material and was entered at the time of the assessment

values: wood, steel, not applicable

blockOutMaterial

blockOutMaterial is a string data type representing the guide rail block-out material and was entered at the time of the assessment

values: wood, steel, plastic, not applicable

guideRailLength

guideRailLength is a floating-point double data type representing the length of the guide rail and was previously determined during the prior guide rail inventory and for those newly identified guide rails was measured at the time of the assessment using aerial/orthographic photography or field measurements

notes: guideRailLength includes the approach and departure end treatments; however, since these do not assist in providing protection from roadside hazards but assist in providing protection from the blunt ends of the guide rail will be subtracted from any length of need calculations

guideRailAdjacentOffset

guideRailAdjacentOffset is a floating-point double data type representing the horizontal offset (in half-metre increments) of the guide rail from the nearest adjacent lane of the roadway adjacent to the guide rail and was entered at the time of assessment

guideRailOpposingOffset

guideRailOpposingOffset is a floating-point double data type representing the horizontal offset (in half-metre increments) of the guide rail from the nearest opposing lane of the roadway adjacent to the guide rail and was calculated at the time of the assessment using *adjacentLanes*, *dividedRoadway*, *leftTurnLane*, and *guideRailAdjacentOffset*

$$guideRailOpposingOffset = (guideRailAdjacentOffset + 3.5 \times adjacentLanes + 3.5 \times leftTurnLane) \times dividedRoadway$$

guideRailValue

guideRailValue is a currency data type representing the total cost to replace the existing guide rail with the same type and quantity of materials and was calculated at the time of the assessment using costs adapted from the Ministry of Transportation Ontario’s Highway Costing (HiCo) System

Table 2-1
Guide Rail Value and HiCo System Unit Costs

No.	Installation Cost	Cost/Unit
1	Install Hazard Markers	$200.00
2	Install Snow Plow Markers	$200.00
3	Install Delineation Strips	$200.00
4	Install Approach End Treatment	$5,100.00
5	Install Departure End Treatment	$5,100.00
6	Install System Transitions	$5,100.00
7	Install Guide-Post	$20.00
8	Install Three-Cable	$34.00
9	Install Box-Beam	$305.00
10	Install Entrance or Intersecting Roadway	$82.00
11	Install High-Tension Cable	$51.00
12	Install Steel-Beam	$82.00
13	Install Steel-Beam with Channel	$96.00
14	Install Thrie-Beam	$510.00
15	Install Concrete	$190.00

3 HAZARD INFORMATION

hazardClassification

hazardClassification is a string data type representing the classification of the hazard and was entered at the time of the assessment

values: embankment, fixed object, not applicable

hazardType

hazardType is a string data type representing the type of the hazard and was entered at the time of the assessment

values: embankment, watercourse, other (embankment), box-culvert, bridge abutment, bridge rail or wall, other (fixed object), not applicable

hazardLength

hazardLength is a floating-point double data type representing the length of the hazard and was calculated at the time of the assessment using *guideRailLength*, *approachDistanceHazard*, and *departureDistanceHazard*

$$hazardLength = guideRailLength \pm approachDistanceHazard \pm departureDistanceHazard$$

hazardAdjacentOffset

hazardAdjacentOffset is a floating-point double data type representing the horizontal offset (in half-metre increments) of the hazard from the nearest adjacent lane of the roadway adjacent to the hazard and was entered at the time of assessment

hazardOpposingOffset

hazardOpposingOffset is a floating-point double data type representing the horizontal offset (in half-metre increments) of the hazard from the nearest opposing lane of the roadway adjacent to the hazard and was calculated at the time of the assessment using *adjacentLanes*, *dividedRoadway*, *leftTurnLane*, and *hazardAdjacentOffset*

$$hazardOpposingOffset = (hazardAdjacentOffset + 3.5 \times adjacentLanes + 3.5 \times leftTurnLane) \times dividedRoadway$$

guideRailApproachBeforeHazard

guideRailApproachBeforeHazard is a “yes” or “no” indicator of whether or not the approach point of the guide rail begins prior to the approach point of the hazard and was entered at the time of the assessment

approachDistanceHazard

approachDistanceHazard is a integer type representing the absolute distance from the approach point of the guide rail to the approach point of the hazard and was entered at the time of the assessment

note: if a guide rail is not present (i.e. an unprotected hazard), then the *approachDistanceHazard* will be equal to half of the length of the hazard

guideRailDepartureAfterHazard

guideRailDepartureAfterHazard is a “yes” or “no” indicator of whether or not the departure point of the guide rail ends after the departure point of the hazard and was entered at the time of the assessment

departureDistanceHazard

departureDistanceHazard is a integer data type representing the absolute distance from the departure point of the guide rail to the departure point of the hazard and was entered at the time of the assessment

note: if a guide rail is not present (i.e. an unprotected hazard), then the *departureDistanceHazard* will be equal to half of the length of the hazard

makeTraversable

makeTraversable is a “yes” or “no” indicator of whether or not a hazard can be made traversable to remove it from the clear zone without the installation of other roadside protection measures and was entered at the time of assessment

4 CONDITION ASSESSMENT INFORMATION

hazardMarkers

hazardMarkers is a string data type representing the adequacy of the current state of the hazard markers and was entered at the time of the assessment

values: yes, no, not applicable

snowPlowMarkers

snowPlowMarkers is a string data type representing the adequacy of the current state of the snow plow markers and was entered at the time of the assessment

values: yes, no, not applicable

delineationStrips

delineationStrips is a string data type representing the adequacy of the current state of the delineation strips and was entered at the time of the assessment

values: yes, no, not applicable

mountingHeight

mountingHeight is a string data type representing the adequacy of the current state of the mounting height with respect to the guide rail type, applicable mounting height design standards, and applicable mounting height tolerances and was entered at the time of the assessment

values: yes, no, not applicable

plumbAngle

plumbAngle is a string data type representing the adequacy of the current state of the plumb angle and was entered at the time of the assessment

values: yes, no, not applicable

cableTension

cableTension is a string data type representing the adequacy of the current state of the cable tension with respect to three-cable and high-tension cable guide rails and was entered at the time of the assessment *values:* yes, no, not applicable

systemTransitions

systemTransitions is a string data type representing the adequacy of the current state of the system transitions with respect to post spacing, changes in rigidity, and overlap and was entered at the time of the assessment

values: yes, no, not applicable

railLapping

railLapping is a string data type representing the adequacy of the current state of the rail lapping with respecting to steel-beam, steel-beam with channel, and thrie-beam guide rails and was entered at the time of the assessment

values: yes, no, not applicable

deflectionArea

deflectionArea is a string data type representing the adequacy of the current state of the deflection area with respect to embankments or fixed objects within the deflection area behind a guide rail and was entered at the time of the assessment

values: yes, no, not applicable

runOutArea

runOutArea is a string data type representing the adequacy of the current state of the run-out area with respect to embankments or fixed objects within the run-out area behind a gating end treatment and was entered at the time of the assessment

values: yes, no, not applicable

shoulderDesign

shoulderDesign is a string data type representing the adequacy of the current state of the shoulder design with respect to the presence and horizontal offset of barrier curbs in relation to the face of a guide rail and was entered at the time of the assessment

values: yes, no, not applicable

shoulderStability

shoulderStability is a string data type representing the adequacy of the current state of the shoulder stability with respect to erosion, slope, and stabilization and was entered at the time of the assessment

values: yes, no, not applicable

railConditionRating

railConditionRating is an integer data type representing the condition rating of the current state of the rail component of a guide rail and was entered at the time of the assessment. A *railConditionRating* of 1 represents a completely failing rail which is between 0% and 20% condition while a *railConditionRating* of 5 represents a completely adequate rail which is between 80% and 100%

values: 1, 2, 3, 4, 5

postConditionRating

postConditionRating is an integer data type representing the condition rating of the current state of the post component of a guide rail and was entered at the time of the assessment. A *postConditionRating* of 1 represents completely failing posts which are between 0% and 20% condition while a *postConditionRating* of 5 represents completely adequate posts which are between 80% and 100% condition

values: 1, 2, 3, 4, 5

blockOutConditionRating

blockOutConditionRating is an integer data type representing the condition rating of the current state of the block-out component of a guide rail and was entered at the time of the assessment. A *blockOutConditionRating* of 1 represents completely failing block-outs which are between 0% and 20% condition while a *blockOutConditionRating* of 5 represents completely adequate block-outs which are between 80% and 100% condition

values: 1, 2, 3, 4, 5

5 RISK ASSESSMENT INFORMATION

designConformance

designConformance is a string data type representing the overall conformance to the applicable design standards and the overall condition rating of the guide rail's components and its ability to serve its intended function to protect against roadside hazards in the event of a collision and was determined at the time of the assessment using *mountingHeight*, *plumbAngle*, *cableTension*, *railLapping*, *deflectionArea*, *shoulderDesign*, *shoulderStability*, *railConditionRating*, *postConditionRating*, and *blockOutConditionRating*

$IF\ mountingHeight\ OR\ plumbAngle\ OR\ cableTension\ OR\ railLapping\ OR\ deflectionArea\ OR\ shoulderDesign\ OR\ shoulderStability = No$
$THEN\ designConformance = No$

$IF\ railConditionRating \leq 3\ OR\ postConditionRating \leq 3\ OR\ blockOutConditionRating \leq 3$
$THEN\ designConformance = No$

values: yes, no, not applicable

approachLengthNeed

approachLengthNeed is a floating-point doubled data type representing the length of need required on the approach end of the guide rail and was determined at the time of the assessment using *designSpeed* with the *Geometric Design Guide*[2]

approachLengthConformance

approachLengthConformance is a string data type representing the adequacy of the length of the approach of the guide rail in order to protect against the hazard and was determined at the time of the assessment using *approachDistanceHazard* and *approachLengthNeed*

$IF\ approachDistanceHazard > approachLengthNeed\ THEN\ approachLengthConformance = Yes$

values: yes, no, not applicable

notes: if the guide rail is bounded by a nearby entrance or intersecting roadway or is part of a system, then the *approachLengthConformance* is insignificant as the guide rail cannot be recommended for extension but instead an entrance or intersecting roadway end treatment would be recommended

approachLengthExtension

approachLengthExtension is a floating-point double data type representing the length of extension (in metres) recommended for the approach end of the guide rail if the guide rail is too short to adequately protect against the hazard

---

[2] Transportation Association of Canada, *Geometric Design Guide for Canadian Roads*, 2017.

and was calculated at the time of the assessment using *approachDistanceHazard* and *approachLengthNeed* and is only calculated if the *hazardAdjacentOffset* is within the clear zone

notes: *approachLengthExtension* is 0 if the end treatment is a system transition

departureLengthNeed

departureLengthNeed is a floating-point doubled data type representing the length of need required on the departure end of the guide rail and was determined at the time of the assessment using *designSpeed* with the *Geometric Design Guide*[2]

departureLengthConformance

departureLengthConformance is a string data type representing the adequacy of the length of the departure of the guide rail in order to protect against the hazard and was determined at the time of the assessment using *departureDistanceHazard* and *departureLengthNeed*

$$IF\ departureDistanceHazard > departureLengthNeed\ THEN\ departureLengthConformance = Yes$$

values: yes, no, not applicable

notes: if the guide rail is bounded by a nearby entrance or intersecting roadway or is part of a system, then the *departureLengthConformance* is insignificant as the guide rail cannot be recommended for extension but instead an entrance or intersecting roadway end treatment would be recommended

departureLengthExtension

departureLengthExtension is a floating-point double data type representing the length of extension (in metres) recommended for the departure end of the guide rail if the guide rail is too short to adequately protect against the hazard and was calculated at the time of the assessment using *departureDistanceHazard* and *departureLengthNeed* and is only calculated if the *hazardOpposingOffset* is within the clear zone

notes: departureLengthExtension is 0 if the departure end treatment is a system transition

Table 5-1
Length of Need

Design Speed (kilometres per hour)	Encroachment Distance (E) Given Traffic Volume (ADT) (m)			
	Over 10,000 veh/day	5,000 to 10,000 veh/day	1,000 to 5,000 veh/day	Under 1,000 veh/day
130	143	131	116	101
110	110	101	88	76
100	91	76	64	61
80	70	58	49	46
60	49	40	34	30
50	34	27	24	21

guideRailAdjacentProbability

guideRailAdjacentProbability is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the guide rail from the adjacent lane and was determined at the time of the assessment using *designSpeed* and *guideRailAdjacentOffset* and with the *Roadside Design Guide*[3]

$IF\ guideRailAdjacentOffset > clearZone\ THEN\ guideRailAdjacentProbability = 0.00$

guideRailOpposingProbability

guideRailOpposingProbability is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the guide rail from the opposing lane and was determined at the time of the assessment using *designSpeed* and *guideRailOpposingOffset* and with the *Roadside Design Guide*[3]

$IF\ guideRailOpposingOffset > clearZone\ THEN\ guideRailOpposingProbability = 0.00$

hazardAdjacentProbability

hazardAdjacentProbability is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the hazard from the adjacent lane and was determined at the time of the assessment using *designSpeed* and *hazardAdjacentOffset* and with the *Roadside Design Guide*[3]

[3] American Association of State Highway and Transportation Officials, *Roadside Design Guide*, 2011.

$IF\ hazardAdjacentOffset > clearZone\ THEN\ hazardAdjacentProbability = 0.00$

hazardOpposingProbability

hazardOpposingProbability is a floating-point double data type representing the probability, that in the event of roadway departure, an errant vehicle will collide with the hazard from the opposing lane and was determined at the time of the assessment using *designSpeed* and *hazardOpposingOffset* and with the *Roadside Design Guide*[3]

$IF\ hazardOpposingOffset > clearZone\ THEN\ hazardOpposingProbability = 0.00$

Table 5-2
Horizontal Offsets and Encroachment Rates

Horizontal Offset (metres)	Encroachment Rate					
	Design Speed (kilometres per hour)					
	≤ 50	60	70	80	90	≥ 100
0.00	1.00	1.00	1.00	1.00	1.00	1.00
0.50	0.68	0.74	0.78	0.82	0.86	0.89
1.00	0.52	0.59	0.64	0.69	0.73	0.77
1.50	0.41	0.49	0.55	0.60	0.64	0.68
2.00	0.33	0.41	0.48	0.53	0.57	0.61
2.50	0.27	0.35	0.42	0.47	0.51	0.55
3.00	0.22	0.30	0.36	0.42	0.46	0.50
3.50	0.18	0.25	0.32	0.38	0.42	0.46
4.00	0.15	0.22	0.28	0.34	0.38	0.42
4.50	0.12	0.19	0.25	0.30	0.35	0.38
5.00	0.10	0.16	0.22	0.27	0.32	0.35
5.50	0.09	0.14	0.19	0.24	0.29	0.32
6.00	0.07	0.12	0.17	0.22	0.26	0.30
6.50	0.06	0.10	0.15	0.19	0.24	0.27
7.00	0.05	0.09	0.13	0.17	0.22	0.25
7.50	0.04	0.08	0.11	0.16	0.20	0.23
8.00	0.03	0.07	0.10	0.14	0.18	0.21
8.50	0.03	0.06	0.09	0.13	0.16	0.19

Horizontal Offset (metres)	Encroachment Rate					
	Design Speed (kilometres per hour)					
	≤ 50	60	70	80	90	≥ 100
9.00	0.02	0.05	0.08	0.11	0.15	0.18
9.50	0.02	0.04	0.07	0.10	0.13	0.16
10.0	0.02	0.04	0.06	0.09	0.12	0.15

guideRailSeverityIndex

guideRailSeverityIndex is an integer data type representing the severity index of the guide rail and was determined at the time of the assessment using *designSpeed*, *guideRailType*, and *designConformance* and with the *Roadside Design Guide*[3]

hazardSeverityIndex

hazardSeverityIndex is an integer data type representing the severity index of the hazard and was determined at the time of the assessment using *designSpeed* and *hazardClassification* and with the *Roadside Design Guide*[3]

Table 5-3
Severity Indices by Guide Rail Type or Hazard Type (Part 1)

Design Speed (kilometres per hour)	Severity Index									
	Guide-Post		Three-Cable		Steel-Beam		Steel-Beam with Channel		Thrie-Beam	
	Conf.	Non Conf.	Conf.	Non Conf.	Conf.	Non Conf.	Conf.	Non Conf.	Conf.	Non Conf.
50	3	4	3	4	2	3	2	4	2	4
60	3	4	3	4	2	3	2	4	2	4
70	3	5	3	5	2	3	2	4	2	4
80	4	5	4	5	2	4	2	5	2	5
90	4	6	4	6	3	5	3	5	3	5
100	4	6	4	6	3	5	3	6	3	6

Table 5-4
Severity Indices by Guide Rail Type (Part 2)

Design Speed (kilometers per hour)	Severity Index							
	Box-Beam		Entrance or Intersecting Roadway		High-Tension Cable		Concrete	
	Conf.	Non Conf.	Conf.	Non Conf.	Conf.	Non Conf.	Conf.	Non Conf.
50	2	3	2	4	2	3	2	4
60	2	3	2	4	2	3	2	4
70	2	3	2	4	2	3	2	4
80	2	4	2	5	2	4	2	5
90	3	5	3	5	3	5	3	5
100	3	5	3	6	3	5	3	6

Table 5-5
Severity Indices by Hazard Classification

Design Speed (kilometres per hour)	Severity Index	
	Embankment	Fixed Object
50	4	4
60	4	4
70	4	4
80	5	5
90	6	6
100	7	7

guideRailRiskScore

guideRailRiskScore is a floating-point double date type representing the risk score of the guide rail and was calculated at the time of the assessment using *currentAADT*, *guideRailLength*, *guideRailAdjacentProbability*, *guideRailOpposingProbability*, and *guideRailSeverityIndex* with the *Roadside Design Guide*[3]

$$exposure = 0.0003 \times currentAADT \,/\, 2 \times guideRailLength \,/\, 1000$$

$$probability = guideRailAdjacentProbability + guideRailOpposingProbability$$

$$consequence = (1 \times prob^{property\ damage\ only}) + (10 \times prob^{non-fatal\ injury}) + (1967 \times prob^{fatality})$$

$$guideRailRiskScore = exposure \times probability \times consequence$$

hazardRiskScore

hazardRiskScore is a floating-point double date type representing the risk score of the hazard if it were fully-unprotected and was calculated at the time of the assessment using *currentAADT*, *hazardLength*, *hazardAdjacentProbability*, *hazardOpposingProbability*, and *hazardSeverityIndex* with the *Roadside Design Guide*[3]

$$exposure = 0.0003 \times currentAADT \;/\; 2 \times hazardLength \;/\; 1000$$

$$probability = hazardAdjacentProbability + hazardOpposingProbability$$

$$consequence = (1 \times prob^{property\ damage\ only}) + (10 \times prob^{non-fatal\ injury}) + (1967 \times prob^{fatality})$$

$$hazardRiskScore = exposure \times probability \times consequence$$

Table 5-6
Severity Indices and Probability of Collision Severity

Collision Type	Probability of Collision Severity											
	Severity Index											
	0.0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Property Damage Only	0	100	90	71	43	30	15	7	2	0	0	0
Non-Fatal Injury	0	0	10	29	56	67	77	75	68	50	25	0
Fatality	0	0	0	0	1	3	8	18	30	50	75	100
Total	0	100	100	100	100	100	100	100	100	100	100	100

combinedRiskScore

combinedRiskScore is a floating-point double data type representing the summation of the risk associated with the guide rail and proportioned risk of the hazard and was calculated at the time of the assessment using *guideRailLength*, *hazardLength*, *designConformance*, *approachLengthConformance*, *departureLengthConformance*, *approachLengthExtension*, *departureLengthExtension*, *guideRailRiskScore*, and *hazardRiskScore*

$$IF\ designConformance = Yes\ AND\ approachLengthConformance = Yes\ AND\ departureLengthConformance = Yes$$
$$THEN\ combinedRiskScore = guideRailRiskScore$$

$$IF\ designConformance = No$$
$$THEN\ combinedRiskScore = guideRailRiskScore + hazardRiskScore$$

$$IF\ designConformance = Yes\ AND\ approachLengthConformance = No$$
$$THEN\ combinedRiskScore = guideRailRiskScore + hazardRiskScore \times approachLengthExtension \;/\; guideRailLength$$

$$IF\ designConformance = Yes\ AND\ departureLengthConformance = No$$

$THEN\ combinedRiskScore = guideRailRiskScore + hazardRiskScore \times departureLengthExtension\ /\ guideRailLength$

systemRiskScore

systemRiskScore is a floating-point double data type representing the summation of the risk associated with all guide rails within a system and was calculated at the time of the assessment using *systemID* and *combinedRiskScore*

6 REMEDIATION INFORMATION

installHazardMarkers

installHazardMarkers is a integer data type representing the recommended number of hazard markers to be installed as part of the remediation measures

values: 0, 1, 2

installSnowPlowMarkers

installSnowPlowMarkers is a integer data type representing the recommended number of snow plow markers to be installed as part of the remediation measures

values: 0, 1, 2

installDelineationStrips

installDelineationStrips is a integer data type representing the recommended number of delineation strips to be installed as part of the remediation measures

values: 0, 1

installApproachEndTreatment

installApproachEndTreatment is a integer data type representing the recommended number of approach end treatments to be installed as part of the remediation measures

values: 0, 1

installDepartureEndTreatment

installDepartureEndTreatment is a integer data type representing the recommended number of departure end treatments to be installed as part of the remediation measures

values: 0, 1

addressSystemTransitions

addressSystemTransitions is a integer data type representing the recommended number of system transitions to be addressed as part of the remediation measures

values: 0, 1, 2

installGuideRail

installGuideRail is a floating-point double data type representing the length of guide rail to be installed at a location whereby an unprotected hazard is situated within the clear zone

extendGuideRail

extendGuideRail is a floating-point double data type representing the length of guide rail to be extended at a location whereby a guide rail of insufficient length is in front of a partially protected hazard situated within the clear zone

replaceGuideRail

replaceGuideRail is a floating-point double data type representing the length of guide rail to be installed at a location whereby a guide rail of inadequate condition is in front of a partially protected hazard situated within the clear zone

note: the length of guide rail to be removed is not explicitly recorded but is accounted for in *remediationMeasures* and reflected upon in *totalRemediationCost*

removeGuideRail

removeGuideRail is a floating-point double data type representing the length of guide rail to be removed at a location whereby no hazard exists or is situated outside of the clear zone

remediationMeasures

remediationMeasures is a string data type representing the recommended remediation measures to address deficiencies relating to guide rails and unprotected hazards inventoried and was determined at the time of the assessment

values: install hazard markers, install snow plow markers, install delineation strips, install approach end treatment, install departure end treatment, address system transitions, install guide rail, extend guide rail, replace guide rail, remove guide rail

remediationMeasuresClassification

remediationMeasuresClassification is a string data type representing the classification of the remediation measures and was determined at the time of the assessment

values: minor treatments, install guide rail, extend guide rail, replace guide rail, remove guide rail

totalRemediationCost

totalRemediationCost is a currency data type representing the total cost to implement the remediation measures and was calculated at the time of the assessment using costs adapted from the Ministry of Transportation Ontario's Highway Costing (HiCo) System

Table 6-1
Total Remediation Cost and HiCo System Unit Costs

No.	Installation Cost	Cost/Unit
1	Install Hazard Markers	$200.00
2	Install Snow Plow Markers	$200.00
3	Install Delineation Strips	$200.00
4	Install Approach End Treatment	$5,100.00
5	Install Departure End Treatment	$5,100.00
6	Install System Transitions	$5,100.00
7	Install Guide-Post	$20.00
8	Install Three-Cable	$34.00
9	Install Box-Beam	$305.00
10	Install Entrance or Intersecting Roadway	$82.00
11	Install High-Tension Cable	$51.00
12	Install Steel-Beam	$82.00
13	Install Steel-Beam with Channel	$96.00
14	Install Thrie-Beam	$510.00
15	Install Concrete	$190.00
16	Extend Guide-Post	$20.00
17	Extend Three-Cable	$34.00
18	Extend Box-Beam	$305.00
19	Extend Entrance or Intersecting Roadway	$82.00
20	Extend High-Tension Cable	$51.00
21	Extend Steel-Beam	$82.00
22	Extend Steel-Beam with Channel	$96.00

No.	Installation Cost	Cost/Unit
23	Extend Thrie-Beam	$510.00
24	Extend Concrete	$190.00
25	Remove Guide-Post	$3.00
26	Remove Three-Cable	$5.75
27	Remove Box-Beam	$17.00
28	Remove Entrance or Intersecting Roadway	$9.00
29	Remove High-Tension Cable	$8.65
30	Remove Steel-Beam	$9.25
31	Remove Steel-Beam with Channel	$12.00
32	Remove Thrie-Beam	$17.00
33	Remove Concrete	$88.00

remediationPriority

remediationPriority is a string data type representing the priority for the implementation of remediation measures and was not entered at the time of the assessment

values: high, medium, low, not applicable

Prepared by:

Jordan Frost, P.Eng.
Signature/Seal

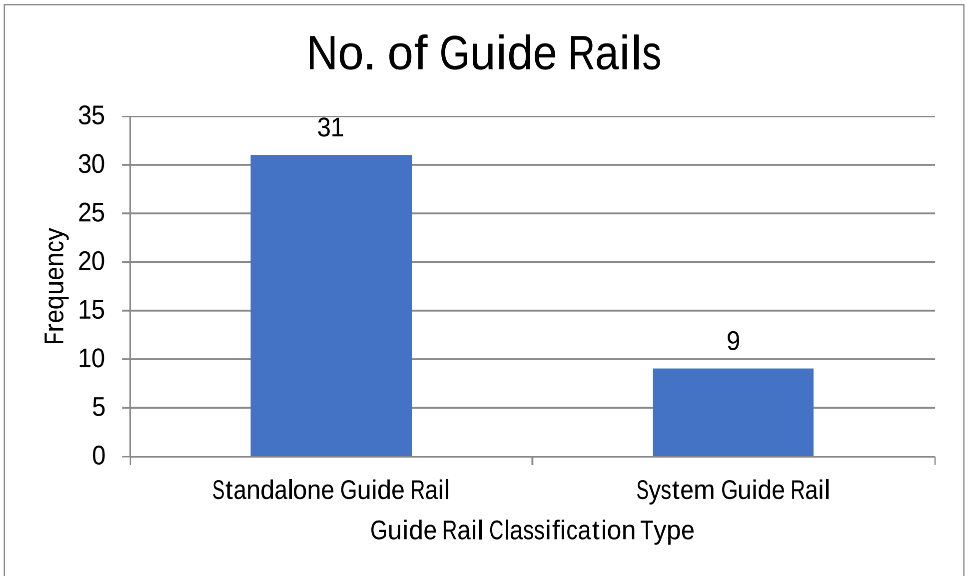
Reviewed by:

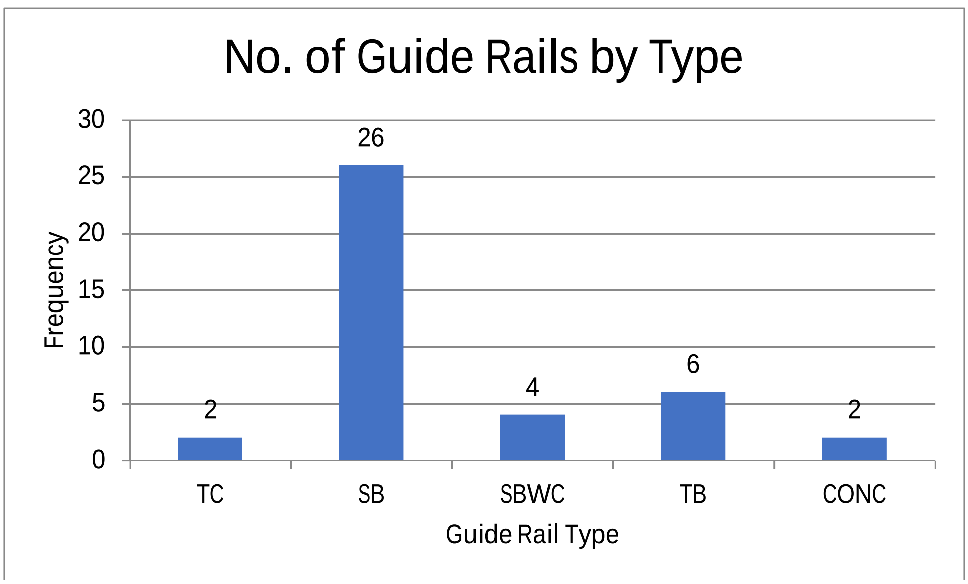
Jeff Suggett, M.Sc.
Signature

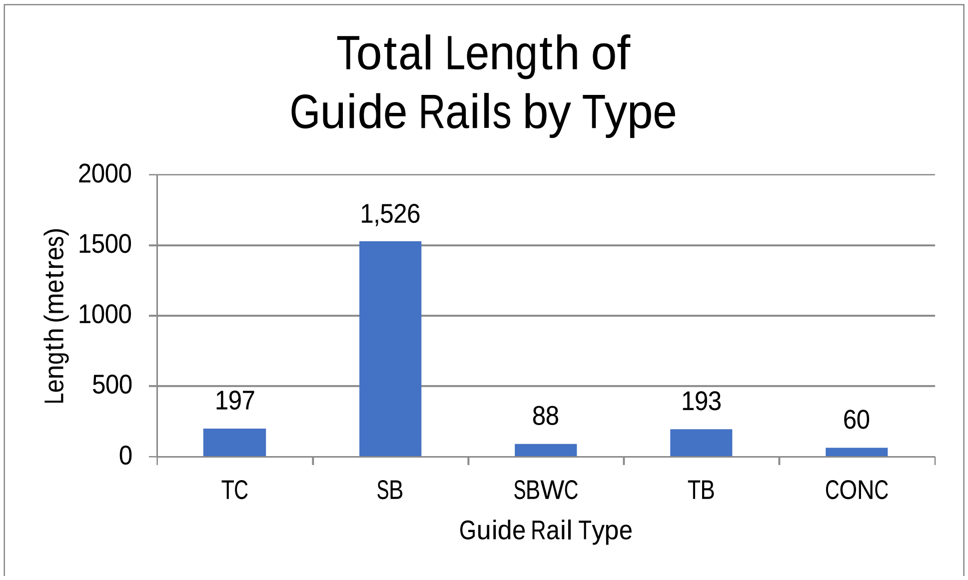
Initials

JF

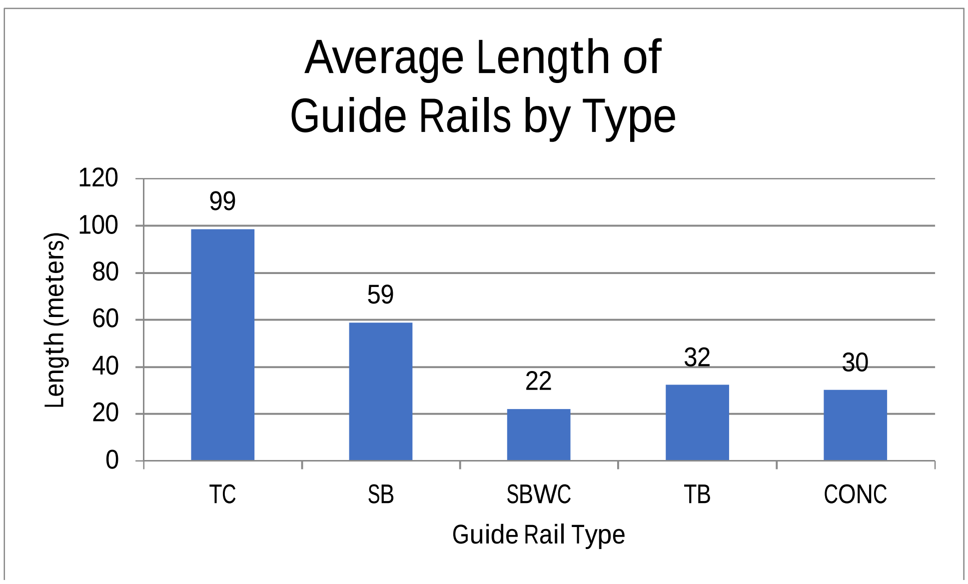
Appendix B – Inventory, and Condition and Risk Assessment Summary Charts


No. of Guide Rails
Frequency
35
30
25
20
15
10
5
0
31
9
Standalone Guide Rail
System Guide Rail
Guide Rail Classification Type

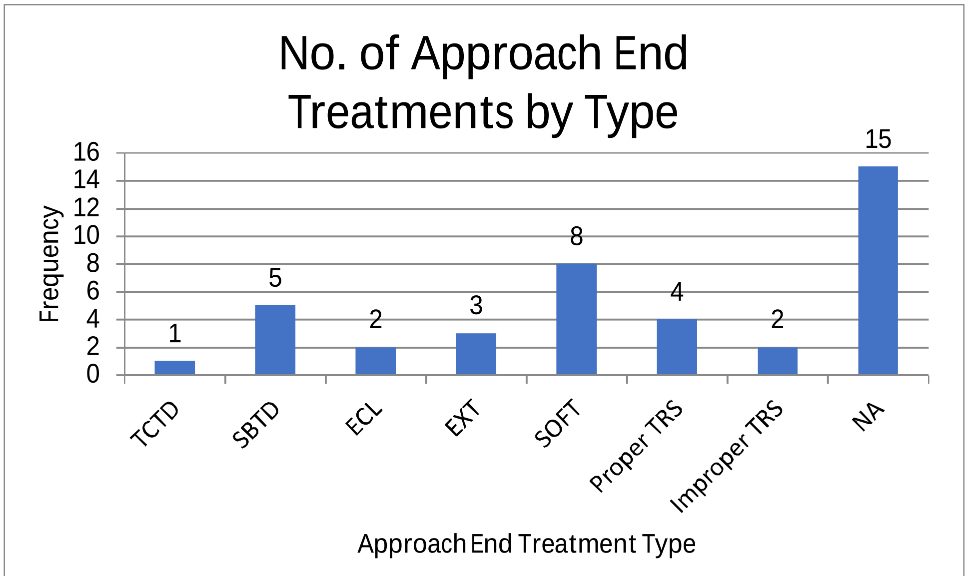

No. of Guide Rails by Type
Frequency
30
25
20
15
10
5
0
2
26
4
6
2
TC
SB
SBWC
TB
CONC
Guide Rail Type

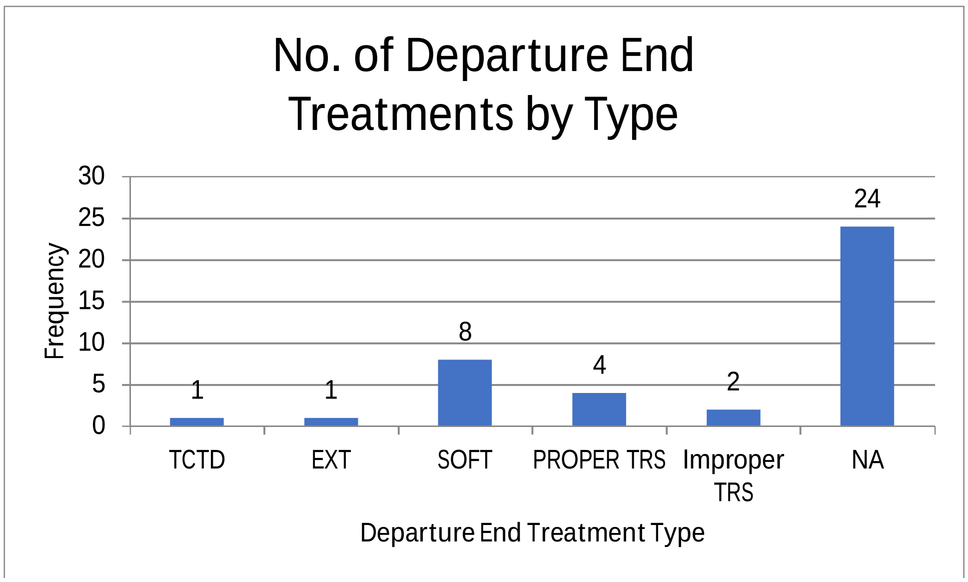


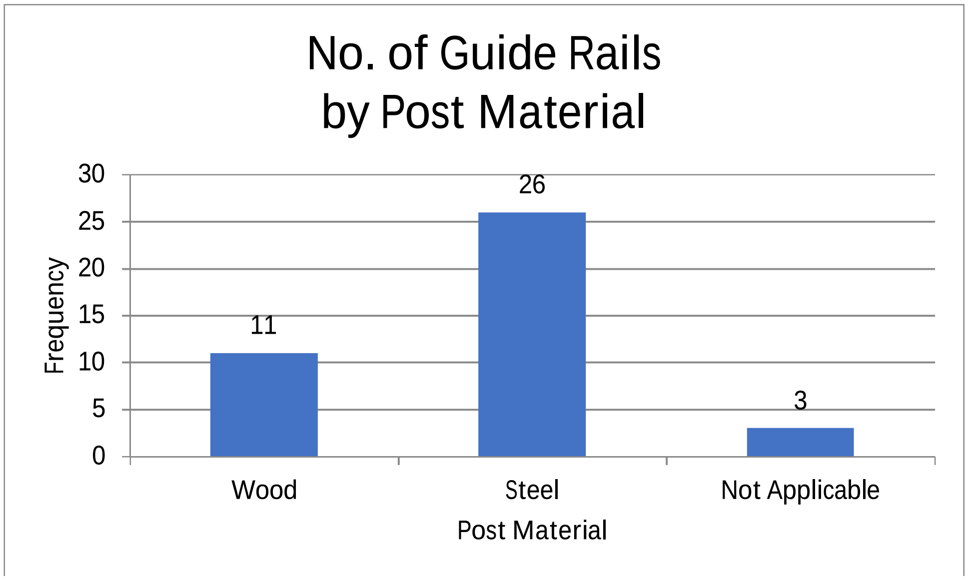
Total Length of
Guide Rails by Type
Length (metres)
2000
1500
1000
500
0
1,526
197
88
193
60
TC
SB
SBWC
TB
CONC
Guide Rail Type



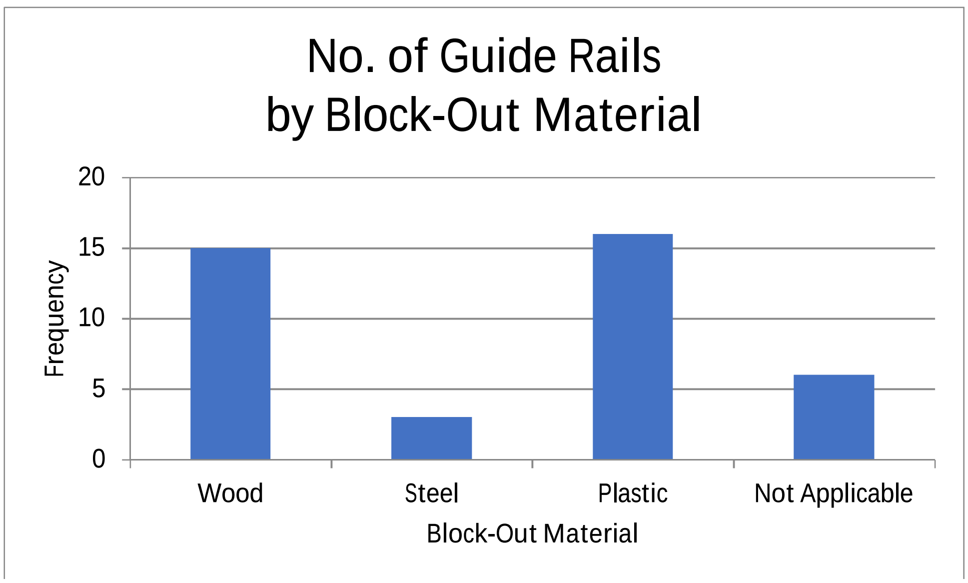
Average Length of
Guide Rails by Type
Length (meters)
120
100
80
60
40
20
0
99
59
22
32
30
TC
SB
SBWC
TB
CONC
Guide Rail Type


No. of Approach End Treatments by Type
Frequency
16
14
12
10
8
6
4
2
0
1
5
2
3
8
4
2
15
TCTD
SBTD
ECL
EXT
SOFT
Proper TRS
Improper TRS
NA
Approach End Treatment Type

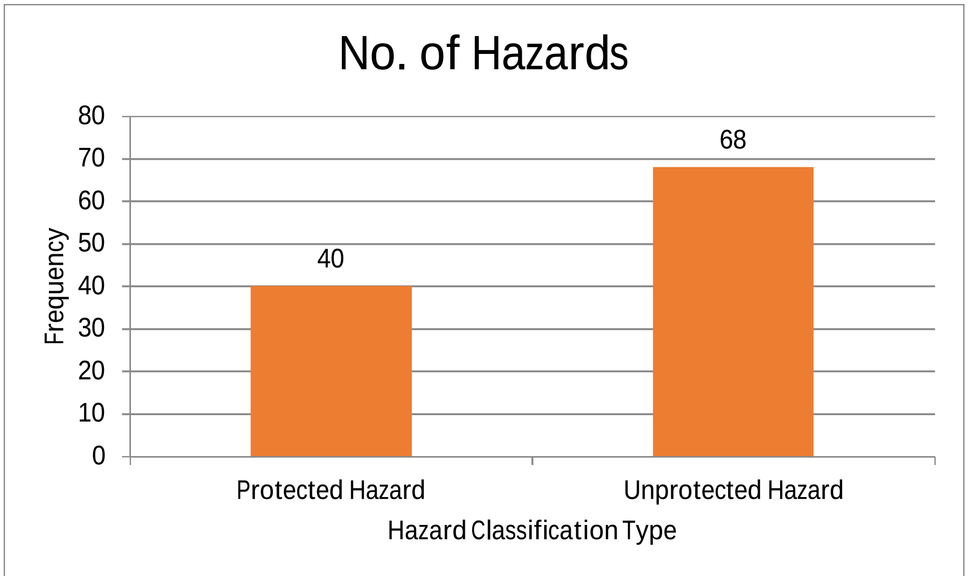

No. of Departure End Treatments by Type
Frequency
30
25
20
15
10
5
0
1
1
8
4
2
24
TCTD
EXT
SOFT
PROPER TRS
Improper TRS
NA
Departure End Treatment Type

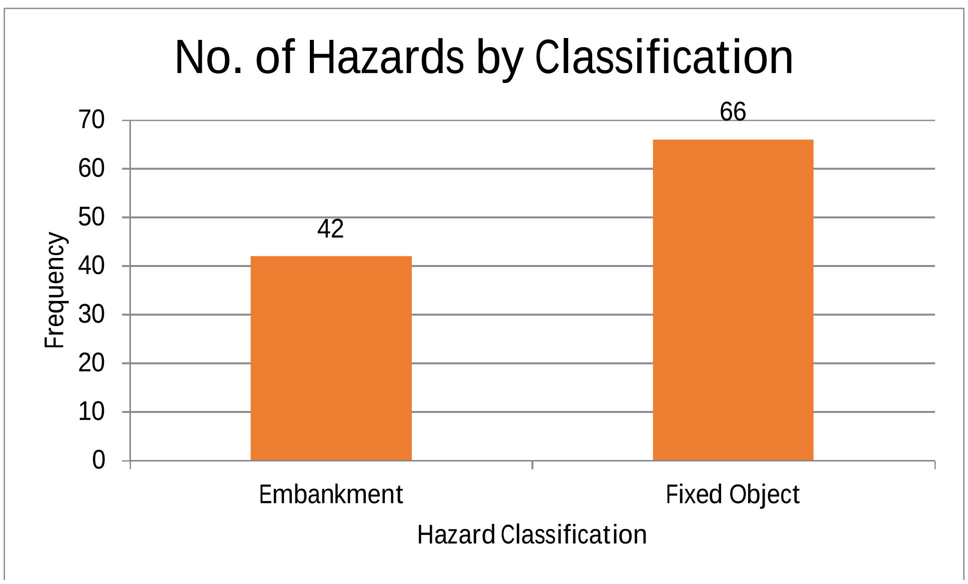


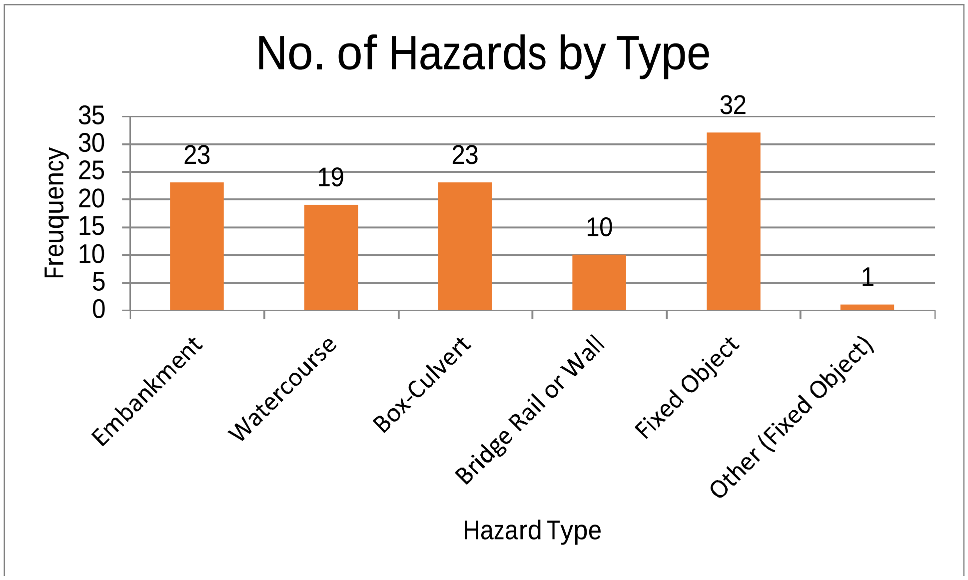
No. of Guide Rails
by Post Material
Frequency
30
25
20
15
10
5
0
26
11
3
Wood
Steel
Not Applicable
Post Material

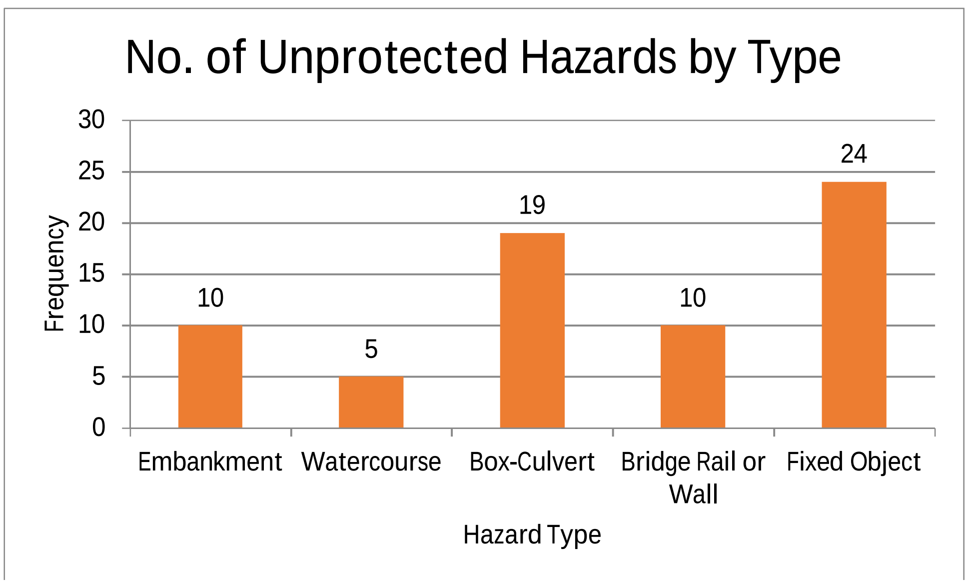


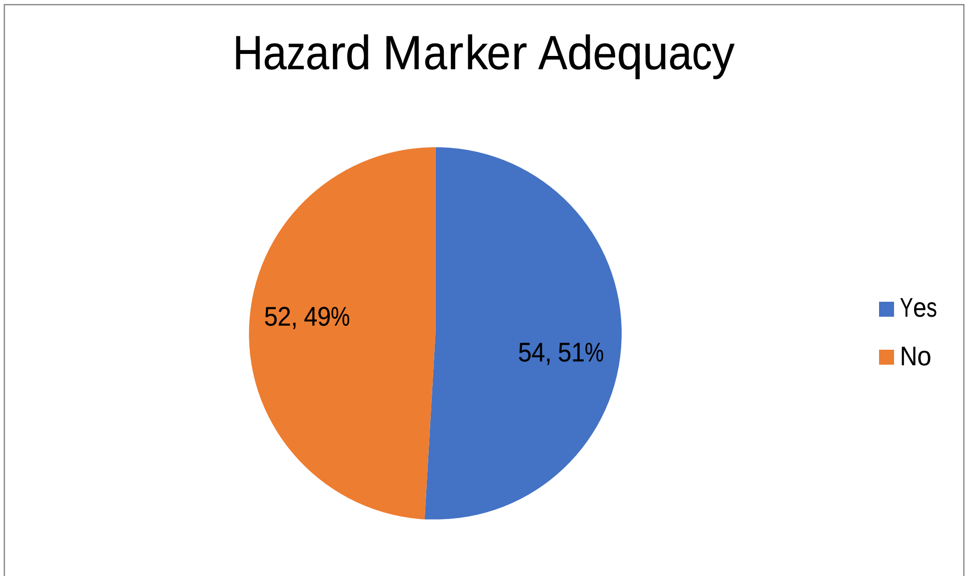
No. of Guide Rails
by Block-Out Material
Frequency
20
15
10
5
0
Wood
Steel
Plastic
Not Applicable
Block-Out Material

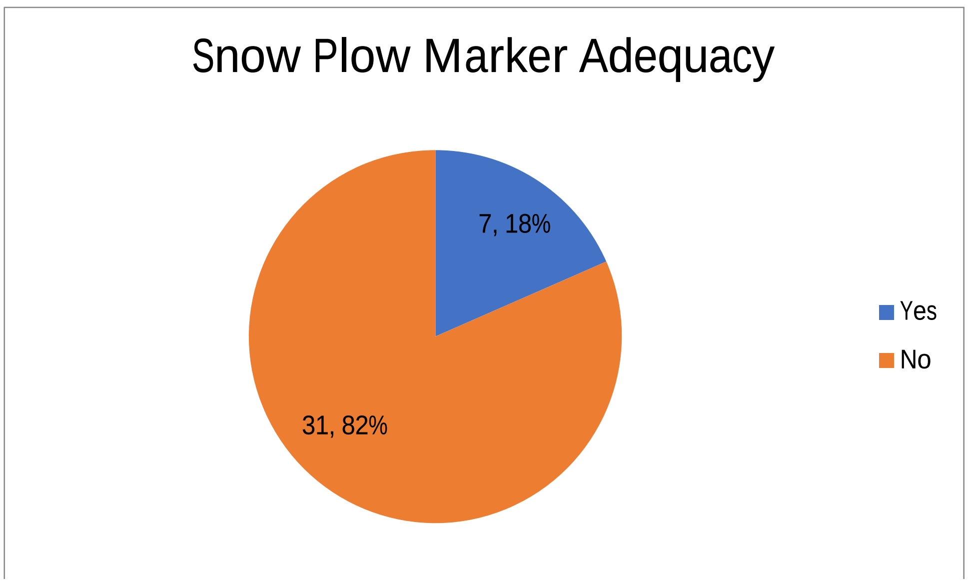

No. of Hazards
Frequency
80
70
60
50
40
30
20
10
0
40
68
Protected Hazard
Unprotected Hazard
Hazard Classification Type

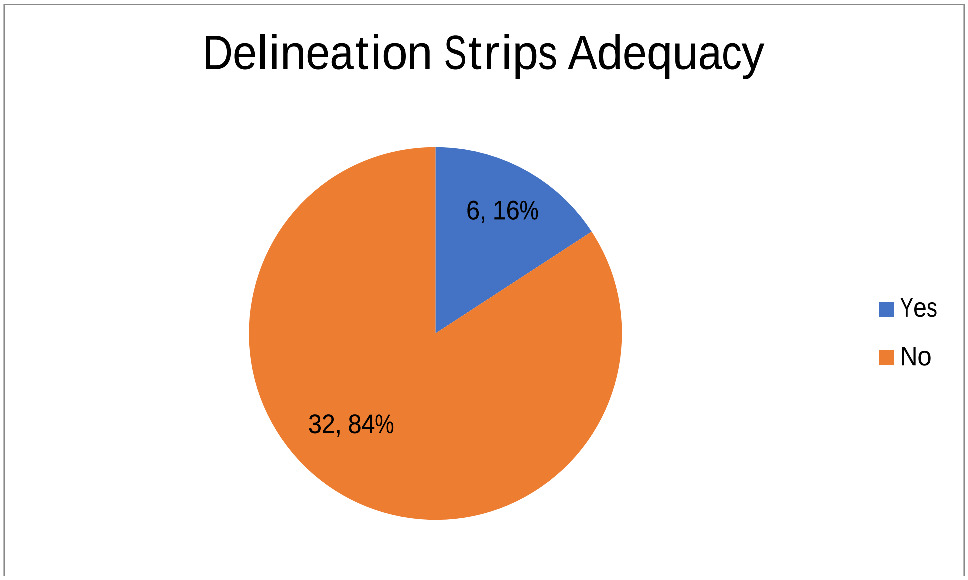

No. of Hazards by Classification
Frequency
70
60
50
40
30
20
10
0
42
66
Embankment
Fixed Object
Hazard Classification

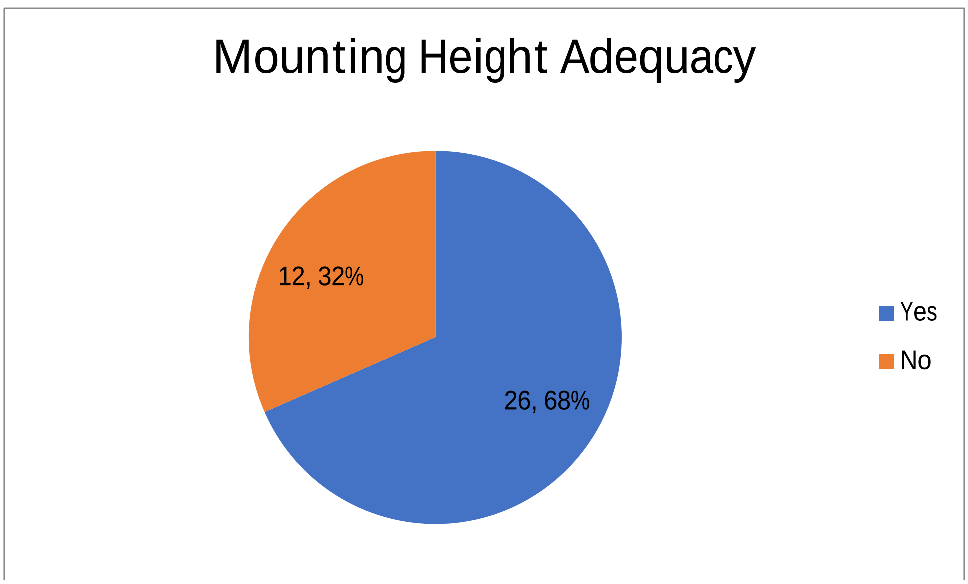

No. of Hazards by Type
Freuquency
35
30
25
20
15
10
5
0
23
19
23
10
32
1
Embankment
Watercourse
Box-Culvert
Bridge Rail or Wall
Fixed Object
Other (Fixed Object)
Hazard Type

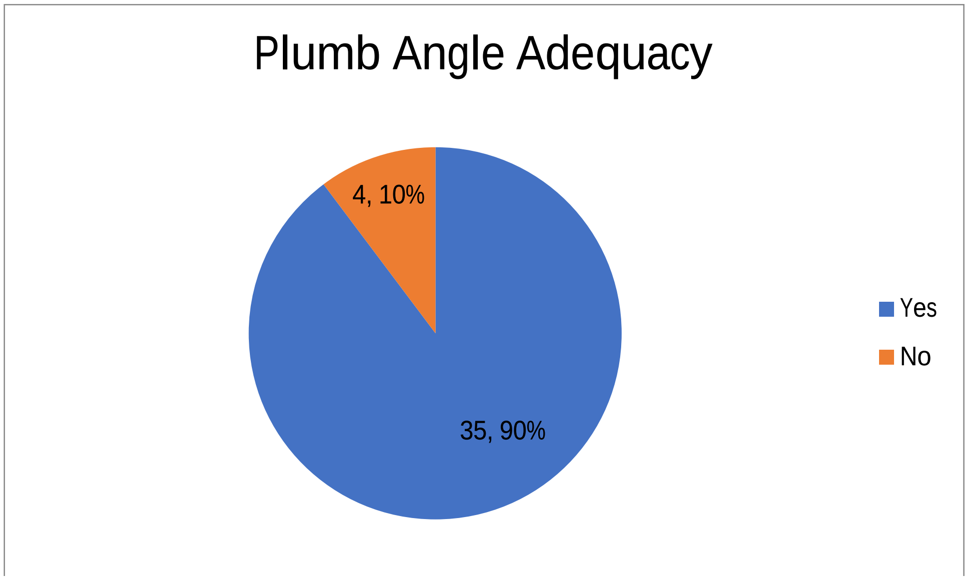

No. of Unprotected Hazards by Type
Frequency
30
25
20
15
10
5
0
10
5
19
10
24
Embankment
Watercourse
Box-Culvert
Bridge Rail or Wall
Fixed Object
Hazard Type

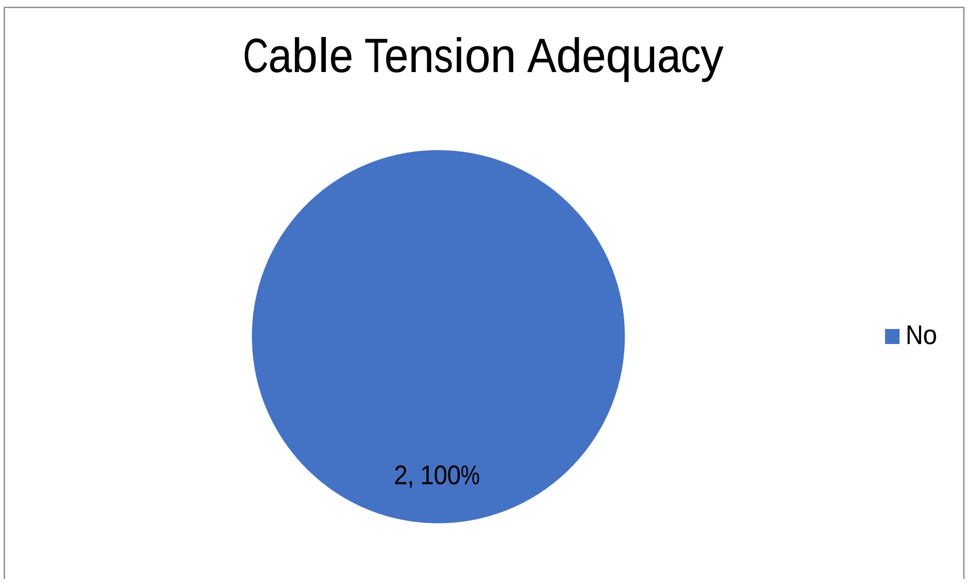

Hazard Marker Adequacy
52, 49%
54, 51%
Yes
No

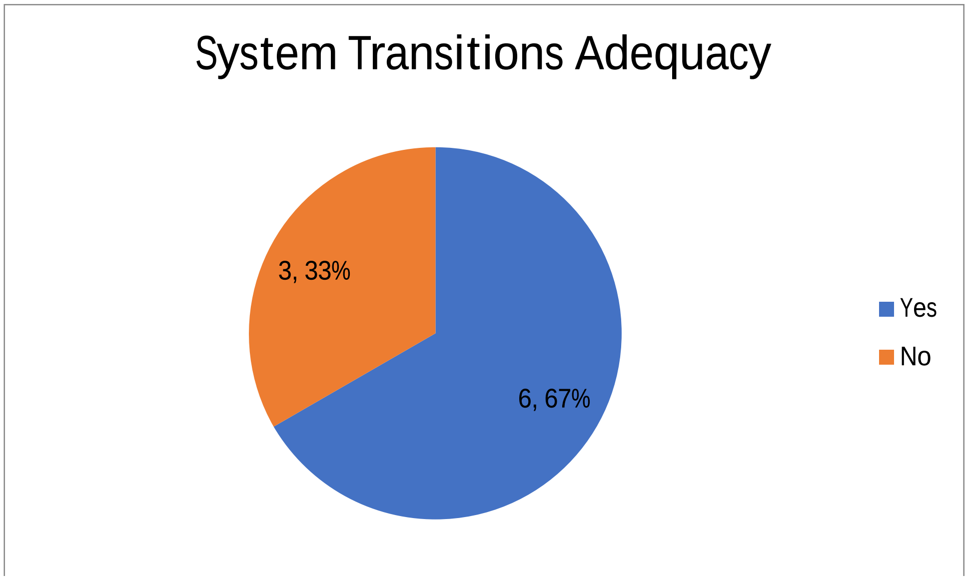

Snow Plow Marker Adequacy
7, 18%
31, 82%
Yes
No

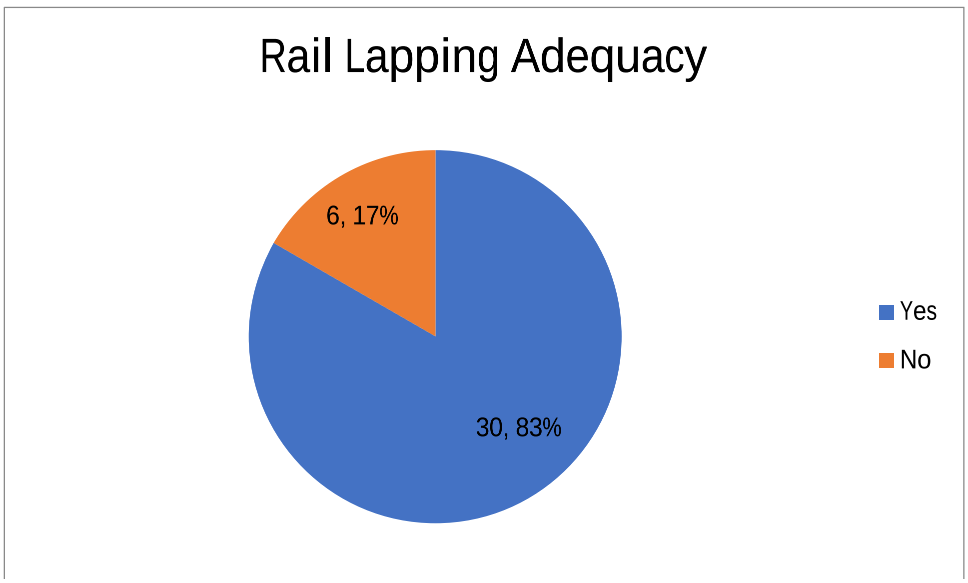

Delineation Strips Adequacy
6, 16%
32, 84%
Yes
No

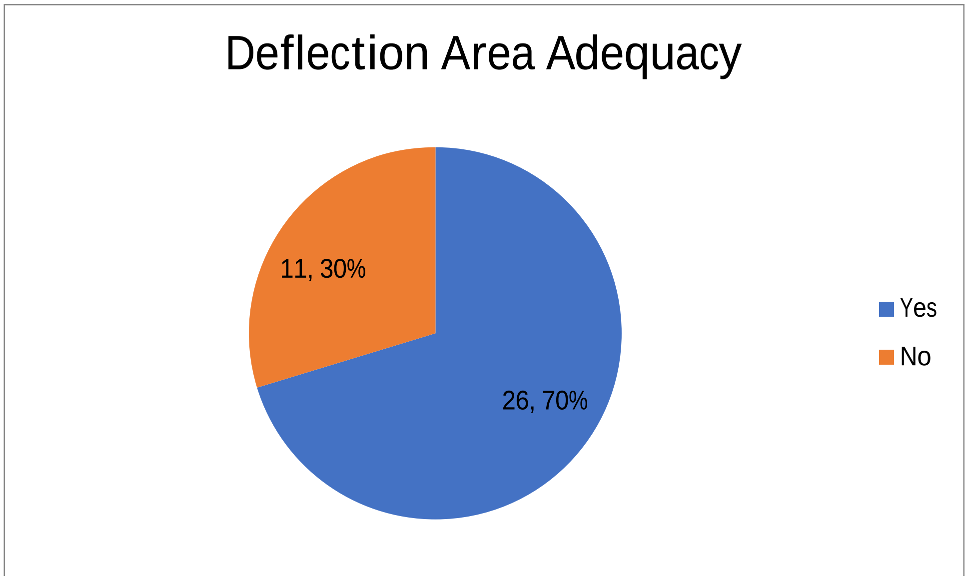

Mounting Height Adequacy
12, 32%
26, 68%
Yes
No

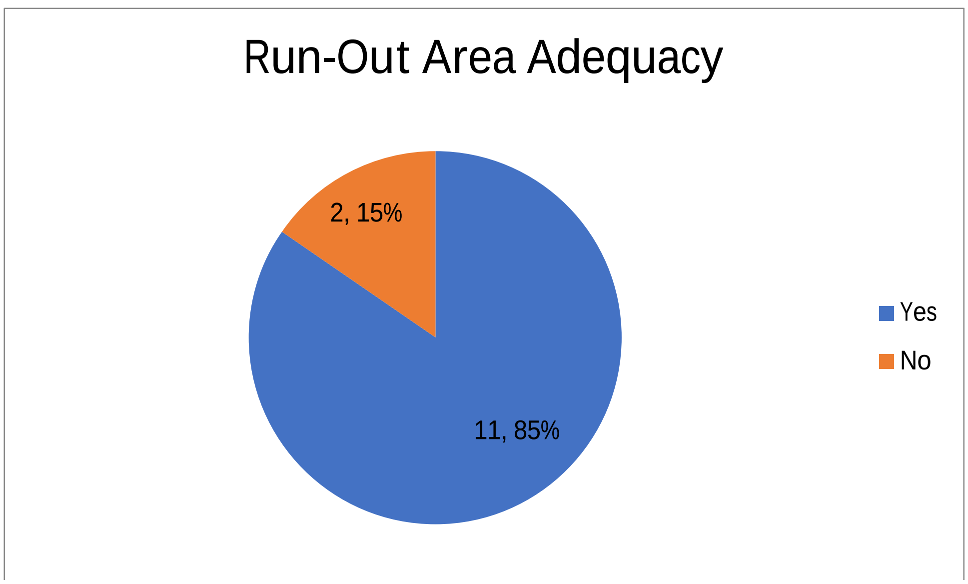

Plumb Angle Adequacy
4, 10%
35, 90%
Yes
No

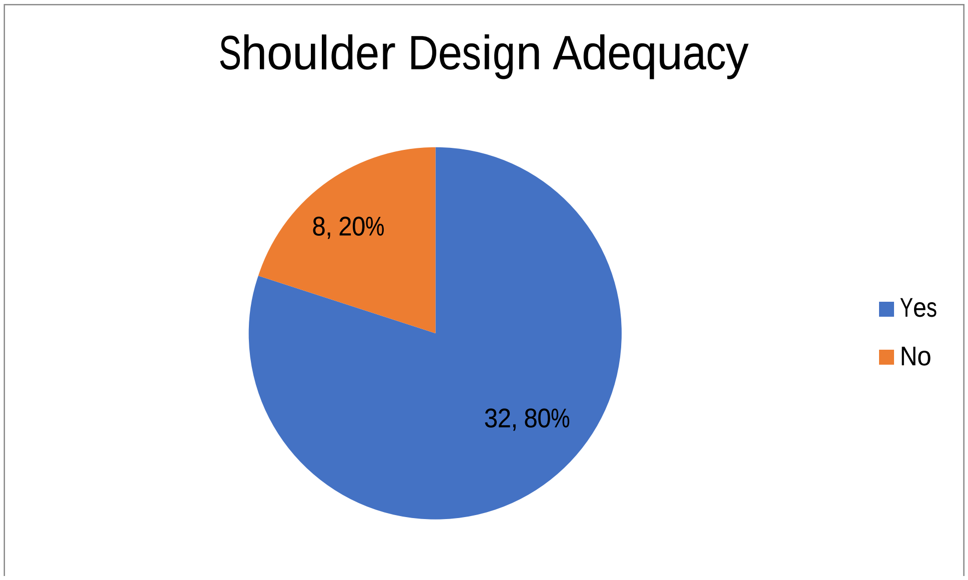

Cable Tension Adequacy
2, 100%
No

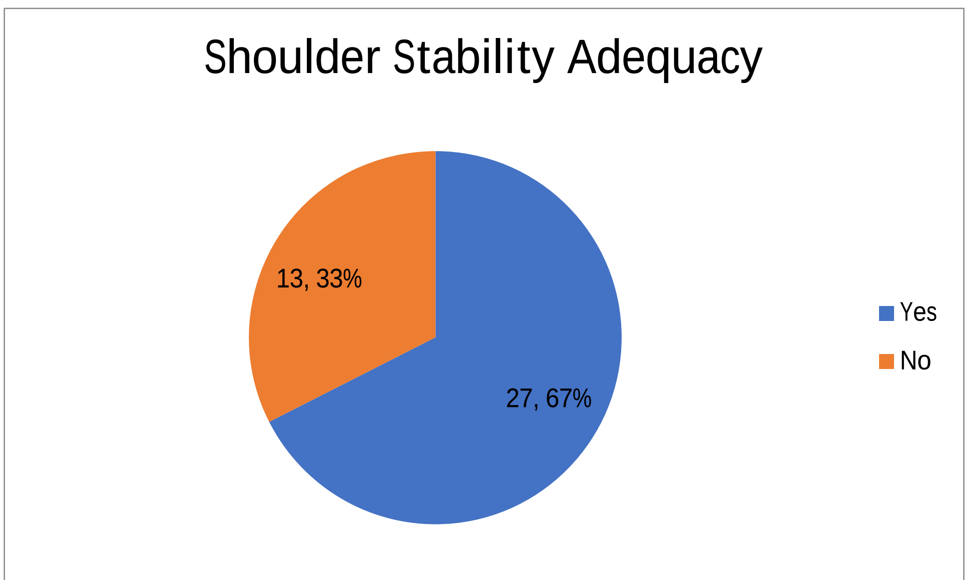

System Transitions Adequacy
3, 33%
6, 67%
Yes
No

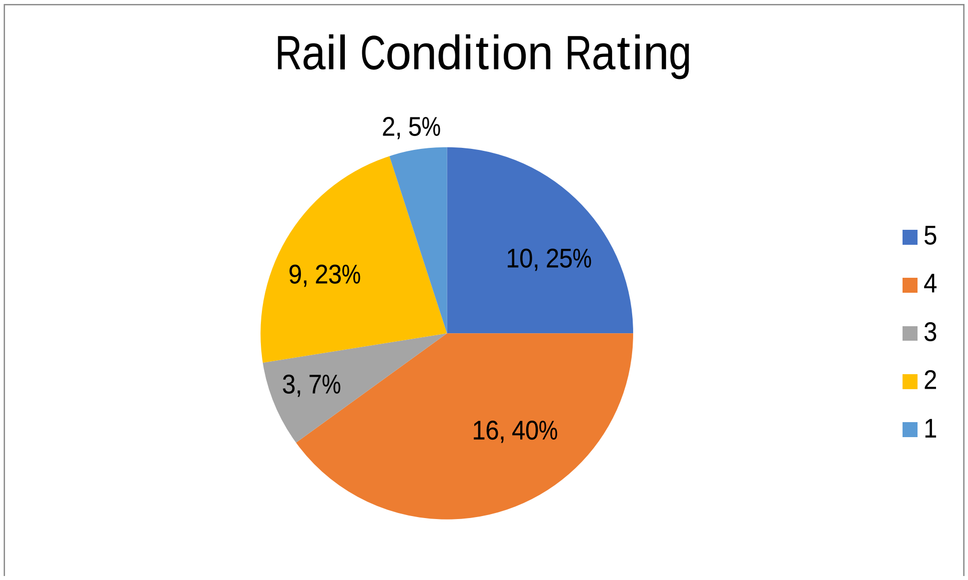

Rail Lapping Adequacy
6, 17%
30, 83%
Yes
No

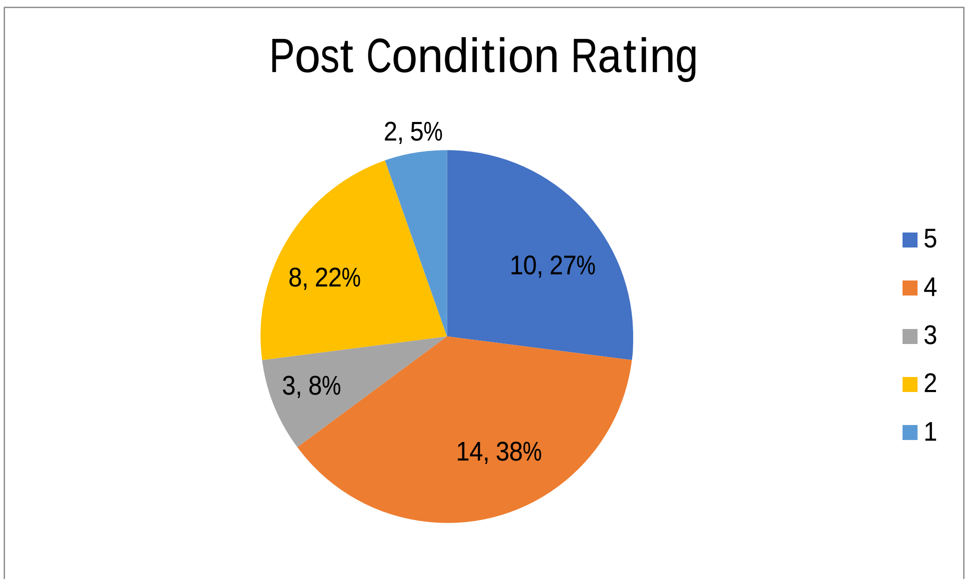

Deflection Area Adequacy
11, 30%
26, 70%
Yes
No

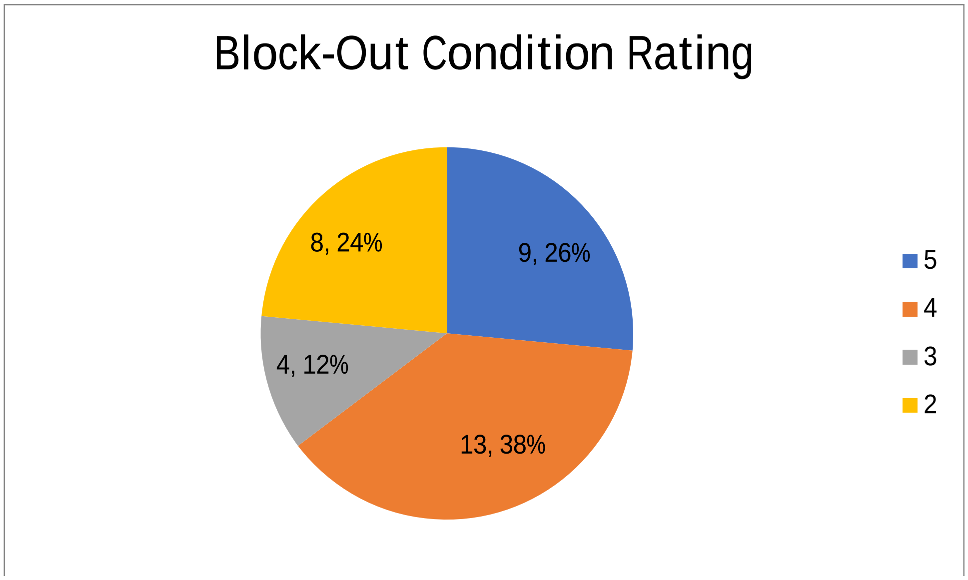

Run-Out Area Adequacy
2, 15%
11, 85%
Yes
No

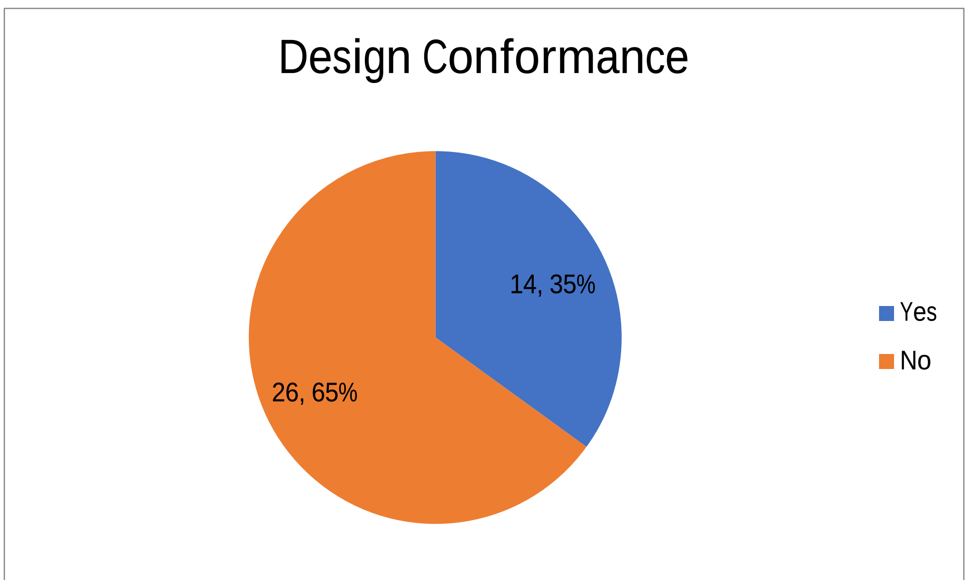

Shoulder Design Adequacy
8, 20%
32, 80%
Yes
No

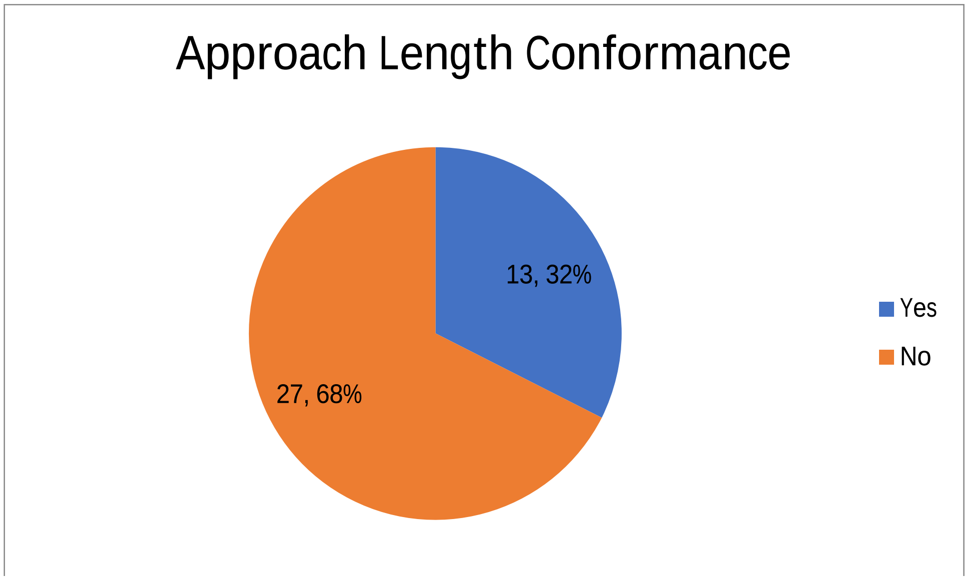

Shoulder Stability Adequacy
13, 33%
27, 67%
Yes
No

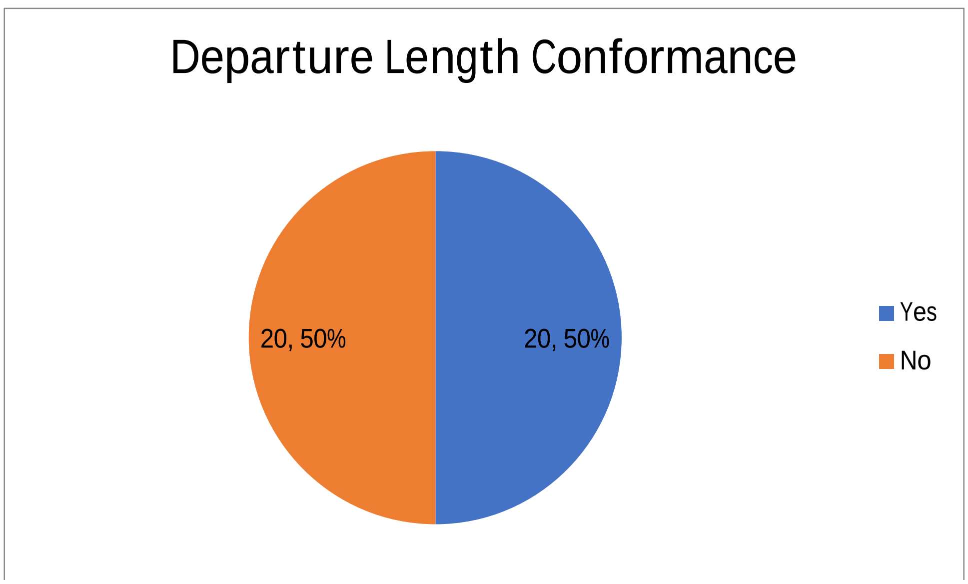

Rail Condition Rating
2, 5%
10, 25%
9, 23%
3, 7%
16, 40%
5
4
3
2
1

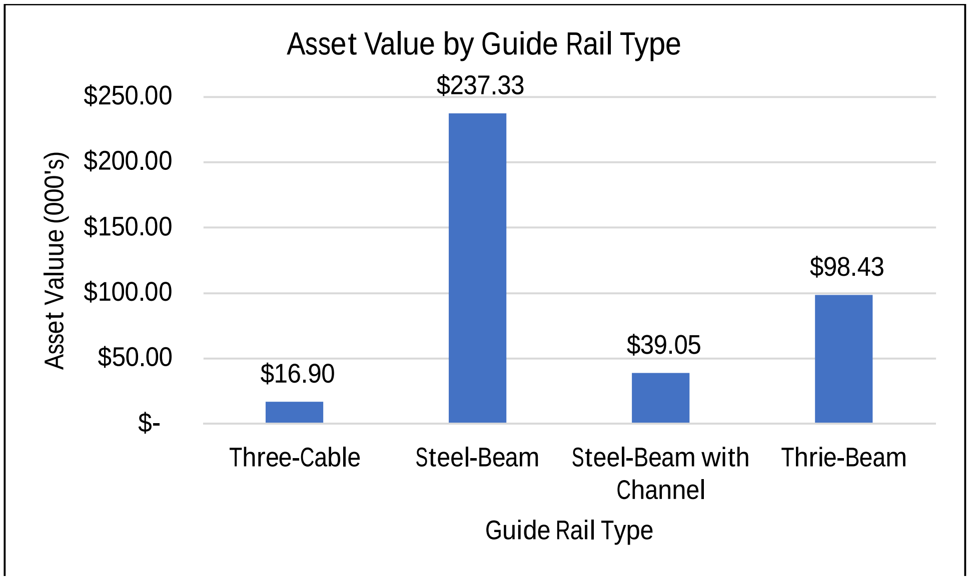

Post Condition Rating
2, 5%
10, 27%
8, 22%
3, 8%
14, 38%
5
4
3
2
1

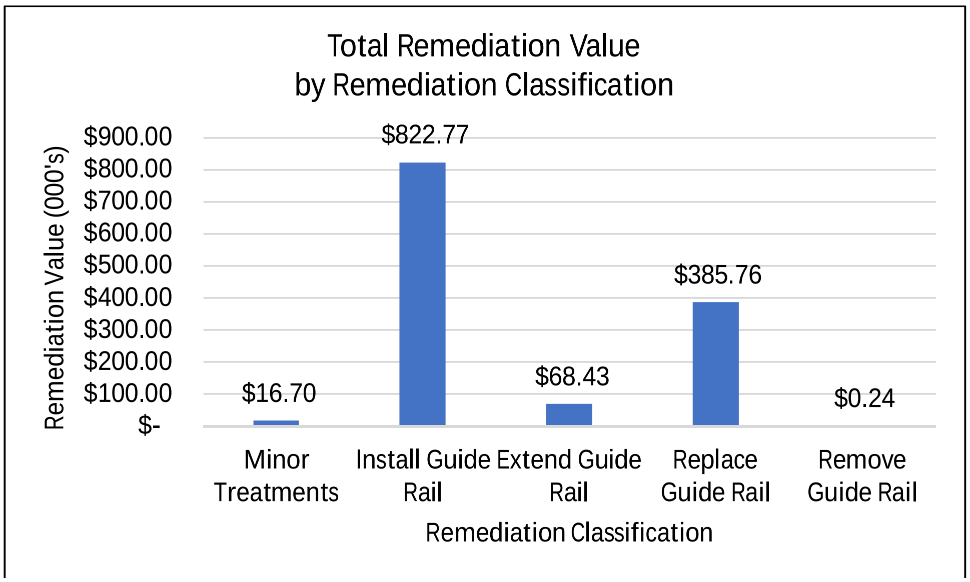

Block-Out Condition Rating
8, 24%
9, 26%
4, 12%
13, 38%
5
4
3
2

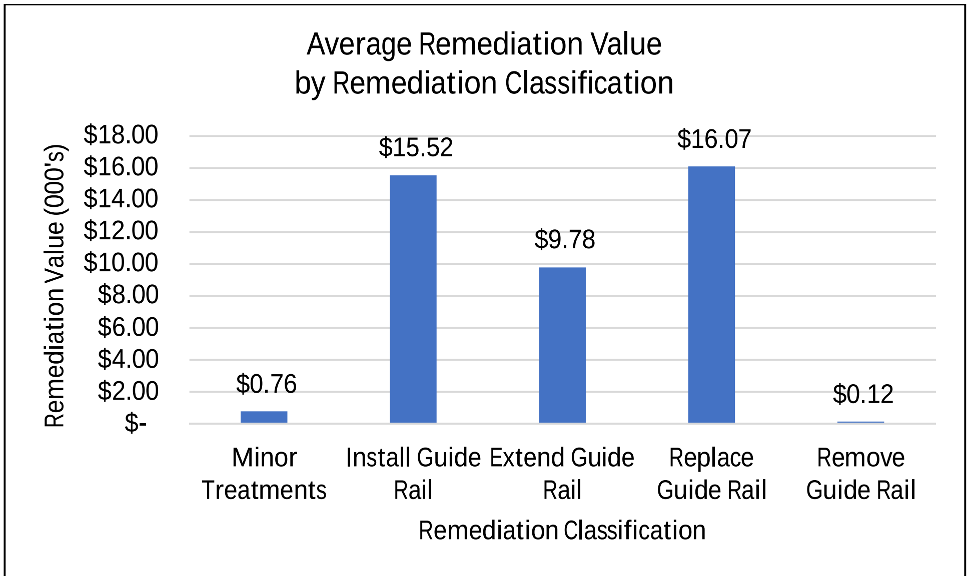

Design Conformance
14, 35%
26, 65%
Yes
No

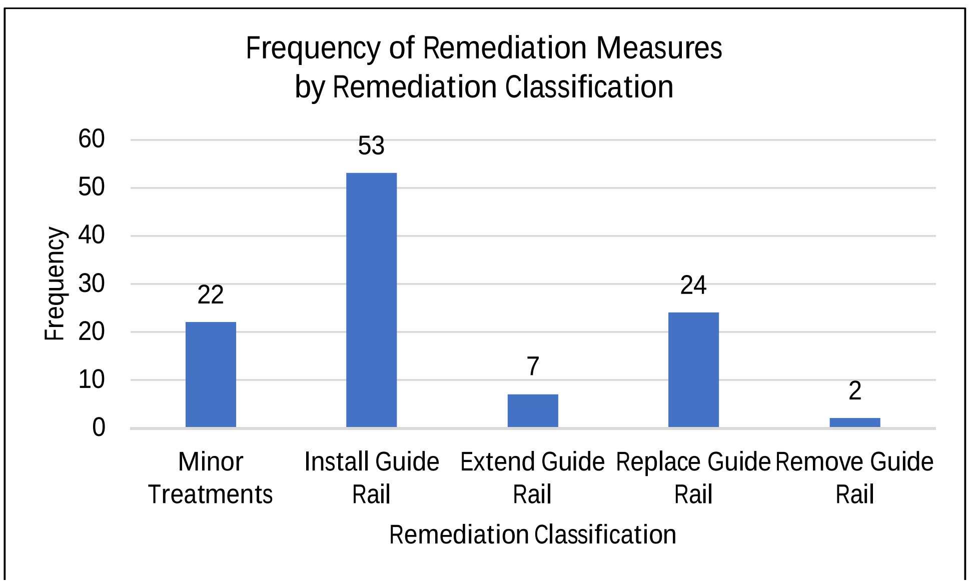

Approach Length Conformance
13, 32%
27, 68%
Yes
No

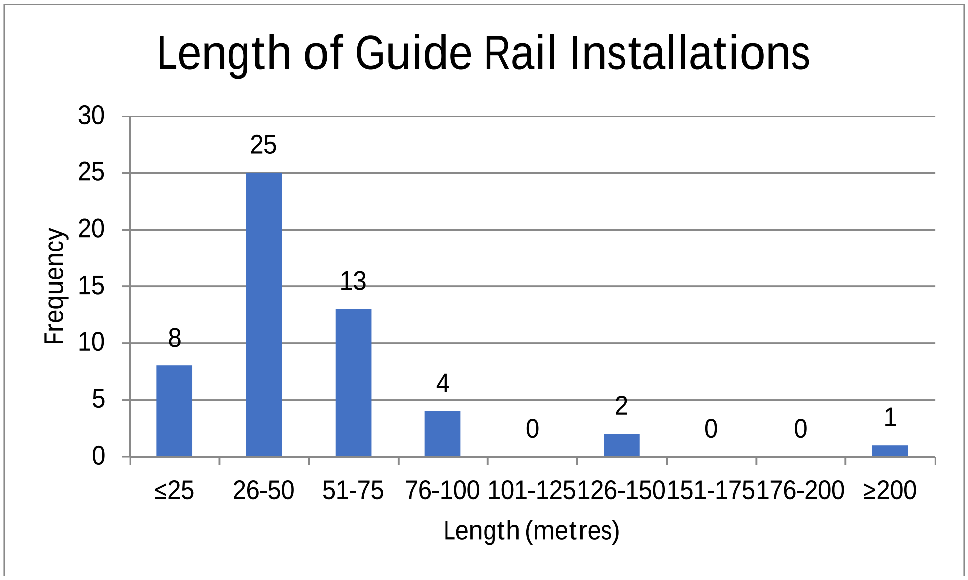

Departure Length Conformance
20, 50%
20, 50%
Yes
No

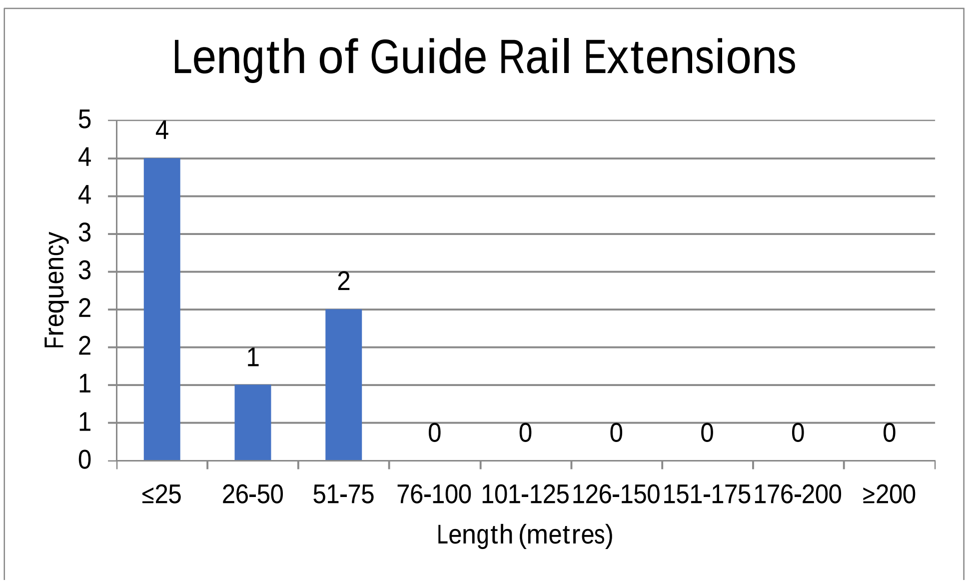

Asset Value by Guide Rail Type
Asset Valuue (000's)
$250.00
$200.00
$150.00
$100.00
$50.00
$-
$16.90
$237.33
$39.05
$98.43
Three-Cable
Steel-Beam
Steel-Beam with Channel
Thrie-Beam
Guide Rail Type

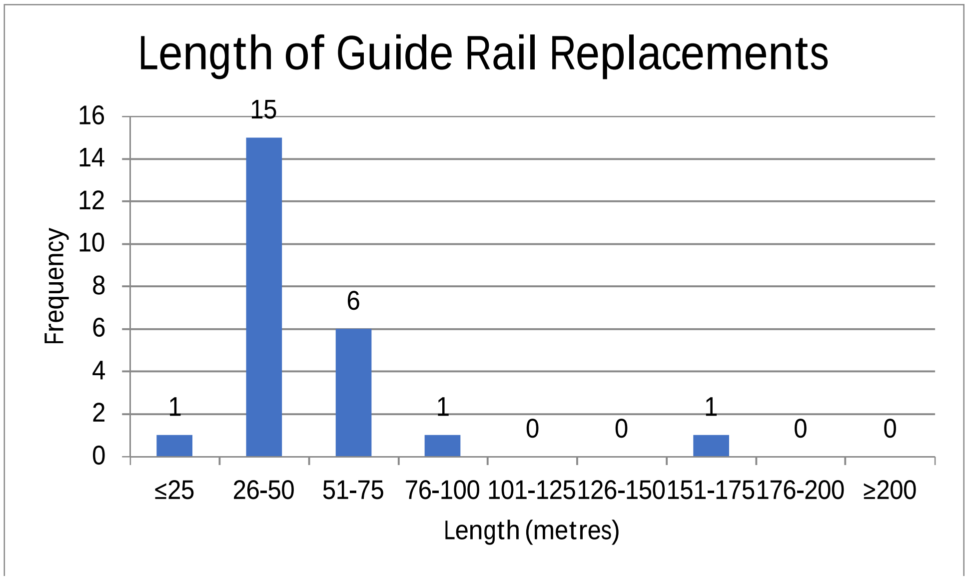

Total Remediation Value by Remediation Classification
Remediation Value (000's)
$900.00
$800.00
$700.00
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$-
$16.70
$822.77
$68.43
$385.76
$0.24
Minor Treatments
Install Guide Rail
Extend Guide Rail
Replace Guide Rail
Remove Guide Rail
Remediation Classification


Average Remediation Value
by Remediation Classification
Remediation Value (000's)
$18.00
$16.00
$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$-
$0.76
$15.52
$9.78
$16.07
$0.12
Minor Treatments
Install Guide Rail
Extend Guide Rail
Replace Guide Rail
Remove Guide Rail
Remediation Classification

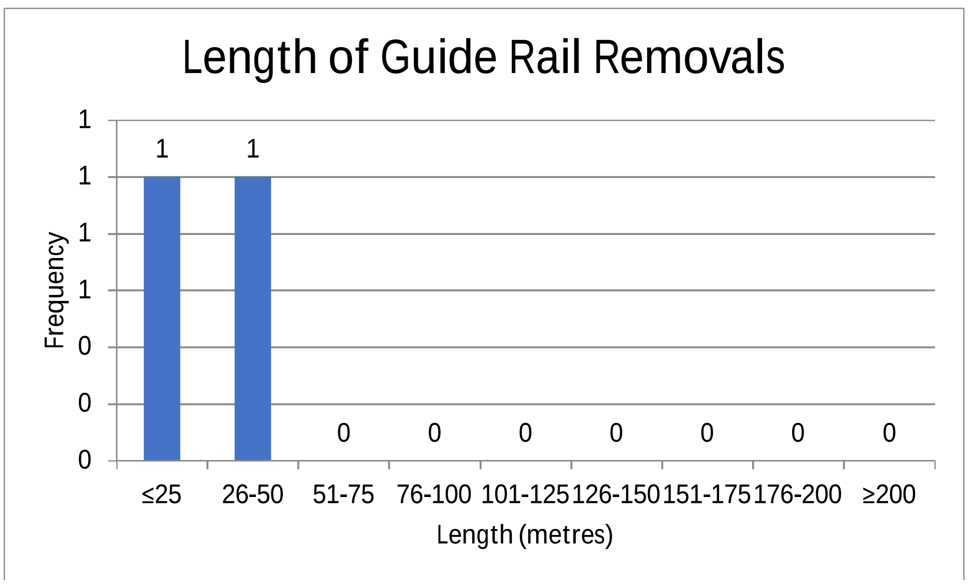

Frequency of Remediation Measures
by Remediation Classification
Frequency
60
50
40
30
20
10
0
22
53
7
24
2
Minor Treatments
Install Guide Rail
Extend Guide Rail
Replace Guide Rail
Remove Guide Rail
Remediation Classification


Length of Guide Rail Installations
Frequency
30
25
20
15
10
5
0
8
25
13
4
0
2
0
0
1
≤25
26-50
51-75
76-100
101-125
126-150
151-175
176-200
≥200
Length (metres)

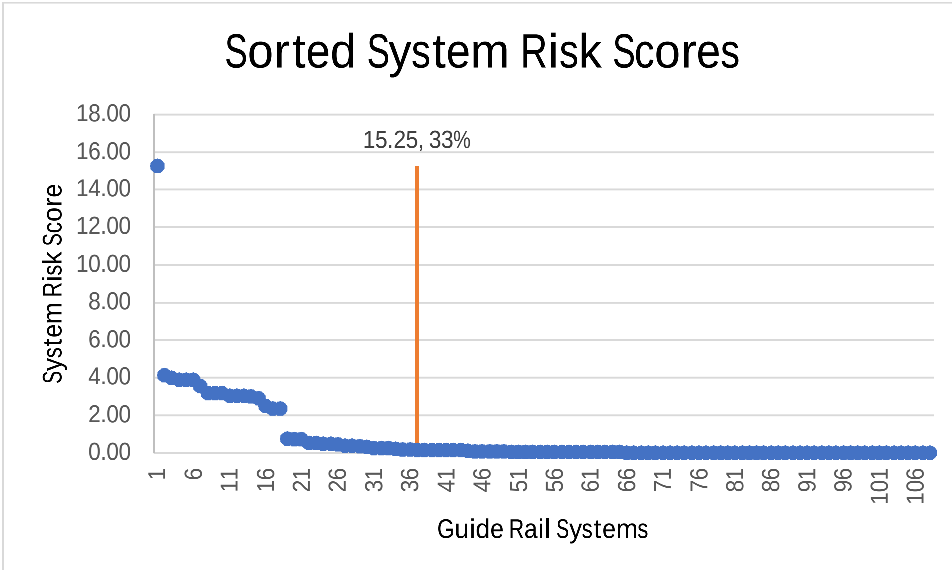

Length of Guide Rail Extensions
Frequency
5
4
4
3
3
2
2
1
1
0
4
1
2
0
0
0
0
0
0
≤25
26-50
51-75
76-100
101-125
126-150
151-175
176-200
≥200
Length (metres)



Length of Guide Rail Replacements
Frequency
0
2
4
6
8
10
12
14
16
1
15
6
1
0
0
1
0
0
≤25
26-50
51-75
76-100
101-125
126-150
151-175
176-200
≥200
Length (metres)

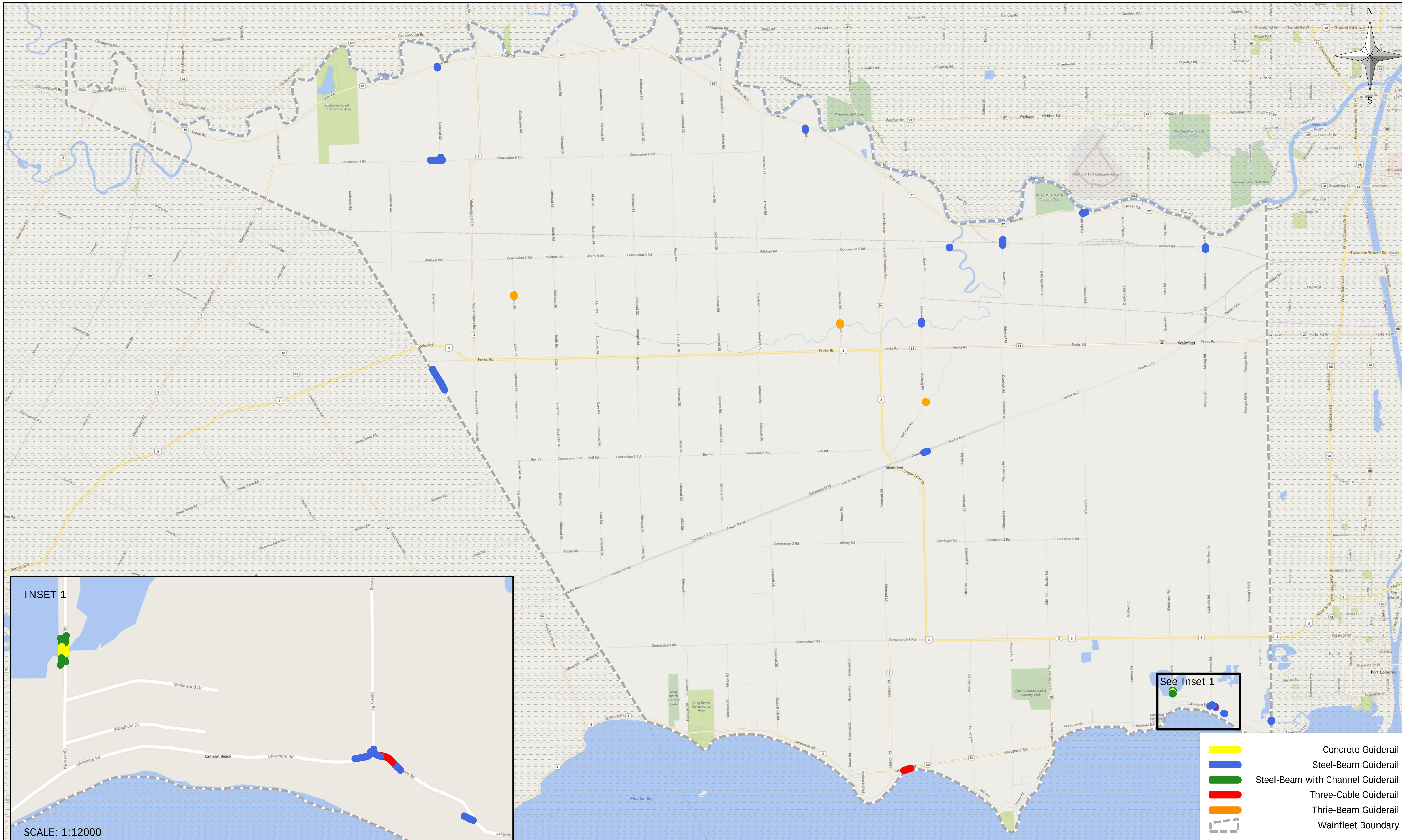


Length of Guide Rail Removals
Frequency
0
0
0
1
1
1
1
1
1
0
0
0
0
0
0
0
≤25
26-50
51-75
76-100
101-125
126-150
151-175
176-200
≥200
Length (metres)



Sorted System Risk Scores
15.25, 33%
System Risk Score
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
Guide Rail Systems

Appendix C – Inventory, and Condition and Risk Assessment Map Data



No.	REVISION	DATE

(Name) (Date)
(Name) (Date)
(Name) (Date)

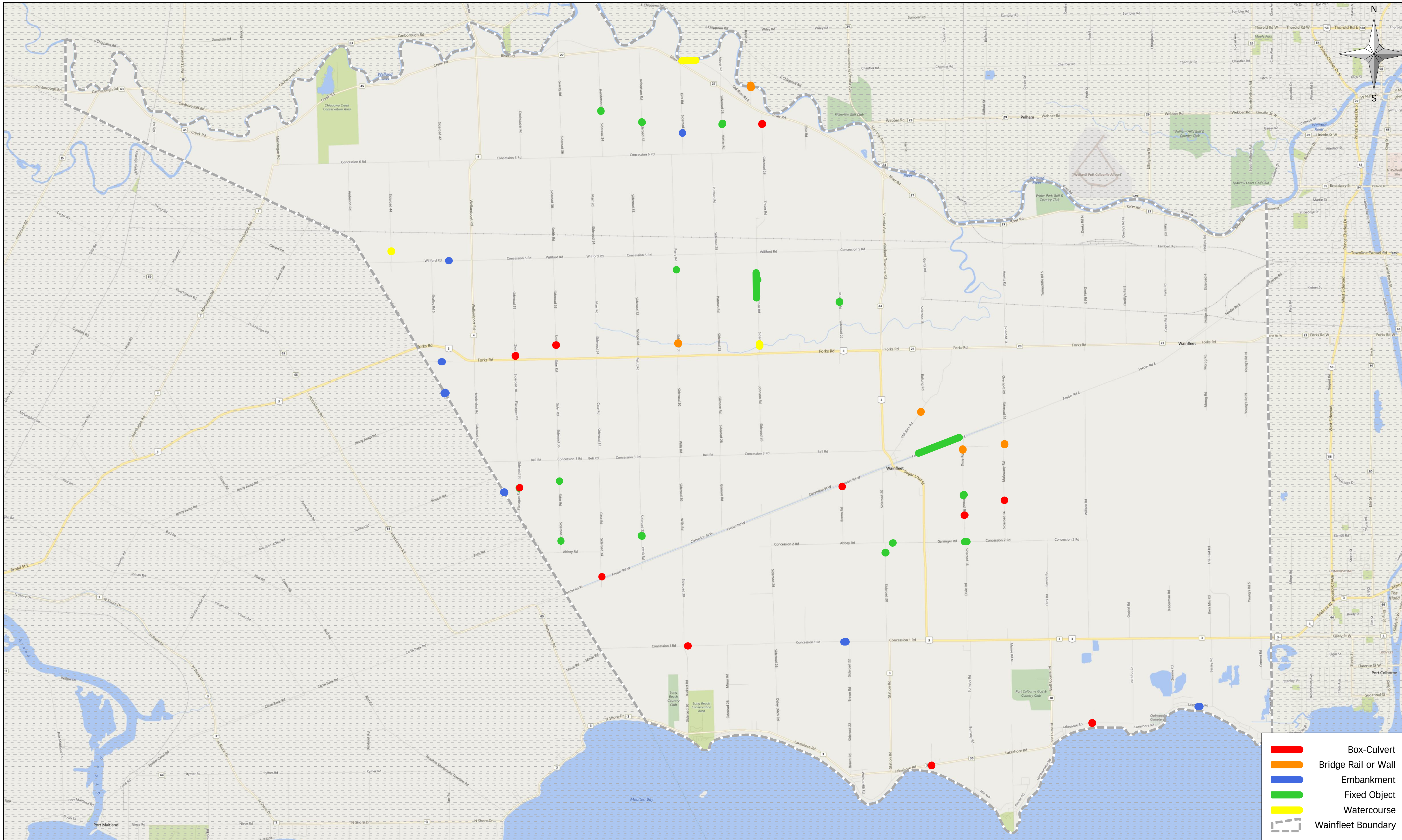
PROJECTION: Mercator, World Geodetic 1984 (WGS84) Auto
PRINTED ON: 7/21/2017
USER: mooradianl
NAME: map_20175109-00_wainfleet_road_needs_assessment_

Associated Engineering

LOCATION OF GUIDERAILS BY GUIDERAIL TYPE

TOWNSHIP OF WAINFLEET
ROADSIDE SAFETY STUDY

PROJECT No.: 2017-5109
DATE: JULY 2017
SCALE: 1:95000



No.	REVISION	DATE

(Name) (Date)

(Name) (Date)

(Name) (Date)

PROJECTION: Mercator, World Geodetic 1984 (WGS84) Auto
PRINTED ON: 7/21/2017
USER: mooradianl
FILE: map_20175109-00_wainfleet_road_needs_assessment_201

Associated Engineering

WAINFLEET

LOCATION OF HAZARDS BY HAZARD TYPE

TOWNSHIP OF WAINFLEET
ROADSIDE SAFETY STUDY

PROJECT No.: 2017-5109

DATE: JULY 2017

SCALE: 1:95000