Estimating Annual Average Daily Traffic (AADT) from Short-Duration Counts in Towns

By

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ABSTRACT

Traffic volume data, commonly summarized as annual average daily traffic (AADT), is a fundamental input for transportation engineering decisions. Current traffic monitoring guidance provides insufficient detail on the development of AADT estimates from short-duration counts conducted within towns. This is due to limited knowledge of the attributes that characterize a town count and uncertainty about the temporal factors required to estimate AADT from short-duration town count data.

This research addressed these gaps by using a decision algorithm and GIS analysis to identify which short-duration counts should be considered town counts and by developing and validating a methodology to estimate AADT from short-duration town count data. The analysis demonstrated that temporal factors generated from continuous counts conducted near towns could be reliably applied to short-duration town count data. This finding enables traffic monitoring authorities to leverage existing data and methods to improve the representativeness of traffic volume estimates in towns.

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DEDICATION

To my loving and encouraging parents, Darlah and David.

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GLOSSARY OF TERMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
CSD	Census Subdivision Boundary
DLP	Census Designated Place Boundary
DOT	Department of Transportation
DOW	Day of Week
FHWA	Federal Highway Administration
GIS	Geographic Information System
LUD	Local Urban District
MHTIS	Manitoba Highway Traffic Information System
MI	Manitoba Infrastructure
MM	Manitoba Municipal Boundary
MPO	Metropolitan Planning Organisation
PAR	Provincial Access Road
PC	Census Population Centre Boundary
PR	Provincial Road
PTH	Provincial Trunk Highway
TAC	Transportation Association of Canada
TMG	The FHWA's Traffic Monitoring Guide
TPG	Traffic Pattern Group
UUC	Unincorporated Urban Centre
VKT	Vehicle Kilometres Travelled

1 INTRODUCTION

1.1 PURPOSE

The purpose of this research is to develop and validate a methodology to estimate

annual average daily traffic (AADT) from short-duration traffic counts conducted in

towns. AADT is defined as the number of vehicles passing a site on a roadway on an

average day of the year. It is a fundamental input to innumerable transportation

planning, design, operations, and management decisions.

Despite the need for AADT estimates in towns and the availability of traffic volume data,

traffic monitoring agencies do not routinely convert these short-duration counts into

AADT estimates. This shortcoming has arisen principally because: (1) interrupted traffic

flow conditions in towns make site selection challenging, considering existing equipment

capabilities; and (2) there is a lack of reliable methods to adjust (or factor) short-duration

counts to account for known traffic periodicities. Additionally, town boundaries and

demographics are dynamic; therefore, traffic monitoring programs need to evolve with

the towns. The methodology developed and validated in this research facilitates the

estimation of AADT from short-duration traffic volume data collected in towns and

enables traffic monitoring agencies to better represent traffic activity at those locations.

1.2 BACKGROUND AND NEED

Traffic data plays a fundamental role in transportation related decisions, so developing

and improving traffic monitoring programs is a crucial activity, most commonly

undertaken by public transportation agencies. Traffic monitoring has existed in some

form since the 1930's and by the 1950's annual traffic summary statistics were being

produced (Albright, 1991b). At that time, traffic monitoring was often a result of

independent activity because national traffic monitoring standards and guidelines did not

yet exist. This resulted in data that lacked consistency and comparability (Albright, 1991a). By the mid 1980's the Federal Highway Administration (FHWA) developed North America's first traffic monitoring guide, commonly known as the *TMG*. Guidance documents like this, provide information to ensure traffic monitoring data and the decisions it supports are reliable.

In general, traffic monitoring programs describe the use and performance of public roadway systems by providing information such as vehicle volume, vehicle classification, vehicle and axle weight, and speed (FHWA, 2016; Regehr et al., 2017; Vandervalk-Ostrander et al., 2009). The public sector, private sector, researchers, and even the general public require this traffic data for a variety of purposes (Vandervalk-Ostrander *et al.*, 2009). Some common data customers include government agencies, consulting engineers, journalists, realtors, and land developers.

Traffic volume data are often the most valued outputs of a traffic monitoring program (FHWA, 2016). For example, this information is used to evaluate transportation infrastructure management needs (Vandervalk-Ostrander *et al.*, 2009), as well as to estimate vehicle kilometres travelled (VKT), which is a necessary input to determine crash rates and environmental impacts (Apronti *et al.*, 2016). In particular, AADT, which quantifies the number of vehicles expected to use a facility on an average day of the year, is the most commonly used traffic volume statistic (Regehr *et al.*, 2017). Milligan et al. (2016) state that the quality of AADT estimates has considerable implications on traffic safety, pavement design, and trend analyses. As a result, traffic monitoring programs aim to produce reliable AADT estimates for all roadways within a transportation network.

However, determining AADT across an entire roadway network is a complex activity and poses many challenges. A particular challenge is the inability to produce reliable AADT

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estimates from short-duration counts that occur on urban roadways (Weijermars, 2007; Hernandez, 2012; Milligan *et al.*, 2016; Regehr *et al.*, 2017), including those within towns. Due to the challenges associated with producing AADT estimates, some jurisdictions, including Manitoba, instead report average daily traffic (ADT), from the data collected by short-duration counts in towns (Olfert *et al.*, 2020). Simply, ADT identifies the number of vehicles that were observed throughout the period of the short-duration count. And although knowledge of ADT is more valuable than no data at all, the downfall of ADT is that it does not account for the seasonal or day-of-week (DOW) temporal variations that are known to exist in traffic volume datasets (FHWA, 2016). Consequently, using ADT in place of AADT could result in either overestimating or underestimating the number of vehicles that use a facility on a typical day. As a result, some guidance recommends strictly using AADT rather than ADT in design. For example, the *Geometric Design Guide* advises against using ADT in place of AADT in the geometric design of highways (AASHTO, 2018).

Current traffic monitoring guidance does not provide specific information about how to develop AADT estimates from short-duration counts in urban areas, and specifically in towns. While the general approach of applying temporal adjustment factors to the traffic volume data collected from town counts is sound, there are methodological questions concerning the characteristics that define a town count and the selection of appropriate temporal factors to convert town count volume data into a reliable AADT estimate. This research addresses these questions.

1.3   OBJECTIVES AND SCOPE

This research comprises two key objectives:

1. to develop and apply criteria to define whether a short-duration count should be considered a town count; and

2. to develop and validate a methodology to determine the AADT from a short-duration town count.

The research utilizes traffic data collected in Manitoba, and particularly addresses the needs and challenges of Manitoba's traffic monitoring program. Despite this focus, the criteria and methods developed and applied in the thesis are considered transferrable to other jurisdictions facing similar challenges.

More specifically, the scope of this research is constrained as follows:

- This research explores the traffic periodicities of short-duration counts that are currently defined as a town count or occur within a geographic area which meets the criteria to be defined as a town. The temporal traffic patterns in geographic areas with lower population and/or population density are not explored.

- This research does not make recommendations for traffic pattern group (TPG) assignment in situations where a current town count is redefined as a general short-duration count.

- This research analyzes seven days of volume data at a sample of short-duration count sites that were scheduled to be surveyed in 2019. Resource constraints limited the initial sampling plan, so counts were not conducted at all the selected sample sites.

- The data collection plan intended to assess hourly, day-of-week, and monthly temporal variations at town count sites; however, due to data limitations, the research was only able to evaluate hourly and day-of-week relationships.

- This research only considers traffic volumes, not vehicle classification.

- This research does not evaluate the accuracy of the current TPG clusters, or the accuracy of the continuous count data used as the inputs to develop the TPG distributions. These traffic data are gathered by Manitoba Infrastructure (MI) and

in 2019 were processed by graduate students through the Manitoba Highway

Traffic Information System (MHTIS). This research solely focuses on identifying

which of the existing TPGs matches most closely with short-duration counts

identified as town counts.

1.4   APPROACH

Currently, short-duration counts in Manitoba are separated into two categories; those

that occur within the boundaries of populated areas, called town counts, and those that

do not, which are simply referred to as short-duration counts. The current traffic

monitoring program applies a methodology to estimate AADT from short-duration

counts; however, it is only able to provide an ADT for town counts. This research uses a

two-phase approach to develop AADT estimates from town counts.

The first phase, which supports the first research objective, employs a GIS-based

analysis using a set of criteria to standardize which short-duration counts should be

called town counts. This phase consists of two parts. The first part defines a town and its

boundary using objective criteria. The second part develops and applies a decision

algorithm to systematically define which short-duration counts should be considered

town counts.

The second phase, which also involves two parts, uses field-based data collection and

statistical analysis to support the second research objective. Part one designs a data

collection program to collect hourly volume data at a representative sample of count

sites that are currently defined as town counts. The second part screens the collected

data and then uses statistical analyses and visual validation to determine appropriate

TPG assignments for the sampled locations. Assigning town count sites to a TPG allows

the count data at these locations to be expanded into AADT estimates using the existing methods applied to short-duration counts conducted outside towns.

1.5 THESIS ORGANIZATION

This thesis is organized into five chapters, including this introductory chapter.

Chapter 2 – Literature and Practice Review: This chapter presents findings from reviewing relevant literature on the topics of traffic monitoring practices, with emphasis on the unique features of short-duration counts. It also reviews short-duration traffic monitoring practices in Canada.

Chapter 3 – Methodology: This chapter describes the methodology of the research, including (1) the criteria and decision algorithm used to determine which short-duration counts should be considered town counts and (2) the approach to develop AADT estimates from short-duration town counts.

Chapter 4 – Results and Discussion: This chapter presents and discusses the results of (1) identifying town counts using the decision algorithm and GIS analysis and (2) assigning town counts to TPGs using statistical methods and expert judgement.

Chapter 5 – Conclusion: This chapter summarizes the key findings and recommendations of the research and outlines opportunities for future work.

1.6 TERMINOLOGY

The following terms are used throughout this research:

Annual Average Daily Traffic (AADT) – the average daily traffic volume of a road segment over an entire year (or, in other words, the number of vehicles expected to use a roadway on an average day of the year). AADT can be calculated at continuous count sites and estimated at short-duration count sites.

Average Daily Traffic (ADT) – the average daily traffic volume of a road segment during the data collection period of a short-duration count.

Combined Count – a count site where traffic data are collected as the sum of both directions.

Continuous Count – a count site where automatic equipment collects traffic data 24 hours a day, 365 days of the year.

Coverage Count Program – the portion of the traffic monitoring program where short-duration counts are performed.

Day-of-Week (DOW) Distribution– the vector of the seven ratios of daily traffic volume on each day of the week to the ADT or AADT at the count site (expressed as a proportion or percent).

Directional Count – a count site where traffic data are collected by travel direction.

Hourly Distribution – the vector of the 24 ratios of hourly traffic volume in each hour of the day to the ADT or AADT at the count site (expressed as a proportion or percent).

Monthly Distribution – the vector of the twelve ratios of average daily traffic volume in each month of the year to ADT or AADT at the count site (expressed as proportion or percent).

Provincial Trunk Highway (PTH) – a primary highway in Manitoba as defined by the Transportation Infrastructure Act (Government of Manitoba, 2021b).

Provincial Road (PR) – a secondary highway in Manitoba as defined by the Transportation Infrastructure Act (Government of Manitoba, 2021b).

Provincial Access Road (PAR) – a tertiary highway in Manitoba as defined by the Transportation Infrastructure Act (Government of Manitoba, 2021b). The purpose of these highways is to provide entrance to or exit from a provincial highway (PTH or PR). Examples of their use include: to connect towns to the provincial highway network, or to connect two highways that are close together. PARs are numbered using the 600 series and unlike PTHs and PRs which are uniquely numbered, the number of a PAR is unique only to its region. Manitoba has five regions, so there are five different PARs numbered 601. A PAR numbered 800 is a provincial highway yet to be numbered by the province.

Shapefile – an electronic file containing geospatial features that can be imported into a geographic information system (GIS).

Short-Duration Count – a count site where traffic data are collected for a specified duration of at least 24 hours, but often between 48 hours and seven days. These counts are also commonly referred to as short-term counts or coverage counts.

Survey – a traffic count scheduled or conducted at a count site.

Traffic Monitoring Program – a program or system designed with the purpose of monitoring and reporting traffic data on the roadways in a given jurisdiction. Traffic monitoring programs collect traffic volume data using a mixture of continuous count sites and short-duration count sites. Other types of traffic data are also routinely collected (e.g., vehicle classification, speed, axle weight).

Traffic Pattern Group (TPG) – a group of continuous count stations identified to have similar hourly, day-of-week, and monthly variations in traffic volume for the purpose of estimating AADT at short-duration count sites.

Town – a rural built-up area with a population equal to or greater than 1000 residents, and a population density equal to or greater than 400 residents per square kilometre.

Current Town Count (prior to analysis) – a type of short-duration count collected within the boundaries of a city, town, or any populated area.

Town Count – a type of short-duration count on a provincial highway that exists within or nearby a geographic area defined as a town. These counts are expected to be influenced by the travel pattern characteristics in an urban or rural built-up environment.

2 LITERATURE AND PRACTICE REVIEW

This chapter presents findings from a review of literature on the principles, practices, and research related to this thesis. Specifically, the literature review focuses on four areas: (1) traffic monitoring guidelines, (2) systemwide traffic monitoring practices, (3) conducting short-duration traffic counts in urban areas, and (4) passive data collection technology. This chapter also summarizes publicly available information on traffic monitoring practices in Canadian provinces – specifically the methods of collecting short-duration traffic data, and the expansion of that data into AADT estimates. Lastly, this chapter summarizes findings and identifies knowledge gaps.

2.1   LITERATURE REVIEW

This section describes the basics of traffic monitoring, focusing specifically on the nature of short-duration counts within these programs.

2.1.1 Traffic Monitoring Guidelines

There are three main traffic monitoring guidance documents available in North America to assist jurisdictions in the development, management, and improvement of their traffic monitoring programs: the *Traffic Monitoring Guide (TMG)*, published by the Federal Highway Administration's (FHWA) Office of Highway Policy Information, the *AASHTO Guidelines for Traffic Data Programs*, published by American Association of State Highway and Transportation Officials (AASHTO), and the *Traffic Monitoring Practices Guide for Canadian Provinces and Municipalities*, published by the Transportation Association of Canada (TAC).

The FHWA developed their first traffic monitoring guide, known as the *TMG,* in 1985 and published the most recent version in 2016, with several updates in between. By providing guidance on the policies, standards, procedures, and equipment used in traffic

monitoring, this guide is intended to support U.S. state and local highway agencies in

meeting local and federal data requirements, which facilitate activities such as design,

maintenance, operations, safety, environmental analysis, finance, engineering

economics, and performance management (FHWA, 2016). The *TMG* focuses on the

characteristics of traffic data and outlines what traffic data to collect.

In 1992, AASHTO developed their own set of guidelines intended to compliment the

TMG, and released the second and most recent edition in 2009. This document is

geared towards U.S. state departments of transportation (DOT), metropolitan planning

organizations (MPO), as well as county and local governments' traffic agencies to

provide guidance on improving the quality of traffic information that is used to support

transportation-related decision making (Vandervalk-Ostrander *et al.*, 2009). Specifically,

this guide outlines how to collect, store, and process the traffic data recommended by

the *TMG*.

TAC developed their own Canadian-tailored traffic monitoring guide in 2017 to be used

by provincial and municipal agencies in Canada. The primary objectives of this guide are

to improve the quality of data produced by traffic monitoring programs and to achieve a

degree of uniformity in the traffic monitoring programs across the country (Regehr *et al.*,

2017). This guide is unique in the sense that it addresses the complexities associated

with traffic monitoring in environments with interrupted traffic flow, such as urban areas.

2.1.2 Systemwide Traffic Monitoring Programs

The Transportation Association of Canada states that the most important function of a

traffic monitoring program is to provide systemwide estimates of traffic statistics (Regehr

et al., 2017). To accomplish this, the basic framework of a traffic monitoring program

consists of two components: continuous counts, to understand temporal variation in

traffic characteristics; and short-duration counts, which provide spatial coverage of the

system (FHWA, 2016). Together, these two types of counts work to enable the development of traffic volume estimates across the entire roadway network.

This section describes continuous counts and identifies the methods used to calculate AADT at continuous count sites. It then discusses the development of TPGs which are fundamental in the development of AADT estimates at short-duration count sites, and provides details related to assigning short-duration count sites to a TPG. Lastly, it describes short-duration counts and presents the methods used to estimate AADT and calculate ADT at short-duration count sites. Each of the three subsections also focuses on the distinctive issues pertaining to town counts.

Continuous Counts

Continuous counts provide the foundation for traffic monitoring programs (Regehr *et al.*, 2017). These sites collect traffic data continuously for 24 hours a day, 365 days a year. Recording continuous data allows practitioners to characterize the temporal variation in traffic volume at a count site. These patterns include how traffic volume varies by time of day, DOW, monthly/seasonally, and/or annually (FHWA, 2016). To obtain reliable estimates of temporal traffic patterns, AASHTO (2009) recommends installing continuous counters on roads with moderate to high traffic volumes. This is because roads with low traffic volumes are more likely to have fluctuations in traffic volume caused by random events than roads with higher traffic volumes.

North American traffic monitoring guidelines describe four methods to calculate AADT at continuous count sites. The complexity and accuracy of each method varies based on how missing data are managed and if the base time period is a day or an hour (Grande *et al.*, 2017; Regehr *et al.*, 2017). All four methods produce nearly identical AADT values when all 365 days of data are available to use (Regehr *et al.*, 2017). However, due to equipment failure or detours caused by weather, construction, or special events, it is

common for some data to be missing or inaccurate, and therefore unusable. The accuracy of AADT will always decrease as the amount of missing data increases, no matter which method is used. However, the more complex methods will produce more accurate AADT values when data is missing, because they were developed with the purpose of reducing the biases caused by missing data (Regehr *et al.*, 2017). In order from least to most accurate (also least to most complex) the methods are *Simple Average* method*, AASHTO* method*, Hourly AASHTO* method*,* and *FHWA* method. Grande et al. (2017) and Jessberger et al. (2016) provide details on the accuracy of these methods.

The Transportation Research Board (2017) indicates that a major challenge traffic monitoring program managers face is appropriately placing continuous count stations to produce the factors needed to adjust short-duration data into suitably accurate AADT estimates. Building off this constraint, a shortcoming for many urban jurisdictions, including towns, is the lack of continuous count stations located within urban environments and towns (Regehr, Montufar and Hernandez-Vega, 2015; Regehr *et al.*, 2017). This absence of information prevents practitioners from knowing the traffic periodicities present on roadways within towns. Without knowing the temporal variations in traffic that exist for counts in towns, it is not possible to adjust short-duration town count data into reliable estimates of AADT.

Traffic Pattern Groups and Assignment

In addition to calculating AADT at continuous count sites, the data obtained from continuous counters can be used to transform the data collected from short-duration counts into AADT estimates (Vandervalk-Ostrander et al., 2009). Estimating AADT from short-duration count data is achieved using variations of a traditional method that was

first introduced by Drusch (1966); this method is still recommended by the *TMG* to expand short-duration counts into AADT estimates (FHWA, 2016).

It is well known that traffic patterns recur on a temporal basis such as by time of day, DOW, and monthly/seasonally (Regehr et al., 2017). TPGs consist of a set of continuous count sites grouped together because they are known to experience similar temporal traffic patterns. Temporal traffic variation exists for all data types including volume, classification, weight, and speed; however, the primary use of TPGs is to develop factors that adjust short-duration volume counts into AADT estimates (Regehr *et al.*, 2017). The FHWA (2016) and AASHTO (2009) suggest that the development of these adjustment factors is one of the most important uses of the data obtained from continuous count programs because they optimize resources to provide systemwide traffic estimates.

Guidance documents describe four methods to develop TPGs: (1) traditional approach, (2) cluster procedure, (3) hybrid approach, and (4) volume factor groups (FHWA, 2016; Regehr et al., 2017). The fourth method, identified by the *TMG,* is specific to the inter-state highway system and therefore is not described in detail in this literature review. The traditional approach uses qualitative information about the roadway system and explanatory factors to explain the temporal traffic variation throughout the system to develop TPGs. Clustering procedures use statistical clustering methods to form TPGs by grouping continuous counters based on the similarities of their temporal characteristics. Hybrid approaches combine statistical clustering, expert judgement, and industry intelligence to develop statistically robust and pragmatically defined TPGs (Reimer and Regehr, 2013). Table 1 outlines the advantages and disadvantages of each method.

Table 1: Advantages and disadvantages of methods used to develop TPGs

Method	Advantages	Disadvantages
Traditional	• TPGs are easily created. • TPGs can be pragmatically explained, making it easier to assign short-duration counts to a TPG.	• May not stand statistical scrutiny due to lack of statistical validity. • Relies heavily on the practitioner's knowledge of the regional road network.
Cluster	• Statistical nature identifies similarities and reduces biases in the groups. • May identify traffic patterns which are not intuitively obvious. • Efficient and accurate TPGs.	• Lack of guidance for optimal number of groups. • TPGs often cannot be pragmatically defined. • May be difficult to assign short-duration counts to a TPG.
Hybrid	• TPGs can be pragmatically explained, making it easier to assign short-duration counts to a TPG. • Statistical nature identifies similarities and reduces biases in the groups. • May identify traffic patterns which are not intuitively obvious.	• Iterative process can be time consuming. • Relies on the practitioner's knowledge of the regional road network.

Once TPGs are developed, the process of assigning short-duration counts to them can begin. The assignment procedure generally uses explanatory variables such as functional class, geographic location, and land use to pair short-duration counts with the TPG that is most similar (Regehr *et al.*, 2017). Knowing which explanatory variables are the best to use is often specific to the jurisdiction. The *Traffic Monitoring Practices Guide for Canadian Provinces and Municipalities* suggests that a decision algorithm can be a helpful way to systematically assign short-duration counts to TPGs but the questions and sequence of questions within such an algorithm will likely vary and there is no universally accepted algorithm.

Work completed by Bagheri et al. (2014) estimated the seasonal patterns at short-duration counts using historical count data at the sites and compared these patterns with

those for each TPG. The study found that the proposed method provides significant improvement in the accuracy of AADT estimates when compared to the FHWA factoring approach (Bagheri, Zhong and Christie, 2014). This result is expected, as the basis of assignment is to match short-duration counts with a TPG with similar temporal patterns. However, it is important to note that it takes years of data or additional data collection resources to understand the temporal characteristics at short-duration count sites. Due to this, explanatory variables are employed as a substitute.

Prior research has shown that the assignment step is the most critical element in the AADT estimation process and the quality of an AADT estimate relies heavily on the method used to assign the TPG to the count site (Sharma, Gulati and Rizak, 1996). Despite this, there is a lack of guidance available for assigning short-duration counts to TPGs (Transportation Research Board, 2017). The subjective nature of the assignment procedure has the potential to create significant errors in AADT estimation (Grande, Paramita and Regehr, 2021). Ineffective allocation of short-duration counts to TPGs may triple the prediction error (Davis, 1997). Research continues to work towards filling this gap in knowledge (Tsapakis *et al.*, 2011, 2014; Transportation Research Board, 2017).

The lack of continuous count data in towns leads to added difficulty associated with assigning these counts to a TPG. The temporal traffic patterns experienced by short-duration count sites in towns are largely unknown, as are the appropriate explanatory variables to characterize town count stations. If a TPG is selected to expand short-duration count data into AADT estimates, it is vital for the assignment procedure to be reviewed periodically to ensure the assignments remain suitable. As town boundaries change over time it is expected that traffic periodicities experienced by some town counts will change too, and this will need to be accounted for by adjusting the assigned

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TPG. Both the FHWA (2016) and TAC (2017) recommend reviewing assignments at least once every five years.

Short-Duration Counts

Short-duration counts exist within traffic monitoring programs as a low-resource, budget-friendly way to provide spatial coverage of traffic volume data across a roadway network. However, not all short-duration counts are equal. Differences in when, where, how often, and the equipment type affect the quality of the data gathered and subsequently the quality the of AADT estimate that can be developed from short-duration count data. Notable characteristics of short-duration counts include count date, location, duration, frequency, return period, equipment, and classification capability. Table 2 describes each characteristic and provides noteworthy details related to common practice.

Table 2: Characteristics of short-duration counts

Characteristic	Common Practice	Relevant Research
Count Date: The day of week and month of year in which the short-duration count survey is performed.	- In general, it is favourable to conduct short-duration counts during a period that experiences stable traffic patterns (i.e., less variation in volumes). - Short-duration counts occurring on weekdays are often considered to be superior to those performed on weekends. Additionally, holidays should be avoided. - Some research recommends not counting on Fridays as this day of the week can experience more variability. Other research has determined it is acceptable to count on Fridays. - The general consensus is that conducting short-duration counts in the spring and summer months (i.e., April to September) is advantageous over counts conducted throughout the winter. However, some research suggests to avoid short-duration counts from June to August, due to higher variability. - Although some research has considered short-duration volume counting in the winter months, traditional equipment often faces challenges in the winter season. - Additionally, the changing weather over the winter can result in a high variation in volume which is unfavourable for a short-duration count.	(Krile, Todt and Schroeder, 2015) (Luo and Zhong, 2015) (Vogt, 2015) (Milligan *et al.*, 2016) (Kenno *et al.*, 2017) (Regehr *et al.*, 2017)

Characteristic	Common Practice	Relevant Research
Location: The location of the short-duration count equipment.	• In general, the aim is to conduct short-duration counts at a sufficient number of locations so that volume estimates accurately represent the traffic volumes on each roadway segment. • To make best use of available counting resources, hierarchical approaches or random stratified sampling may occur. • Other jurisdictions instead choose to sample nearly 100 percent of the homogenous traffic volume segments periodically.	(FHWA, 2016) (Regehr *et al.*, 2017) (Transportation Research Board, 2017)
Duration: The length of each individual short-duration count survey.	• Short-duration counts are recommended to be at least 24 hours in duration. Counting for less than 24 hours is not advised as this could result in missing any large changes in volume that occur over the course of a day. • Most research and guidance identifies that a 48-hour count is likely to be more accurate and that this duration is likely the most effective in both summer and winter months. Counts longer than 48 hours have generally not been found to improve accuracy by a considerable amount. • However, the accuracy of a short-duration count on a low volume road could be improved significantly when short-duration counts are conducted for longer periods.	(Luo and Zhong, 2015) (Vogt, 2015) (FHWA, 2016) (Krile, Todt and Schroeder, 2016) (Regehr et al., 2017)
Frequency: The number of times a short-duration count survey is performed at the same location in each count return period.	• Research has found that surveying a single short-duration count location twice in the same year can help decrease error in the AADT estimate developed for that location. • This practice helps to reduce the variability that may occur from a single count as well as to identify abnormal volumes (i.e., from an unknown event or weather incident).	(Jung-Ah, 2014) (Milligan *et al.*, 2016) (Regehr *et al.*, 2017)
Return Period: The number of years that occur between short-duration count surveys at the same location.	• There is no optimal return period for short-duration counts. Guidance documents identify it is likely unnecessary to conduct surveys at each short-duration count location annually, but that surveys should be completed at least once every 5 or 6 years. • In general, research concludes shorter return periods provide better AADT estimates. • Some jurisdictions apply growth factors to estimate AADT in years when no surveys were conducted. • The specified return period may vary for short-duration counts within a single jurisdiction based on the importance of the roadway segment. • In the case of special needs counts, (i.e., to meet the needs of a specific project), they may be performed only a single time and not counted on a regular return period.	(Vandervalk-Ostrander *et al.*, 2009) (FHWA, 2016) (Krile, Todt and Schroeder, 2016) (Regehr *et al.*, 2017)

Characteristic	Common Practice	Relevant Research
Equipment: The type of equipment used to collect short-duration count data.	• A variety of equipment types are available to collect short-duration count data. Because the purpose of short-duration counting is to achieve broad geographic coverage, many are conducted each year. As a result, the decision of which type to use largely considers the ease and safety of installation and calibration because it is advantageous to use equipment that can be installed and removed quickly. • In general, short-duration counts are collected using portable traffic counters (i.e., pneumatic tubes) or automatic traffic recorders that are permanently installed but operate periodically. Non-intrusive sensors (e.g., side-fire radar cameras) are commonly used on busier roadways. • Each technology collects data differently, and therefore each has its own expected range of error which should be considered when selecting which technology is best to use.	(FHWA, 2016) (Regehr *et al.*, 2017) (Transportation Research Board, 2017)
Classification: The ability for a short-duration count to provide details on the types of vehicles that use a roadway.	• It is recommended that a minimum of 25% of short-duration counts should classify vehicles based on type (i.e., identify truck volumes). • This is encouraged because truck volumes are increasingly important as a result of the role they play in the design and maintenance of infrastructure.	(FHWA, 2016) (Regehr *et al.*, 2017) (Paramita *et al.*, 2020)

Current practice states that producing AADT estimates from short-duration counts involves adjusting the observed short-duration count volume with traffic ratios (often called traffic factors) (Transportation Research Board, 2017). Short-duration counts stations are first assigned to a TPG that is expected to exhibit similar traffic periodicities. The short-duration count data are then factored by a traffic volume ratio developed from the DOW, monthly, and sometimes hourly variation in volume as identified from the assigned TPG. To account for any economic or environmental conditions that occurred in that year, the FHWA (2016) recommends that short-duration counts performed in any year should be adjusted with ratios developed exclusively from continuous count data collected in that same year. Additional adjustments, including an axle-correction factor

(dependent on equipment type) or a growth factor, may also be applied to the short-duration count, if required (FHWA, 2016).

There are three commonly used methods that employ TPGs to transform short-duration count data into AADT estimates (Regehr *et al.*, 2017). They are the *Complete-Day* method*, Partial-Day* method, and *Hourly Average* method. The main difference between the methods is the availability of volume data at the short-duration count site, and the availability of traffic ratios from the assigned TPG. The *Complete-Day* method considers only complete 24-hour daily traffic volumes from the short-duration count, whereas the *Partial-Day* and *Hourly Average* methods both consider all available hourly volumes from the short-duration count. The *Complete-Day* and *Hourly Average* methods both utilize DOW and monthly traffic ratios, whereas the *Partial-Day* method also considers hourly traffic ratios. Despite their differences, each method works in a relatively similar matter. The observed traffic volumes are divided by the appropriate ratio (or multiplied by the factor) to produce an AADT estimate. Equation 1 demonstrates the general form of the factor equation that estimates AADT from short-duration count data.

Equation 1

$$AADT_i = \frac{Volume_{ijhdm}}{TR_{jh} \times TR_{jdm}} \times \frac{G_j}{A_i}$$

Where:

$AADT_i$ is the estimate of AADT at location i.

Vol_{ijhdm} is the hourly or daily volume collected from location i, on hour of the day h, day of week d, and month m for location i assigned to TPG j.

TR_{jh} is the hourly traffic ratio developed for TPG j on hour of day h, if needed.

TR_{jdm} is the daily traffic ratio developed for TPG j on day of week d and month m.

G_j is the traffic growth factor developed for TPG j, if needed.

A_i is the axle correction ratio developed for location i, if needed.

If a short-duration count has not be assigned to a TPG, it can not be factored, and therefore AADT at that location can not be estimated. In this situation, the short-duration count data can only be used to develop an ADT statistic. This statistic is defined as the average traffic volume during the collection period, which is essentially the same as using the *Simple Average method* to calculate AADT at a continuous count site with a lot of missing data. The ADT at a short-duration count site is calculated by dividing the total volume from the count period by the number of days in the count period. As such, the ADT is considered to be an unadjusted or unfactored traffic volume (FHWA 2016).

Short-duration counting within towns is an integral part of a jurisdiction's traffic monitoring program; however, there are certain limitations associated with these counts. First and foremost, without continuous counters in towns, it is difficult to develop accurate AADT estimates from town count data. This leaves practitioners to report only an ADT at town count sites. This is problematic because AADT is a required input to many transportation planning, design, operations, and management applications (Wang, Gan and Alluri, 2013; Krile, Todt and Schroeder, 2015; Luo and Zhong, 2015). And while ADT at a location is certainly more valuable than no data at all, the importance of developing accurate AADT estimates from short-duration count data has been expressed through substantial amounts of research in the field of traffic monitoring (Krile, Todt and Schroeder, 2015). Second, even if adequate continuous counting was performed in towns, town boundaries are dynamic. As these boundaries change over time, the traffic periodicities experienced at town counts are likely to change too, possibly diminishing the appropriateness of previously used TPGs and adjustment factors. A short-duration counting program in towns needs to account for this. Lastly, the

interrupted nature of traffic flow conditions in urban environments, including towns, can make site selection challenging.

2.1.3 Conducting Short-Duration Traffic Counts in Urban Areas

Traffic monitoring practices for highways in rural environments have been heavily studied and ample guidance exists to ensure data are collected, analyzed, and reported appropriately (Vandervalk-Ostrander *et al.*, 2009; FHWA 2016; Regehr *et al.*, 2017). However, despite an increased need for the same data in urban areas (Mergel, 1997), guidance for obtaining this data within an urban context is insufficient (Rempel, Regehr and Montufar, 2013). As a result, the methods used to collect traffic data, in particular traffic volume data, on urban roadways is inconsistent across Canadian jurisdictions (Kriger *et al.*, 2016). This is in part because collecting traffic volume data in urban areas presents unique challenges that do not exist in rural contexts, and as a result the methods traditionally used in rural areas cannot be blindly applied to urban environments (Hernandez, 2012; Regehr, Montufar and Hernandez-Vega, 2015).

Rempel, Regehr and Montufar (2013) identify five common challenges that face traffic monitoring agencies wishing to collect traffic volume data in urban areas:

1. It is common for multiple entities to collect traffic data within an urban area. Without adequate coordination, this can lead to difficulties or an inability to amalgamate data from different sources.
2. Interrupted traffic flow inhibits the use of traditional continuous count devices.
3. Dense street networks with ample accessibility make it challenging to assume homogeneity of volume on individual roadway segments. This can also lead to challenges in comparing traffic segments to one another.

4. Counting non-motorized road users, which are often not counted in rural environments, is relatively important in urban environments but requires unique program design.

5. The dense street network and complex land use distribution create difficulty in differentiating recurrent patterns, anomalous patterns caused by special events or temporary conditions, and erroneous data from faulty equipment.

Combined, these challenges impact the ability for a traffic monitoring agency to develop accurate AADT estimates from short-duration counts collected in urban areas. As outlined in Section 2.1.2, short-duration counting is a vital component of a traffic monitoring program, but this type of count cannot work alone. So although many municipal jurisdictions collect short-duration count data to discern traffic volume in urban areas (Regehr *et al.*, 2017), this data is not being used to its full potential.

In particular, without continuous counting equipment in urban areas there is limited knowledge of the differences in temporal patterns that occur on different types of urban roads (Weijermars, 2007). This lack of information means that most municipalities are unable to develop TPGs (Regehr *et al.*, 2017), which are an essential component to expand short-duration count data into AADT estimates. Research completed by Hernandez (2012) utilized short-duration count data to develop TPGs based on hourly variations in the City of Winnipeg. However, the purpose of these TPGs was to estimate daily volumes from partial day counts, not AADT from short-duration count data.

Recent developments in technology have enabled urban jurisdictions to deploy continuous monitoring equipment (City of Vancouver, no date). However, despite the existence of adequate technology, the effectiveness of using continuous data from urban locations to develop the expansion factors necessary to produce accurate AADT estimates from short-duration count data is still uncertain (Hernandez, 2012). The

intricacies of the roadway network and the complex distribution of land use can make it difficult to know which TPG a particular urban short-duration count should be assigned to. And as noted in Section 2.1.2, improper assignment is a leading cause of error in the AADT estimation process.

2.1.4 Passive Data Collection

With the rise in use of wireless devices, the advantages of collecting traffic data through passive sources has been identified, and as research continues and technologies advance, its use for understanding traffic characteristics and measuring and/or estimating a variety of traffic statistics has been steadily increasing in popularity (Rojas, Sadeghvaziri and Jin, 2016). Passive data sources, also called implicit data, are a type of data that are gathered without the data user asking for them. In the case of traffic monitoring, a commonly used passive data source is the location data from cell phones. Although this data type is not directly related to traffic monitoring, it allows transportation practitioners to infer a variety of travel characteristics.

There are an assortment of applications for passive data technology within traffic analytics and many studies have explored the numerous ways of using this data. Literature reveals that the use of passive data for travel behavioural studies has been relatively effective (Calabrese *et al.*, 2013; Chen *et al.*, 2016; Cambridge Systematics Inc. and Massachusetts Institute of Technology, 2018), with some studies focusing specifically on origin-destination parings (Huang and Levinson, 2015; Zanjani *et al.*, 2015; Bachir *et al.*, 2019; Montero *et al.*, 2019), and others examining route choice applications (Levinson and Zhu, 2013; Dhakar and Srinivasan, 2014). Research has also used passive data to monitor other traffic measures including speed (Bar-Gera, 2007), travel time (Porter, Kim and Magana, 2011; Gudishala, Wilmot and Mokkapati, 2016), and emissions estimation (Bigazzi *et al.*, 2011; Venter and Joubert, 2013).

Researchers have also employed this data to study traffic volumes, specifically with the intent to develop AADT estimates. Earlier studies had little success, declaring conventional methods, such as those discussed in Section 2.1.2, as more accurate in estimating AADT (Turner and Koeneman, 2017). Low volume roadways were found to have the highest errors, likely as a result of the lower quantity of mobile devices on those roads (Turner and Koeneman, 2017). However, as research continues to advance, greater success has been realized. The use of passive data sources for the purpose of AADT estimation continues to be studied with increasingly encouraging results (Codjoe and Zeringue, 2018; Young, Hou and Markow, 2018; Grande *et al.*, 2021). Promising findings were also obtained in recent work that examined AADT estimates in Texas, and at Texas-Mexico border crossings (Tsapakis, Cornejo and Sánchez, 2020). This study found that the accuracy of AADT improved on high volume roads (>10,000 vehicles per day) compared to low volume roads (401-10,000 vehicles per day) and that AADT estimates on urban roadways were more accurate than on rural roadways. Moreover, lower errors were found when using data from 2017 compared to a 2017 report that evaluated data from 2015. The last finding suggests that the accuracy of estimating AADT from passive data is improving over time.

Recent research has demonstrated the potential of using passive data to develop traffic volume statistics, and this trajectory is expected to continue. The FHWA is currently examining the accuracy of AADT estimates developed from passive data sources through a pooled-fund study (FHWA, 2018). The low cost and unique coverage capabilities of passive data justify its value and illustrate its ability to improve the efficiency of collecting AADT for traffic monitoring agencies. Although this technology is currently not necessarily suitable for developing traffic volumes, as the accuracy of AADT estimates from passive data improves, the use of these emerging methods is

likely to be adopted within traffic monitoring programs, particularly in the urban context where more passive data is available.

2.2   PRACTICES IN CANADIAN PROVINCES

A component of this research investigates the methods used by Canadian provinces to estimate traffic volume statistics on provincial highways that exist in rural built-up areas, such as towns. The geographical landscape of Canada is conducive to provincially owned and operated highways being located near or running through populated areas such as towns.

This section summarizes and highlights the key findings of publicly available information on the short-duration traffic monitoring practices in British Columbia, Alberta, Saskatchewan, and Manitoba. The review aimed to assess the practices in all Canadian provinces and territories; however, those without or with little available public data on the elements of short-duration counting and AADT estimation or those that did not respond to contact were removed from the review.

The review, conducted in July 2020 explores the methods used to collect short-duration traffic data in towns, and the procedures used to estimate AADT from that data. Table 3 summarizes the results of the review, specifically by identifying and describing the characteristics of the short-duration count program in each of the four provinces where public data was available.

Table 3: Summary of publicly available characteristics of short-duration traffic counting practices in select Canadian provinces

CRITERIA	British Columbia[1]	Alberta[2]	Saskatchewan[3]	Manitoba[4]
Type of short-duration counts performed	• Screenline counts.	• Intersection turning movement counts.	• Screenline counts.	• Screenline counts.
Are counts performed in towns?	• Yes, volume counting occurs in some but not all towns. • The majority of "town counts" are short-duration counts. These counts generally occur on the outskirts of the populated area not in the centre of the town. • Some continuous counters are located within urban areas such as Victoria, and the Greater Vancouver area. However, in general, continuous counts are not performed in towns.	• Yes, volume counting occurs in most towns. • The majority of "town counts" are short-duration counts. • Continuous counts are generally located in rural areas or on the perimeter of population centres. A few continuous counters are located in towns such as Lethbridge and Medicine Hat, which have major highways running through them that serve longer trip purposes.	• Unknown. • Information on the location of short-duration counters was not available. • A non-interactive map showing the location of continuous counters was available. However, town names were not shown, and the non-interactive nature made it difficult to identify the exact location of the count equipment.	• Yes, volume counting occurs in many towns. • The majority of "town counts" are short-duration counts. These counts occur at the perimeter of towns as well as in the town centres. • Continuous counts are generally located in rural areas.
Duration of short-duration counts	• Minimum of 48 hours. • Many sites have more than 48 consecutive hours. For example, a count in Nelson was 6 days long.	• 12 to 24 hours.	• 48 hours.	• 48 hours.

[1] Information in this column obtained from: (British Columbia Ministry of Transportation and Infrastructure, 2014, no date)
[2] Information in this column obtained from: (Alberta Ministry of Transportation, 2018, no date)
[3] Information in this column obtained from: (Government of Saskatchewan Information Ministry of Highways and Infrastructure, 2016)
[4] Information in this column obtained from: (Olfert *et al.*, 2020)

CRITERIA	British Columbia[1]	Alberta[2]	Saskatchewan[3]	Manitoba[4]
Frequency of short-duration counts	• One count per year.	• One count per year.	• One count per year.	• Two counts per year.
Return period of short-duration counts	• 3-year return period.	• 5-year return period.	• Dependent on location. • Ranges from 1-year return period to 5-year return period.	• 3-year return period.
Equipment used for short-duration counts	• Pneumatic tubes.	• Not specified.	• Not specified.	• Majority use pneumatic tubes. • Some use induction loops.
Methods used to produce AADT estimates from short-duration count data	• TPGs are used to generate factors that expand raw short-duration count data into AADT estimates. • Seasonal and daily factors are applied to the short-duration count data. • Three TPGs exist. • Continuous count sites are grouped together based on the coefficient of variation (CoV) in volume at the site. • TPG titles are consistent (CoV<15%), seasonal (15%<CoV<33%), and highly seasonal (CoV>33%).	• Data collected from intersection counts are adjusted to account for daily and seasonal variation using data from continuous counters. This enables the production of AADT estimates through the intersection.	• TPGs are used to generate factors that expand raw short-duration count data into AADT estimates. • Seasonal and daily factors are applied to the short-duration count data. • Six TPGs exist. • Continuous count sites are grouped together based on an analysis of the traffic volume variation of continuous counts. • TPG titles are regional commuter rural highways, long distance rural highways, rural highways (AADT > 600), rural highways (AADT < 600), rural recreation highways, resort highways.	• TPGs and control stations are used to generate factors that expand raw short-duration count data into AADT estimates. • Seasonal and daily factors are applied to the short-duration count data. • Seven TPGs exist. • Continuous count sites are grouped together based on a cluster analysis and engineering judgement. • TPGs are simply titled one through seven, rather than a descriptive title like other provinces. • AADT estimates are not developed for short-duration counts identified to be "town count" stations.

CRITERIA	British Columbia[1]	Alberta[2]	Saskatchewan[3]	Manitoba[4]
Are short-duration counts assigned to a TPG? If so, how?	• Yes. • Short-duration counts are matched with a TPG based on the expected variation in volume present in the area of the count; consistent, seasonal, or highly seasonal which match the three TPG titles.	• Not exactly. • Intersection counts are assigned to a single continuous counter (rather than a TPG) that is located in proximity close to the intersection. When there are no continuous counters located nearby, engineering judgement is used to select a continuous counter that is expected to have similar traffic patterns to the intersection.	• Yes. • Short-duration counts are matched with a TPG that is expected to have similar traffic patterns. However, the details of the assignment procedure are not clearly described.	• Yes. • Some short-duration counts are assigned to TPGs. • More often, short-duration counts are assigned to a single continuous counter (rather than a TPG) called a control station in the same TPG as the short-duration count. • The assignment procedure to a TPG or control station considers physical proximity, geographical characteristics, temporal traffic patterns, and engineering judgement.
Is there a specific town factor group?	• No. The "consistent" TPG which is identified to be common in and adjacent to urban areas is often paired with short-duration counts near towns, but it is not exclusive to town environments.	• Unknown. Descriptive details of the assignment procedure are not provided.	• No. The "commuter rural highway" TPG is likely the closest to a town factor group, but only considers travel 80 km away from the major urban centres of Regina, Saskatoon, Prince Albert, or Moose Jaw. It does not specify travel within or in the vicinity of smaller population centres like towns.	• No. Two of the seven TPGs exhibit patterns such as morning and afternoon peaks, steady weekday volume, and minimal seasonal variation which would be expected to occur in urban areas. However, it is not clear if town environments would exhibit these same patterns.

In general, this review reveals general uniformity amongst the four western Canadian provinces in how they conduct short-duration counts and expand the data into AADT estimates. This result is not surprising as the methods used are consistent with those outlined by North American guidance literature.

Furthermore, the results of the jurisdictional review demonstrate that despite the existence of numerous towns in the Canadian prairies, these provinces have not invested in continuous count data collection in towns and do not attempt to develop reliable AADT estimates on the provincial highways within towns or in their vicinity. This gap is in part due to the challenges that exist and lack of guidance available for conducting short-duration counts in urban contexts, which includes towns. This finding supports the need for the research documented in this thesis.

2.3   SUMMARY AND RESEARCH GAPS

Ample guidance on the development of traffic monitoring programs exists, specifically, North American documentation provides details on collecting, analyzing, and reporting volume data for rural roadways. However, significantly less guidance is available for urban contexts. As a result, the methods to develop reliable AADT estimates from short-duration counts in rural areas are robust but it can be difficult to develop the same statistic within urban environments, including in towns.

In general, developing traffic statistics such as AADT on roadways requires the use of short-duration and continuous counting equipment. AADT can be calculated at continuous count sites since volume data are measured each day of the year. Short-duration counts on the other hand provide spatial coverage but because they only count for a few days, the data collected is only part of the information required to develop

estimates of AADT. The short-duration volume collected needs to be adjusted with appropriate factors, developed from TPGs, to yield reliable AADT estimates.

Due to the dense and complex roadway network in urban environments, it can be difficult to use traditional methods (such as those used in rural areas) to develop reliable AADT estimates at short-duration counts in urban regions. In general, this difficulty arises due to a lack of continuous count data in urban areas, which in turn means a lack of knowledge of the traffic periodicities on urban roadways.

The future of developing AADT estimates from passive data is promising, particularly in urban contexts since more people equates to increased availability of passive data. However, at this point in time, the technology is not yet useable for this purpose. Additional study is required before this concept can be used to develop accurate AADT estimates on urban roads.

A review of the practices used by provincial traffic monitoring authorities in the Canadian prairies identified a need to improve the practices used to understand traffic volumes within towns. In particular, an opportunity to develop a method to produce reliable AADT estimates from short-duration counts within towns was revealed. This opportunity corroborates the findings from the literature. Currently, due to a lack of continuous count data on roadways within towns it is not possible to assign a short-duration town count to a TPG. This leaves practitioners to report only an ADT at town count sites. This finding recognizes the need for further research into the methods of developing accurate AADT estimates from short-duration count sites located in towns. This would allow traffic monitoring agencies to improve the value of the data they already collect.

3 METHODOLOGY

This chapter describes the methodology to estimate AADT from short-duration counts in towns. The methodology involves two phases: (1) identifying which short-duration counts should be considered town counts, and (2) developing a procedure to determine AADT from counts identified as town counts. The identification of town counts uses seven criteria, applied within a decision algorithm, and supported by GIS analysis. The determination of AADT from identified town counts involves studying a representative sample of short-duration count sites by way of statistical analysis.

3.1   DETERMINATION OF WHICH COUNTS ARE TOWN COUNTS

This section outlines the procedure to determine which short duration counts should be categorized as town counts (i.e., Objective 1 of the research). Reasoning behind criteria selection, application of criteria, and descriptions of spatial data sources are described.

3.1.1 Criteria Selection and Application

Seven criteria are selected to determine which short duration counts should be town counts:

1. Population
2. Population density
3. Town boundary
4. Speed limit
5. Highway arrangement
6. Number of intersections
7. Land use

The first two criteria are used to answer the question: What is a town? Criteria 3 through 7 are used to answer the question: Which counts are town counts?

Question 1: What is a town?

The definition of a town, or more broadly a rural built-up area, is not clear or consistent among jurisdictions, and no relevant literature was identified on the subject. This inconsistency results in a need to understand the types of populated areas and their attributes. Consequently, for the purpose of this thesis, it was necessary to establish a definition for a town in the context of Manitoba.

This begins by studying the various civic designations given to inhabited areas in Manitoba. The Manitoba Municipal Act states that there are two types of municipalities: urban municipalities and rural municipalities, with the differentiating factor between them being the population density of the area (Government of Manitoba, 2021a).

According to the Act, the following points describe urban municipalities:

- May be formed in an area with at least 1000 residents, and a minimum population density of 400 residents per square kilometre.
- Can be given the name of "The City of [name]", "The Town of [name]", "The Village of [name]", or "The Municipality of [name]".
- May only be named as a city if the population is greater than 7500 residents.

Likewise, the following points describe rural municipalities:

- May be formed in an area with at least 1000 residents, with a population density less than 400 residents per square kilometre.
- Can be given the name of "The Rural Municipality of [name]" or "The Municipality of [name]".
- Within a rural municipality there may be one of two types of populated areas:
  - Local Urban Districts (LUD)
  - Unincorporated Urban Centres (UUC)

An LUD may be formed for a locality within a rural municipality if the locality meets these three criteria:

(a) Minimum of 250 residents and minimum population density of 400 residents per square kilometre. In some cases, the minister may consider other densities.

(b) It is contained within the boundary of a rural municipality.

(c) It is contiguous with the rest of the locality and there is no area within the boundary of the local urban district that is not part of it.

UUCs are not explicitly defined in the Manitoba Municipal Act, despite their existence in the province. These areas refer to populated places, such as a cluster of homes or a residential community, that are located within a rural municipality but have not been formally incorporated as a place of their own. Although these locations have not made the choice to be legally identified as a town or LUD, the characteristics of some UUCs closely match those of incorporated communities.

Next, on reserve populated areas identified by Statistics Canada as Indian reserves[5] are considered. An Indian reserve is defined as an area of federally owned land that is designated for the use and benefit of an Indian band and as of the 2016 Census were governed by the Aboriginal Affairs and Northern Development Canada (AANDC) (Statistics Canada, 2018a). In 2011, Statistics Canada recognized 961 Indian reserves as being populated from the more than 3100 Indian reserves across Canada.

Lastly, the term "population centres", as defined by Statistics Canada is investigated. A population centre is described as an area with a population of least 1000 people and a

_____

[5] Terminology used reflects the current legal definitions of communities affiliated with First Nations or Indian bands.
The 376 reserves in Manitoba are the "intergenerational homelands of the Ininew (Cree), Anishinaabe (Ojibwe), Oji-Cree, Dakota/Lakota (Sioux) and Dene peoples" (Kulchyski, 2021).

minimum population density of 400 residents per square kilometre (Statistics Canada, 2018c). All areas outside population centres are classified as rural areas. Therefore together, population centres and rural areas cover all of Canada.

Population size is used to separate population centres into three groups to reflect the existence of an urban-rural continuum:

- small population centres → population between 1,000 and 29,999
- medium population centres → population between 30,000 and 99,999
- large urban population centres → population of 100,000 or more

All population centres in Manitoba are considered small, with the exception of Winnipeg (large), and Brandon (medium).

Table 4 provides a summary of the different geographic types, how many of each exist within the province of Manitoba, and the relevant authority.

Table 4: Summary of types of geographic areas in Manitoba

Geographic Term	Number in Manitoba (2020)	Relevant Authority
City	10	Manitoba Municipal Act
Town	25	Manitoba Municipal Act
Village	2	Manitoba Municipal Act
Municipality	37	Manitoba Municipal Act
Rural Municiaplity	62	Manitoba Municipal Act
Local Urban District	44	Manitoba Municipal Act
Unincorporated Urban Centre	43	Manitoba Municipal Act
Indian reserve	77 "populated" 376 "total"	AANDC (2016) & Statistics Canada
Population Centre	53	Statistics Canada

As shown, multiple names are given to rural built-up areas. Thus, it is evident that there are many types of areas that, from a traffic perspective, behave like a town even if they

do not have that particular legal designation. Subsequently, the first two criteria

(population and population density) are selected for their ability to objectively

characterize how urban an area is. The thresholds chosen are a population equal or

greater than 1000 residents and population density equal or greater than 400 residents

per square kilometre. These limits are selected directly from Statistics Canada's

definition of a population centre. Additionally, the Manitoba Municipal Act uses a

population density of 400 residents per square kilometre to differentiate between urban

and rural municipalities (Government of Manitoba, 2021a). Thus, if the population of an

area is at least 1000 people, and population density is at least 400 residents per square

kilometre, the geographical area will be considered urban and thus will be referred to as

a town within this thesis.

The town selection procedure begins by gathering geographic type, population, and

population density data for populated areas from the 2016 Census. Locations selected

for analysis include: all geographic types classed as urban municipalities (towns, cities,

and villages), and any other locations that satisfied or nearly satisfied the minimum

requirements for population and population density. A total of 68 locations are initially

selected.

The analysis revealed that there are eight locations in Manitoba which by legal definition

are urban areas (town or village), but do not meet population and population density

requirements. As a result, they are not expected to exhibit the same traffic

characteristics as areas which meet the requirements and are removed from the

analysis. In total, 13 of the initially selected locations are removed. Table 5 provides a

summary of the reasons each location is removed.

Table 5: Summary of locations removed from "what is a town?" analysis

Name	Geographic Type	Reason Removed
Churchill	Town	Population and population density too low
Dunnottar	Village	Population and population density too low
Garson (Tyndall-Garson)	Local Urban District	Population too low
Gillam	Town	Error with boundary data for population centre[a]
Grand Rapids	Town	Population and population density too low
La Broquerie	Local Urban District	Population density too low
Leaf Rapids	Town	Population and population density too low
Lundar	Local Urban District	Population too low
Lynn Lake	Town	Population and population density too low
Powerview-Pine Falls	Town	Population density too low
Snow Lake	Town	Population and population density too low
St. Malo	Local Urban District	Population density too low
Winnipeg Beach	Town	Population density too low

[a] The boundary data available in the shapefile did not match the known location of the town.

Evaluation of the data yielded a total of 51 locations within the province of Manitoba that meet the population and population density criteria. Table 6 displays these locations along with their respective geographic type, population, and population density in units of residents per square kilometre.

Table 6: List of locations that satisfy minimum population and population density requirements and are considered "towns" in this thesis

Town Name	Geographic Type	Population, 2016	Population Density, 2016
Altona	Town	4212	449.1
Arborg	Town	1232	556.3
Beausejour	Town	3219	593.8
Blumenort	Local Urban District	1675	526.3
Boissevain	Population centre	1656	679.7
Brandon	City	48,859	631.2
Carberry	Population centre	1682	961.3
Carman	Town	3164	728.3
Chemawawin 2	Indian reserve	1252	465
Cross Lake 19A	Population centre	2018	603.3
Dauphin	City	8457	670.7
Flin Flon	Population centre	4791	1099.7
Gimli	Population centre	2246	746.6
Grunthal	Local Urban District	1680	593.7
Ile des Chênes	Unincorporated Urban Centre	1546	755.7
Killarney	Population centre	2150	730.9
La Salle	Population centre	1589	1060.2
Lac du Bonnet	Town	1089	506.6
Landmark	Local Urban District	1292	433.4
Lorette	Local Urban District	3208	685
Minnedosa	Population centre	2178	1220
Mitchell	Population centre	2523	629.7
Moose Lake	Population centre	1225	951.9
Morden	City	8668	529.4
Morris	Population centre	1714	651.9
Neepawa	Population centre	3939	1685.6
Niverville	Town	4610	530.6
Oak Bluff	Population centre	1051	417
Oakbank	Population centre	4604	856.1
Pinawa	Population centre	1331	856.1
Portage la Prairie	City	13,304	539.1
Rivers	Population centre	1257	1454.7
Roblin	Population centre	1614	627.2
Russell	Population centre	1395	923
Selkirk	City	10,278	413.4
Shilo CFB-BFC	Population centre	1419	1151.3
Souris	Population centre	1876	826.5
St. Adolphe	Population centre	1362	853.9
St. Theresa Point	Population centre	1038	5897.7
St. Pierre-Jolys	Village	1170	440.5
Ste. Anne	Town	2114	499.4
Ste. Rose du Lac	Unincorporated Urban Centre	1021	408.5

Town Name	Geographic Type	Population, 2016	Population Density, 2016
Steinbach	City	15,829	618.6
Stonewall	Town	4809	802.8
Stony Mountain	Population centre	1800	988.6
Swan River	Town	4014	560.4
Teulon	Population centre	1095	580.8
The Pas	Population centre	5368	1022.1
Thompson	City	13,678	657.8
Virden	Population centre	3082	1322
Winkler	City	12,591	740.5

As indicated, locations that are close to meeting the selected criteria are also analyzed. In total, four towns are identified that are close to but did not quite meet the minimum population and population density requiements. These towns are Deloraine, MacGregor, Melita, and Tyndall. Three of the four exceptions meet one of the two criteria and are very close to meeting the second. The fourth, Deloraine, is very close to meeting both criteria. These locations are included in the analysis because they are deemed to be sufficiently close to meeting the criteria, given the traffic monitoring application considered in this thesis. Table 7 shows the same information (as Table 6) for these locations.

Table 7: List of locations that nearly satisfy minimum population and population density requirements and are considered "towns" in this thesis

Town Name	Geographic Type	Population, 2016	Population Density, 2016
Deloraine	Unincorporated Urban Centre	978	385.7
MacGregor	Unincorporated Urban Centre	973	456.9
Melita	Town	1042	342.7
Tyndall (Tyndall-Garson)	Local Urban District	935	428.2

The geographic type indicated in both Table 6 and Table 7 corresponds to the final boundary type selected as described in Section 3.1.2, which in some cases is not the

same as the town's civic geographic type. For example, Manitoba's Municipal Status and Boundaries Regulation (567/88R) indicates that Flin Flon is by legal definition a city (Government of Manitoba, 2019). However, the area defined as the City of Flin Flon does not meet the minimum population density requirement, but the population centre area of Flin Flon does meet both requirements. As a result, the population centre of Flin Flon is selected as a town, not the legal city area. Therefore, population centre is the geographic type displayed in Table 6 for Flin Flon.

In summary, 55 locations are identified in Manitoba that are considered "towns" for the purpose of this thesis. The final selection of 55 towns includes a variety of geographic types, including eight cities, one Indian reserve, five LUDs, 26 population centres, 10 towns, four UUCs, and one village.

Question 2: Which counts are town counts?

The simple answer to this question is that short-duration counts within a town should be considered town counts. However, this question is more complex because a geographic boundary does not necessarily induce a change in travel patterns. Criteria 3 through 7 are selected for their ability to aid in indicating the presence of urban characteristics within and around a town. The following paragraphs describe each criterion individually. A decision algorithm is developed to apply these criteria in a repeatable and systematic way.

Determining town boundaries (Criterion 3) is the first step in identifying which counts are town counts. This step involves gathering available boundary shapefile data for the identified towns and selecting the largest area that satisfied population and population density requirements. Section 3.1.2 provides detailed information about the boundary datasets and the selection procedure.

The town boundary differentiates counts within the town boundary and counts outside the town boundary. As shown later in the decision algorithm, counts within the town boundary are not guaranteed to be town counts and, in some situations, counts outside the town boundary may be classified as town counts. This criterion simply allows for each scenario to be analysed independently.

Once the boundary is defined, the next step is to analyze the speed limit at the location of the count (Criterion 4). Speed limit data for provincial roadways was acquired from MI and Section 3.1.2 provides further details on this data.

Speed limit is selected because it is an objective indicator of urban roadside characteristics and land use. It is observed that speed limit and urban characteristics are inversely related; that is as speed limit decreases, the corresponding roadside typically has an increasingly urban nature. Road authorities choose to reduce speed limits upon the presence of operational and safety concerns. Urban areas typically face these challenges and therefore, speed limits are reduced. Consequently, from an analytical perspective, speed limit can serve as a surrogate for urban features that are driven by higher density land use. Table 8 provides target speed limit ranges for various roadway contexts and functional classifications in Manitoba (Manitoba Infrastructure, 2019).

Table 8: Appropriate target speed limits that promote safer operations. Adapted from "*Guide for Setting Posted Speed Limits on Manitoba Roadways,*" by Manitoba Infrastructure.

	Rural	Rural Town	Suburban	Urban	Urban Core
Freeway	80-110 km/h	NA	80-110 km/h	NA	NA
Expressway	80-110 km/h	NA	80-110 km/h	NA	NA
Primary Arterial	80-100 km/h	50-80 km/h	60-80 km/h	50-60 km/h	50-60 km/h
Secondary Arterial	70-100 km/h	50-70 km/h	50-80 km/h	40-50 km/h	40-60 km/h
Collector	60-100 km/h	40-50 km/h	40-60 km/h	40-50 km/h	30-50 km/h
Local	50-90 km/h	30-50 km/h	30-50 km/h	30-50 km/h	30-50 km/h

From the table, it is evident that:

1. Roadways with speed limits of 90 km/h or more are unlikely to occur in urban areas and are therefore unlikely to exhibit urban traffic periodicities.

2. Roadways with speed limits of 60 km/h or less are likely to only occur in urban areas and are therefore likely to exhibit urban traffic periodicities.

3. Roadways with speed limits between 60 km/h and 90 km/h may or may not occur in urban areas and therefore may or may not exhibit urban traffic periodicities.

As a result of these statements, the thesis defines the following rules:

1. When a count occurs outside a town boundary and the speed limit is 90 km/h or greater, the count will not be considered a town count.

2. When a count occurs inside a town boundary and the speed limit is 60 km/h or less, the count will be considered a town count.

3. Whether the count is inside or outside a town boundary, if the speed limit is between 60 km/h and 90 km/h, more analysis is required.

Exploring highway arrangement at the location of the count (Criterion 5) is the next step. Highway arrangement is evaluated using two questions:

1. Does the roadway lead directly to the town? (Yes/No)

2. Does the roadway by-pass the town? (Yes/No)

Figure 1 illustrates the two highway arrangement scenarios in the vicinity of Beausejour, Manitoba. PTH 44 (highlighted in blue) bypasses Beausejour to the north and east, whereas PR 215 and PAR 601 (highlighted in orange) lead directly to the town centre.
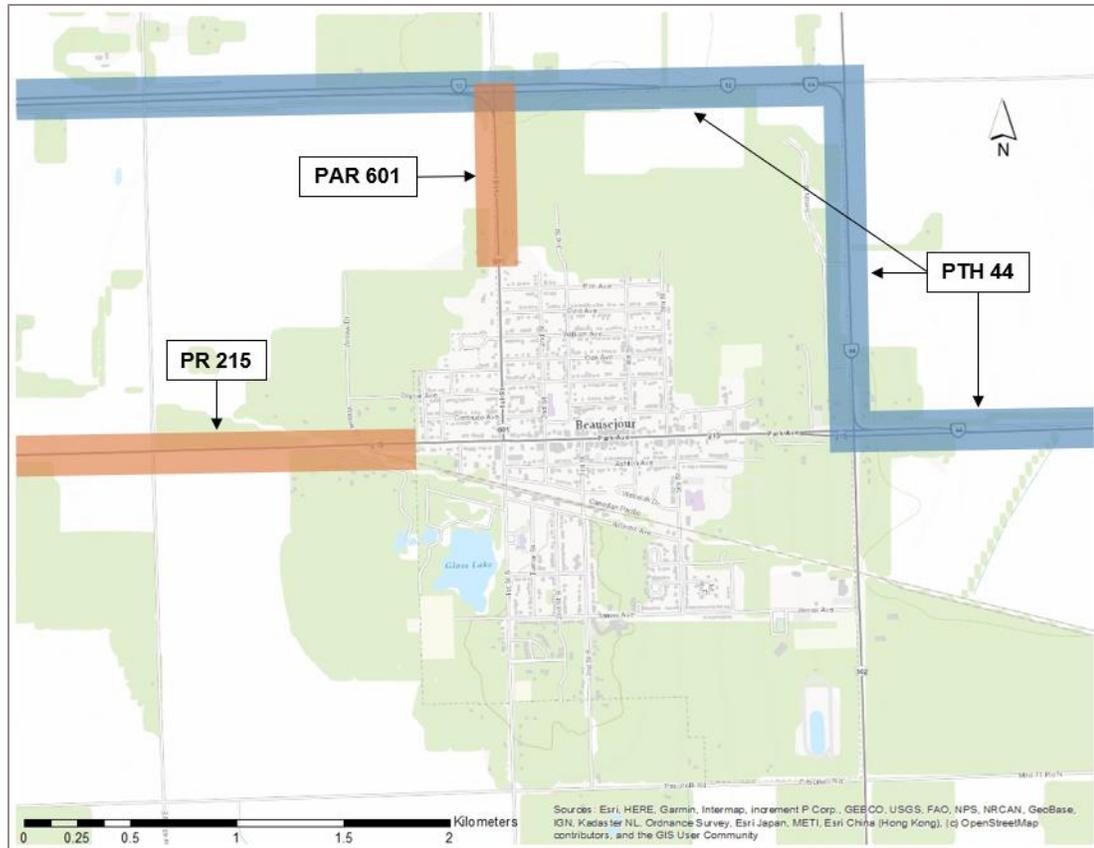
Figure 1: Highway bypass arrangement shown in blue, and highway lead to arrangement shown in orange

This criterion is selected because the arrangement of the roadway within the network and relative to the town is expected to influence the travel patterns experienced. Understanding the purpose of the roadway is an important factor in determining the temporal travel characteristics the short duration count will exhibit. If the roadway bypasses the town, it is unlikely that the short duration count will exhibit urban travel behaviour, and therefore, a count taken on a bypass should not be categorized as a town count. Otherwise, more information is required to make a decision.

Consideration of the number of intersections between the count and the town boundary (Criterion 6) only applies in the event that the short duration count exists outside of a defined town boundary. It is expected that in some cases, a count outside the defined

town boundary may be influenced by the urban travel within the boundary due to its proximity to the defined town area.

A major intersection is defined as one of the following three circumstances:

- Junction of two or more PTHs,

- Junction of a PTH with one or more PRs, or

- Junction of two or more PRs where historical evidence reveals traffic volume changes.

The number of major intersections between the count and the town boundary is selected as an objective indicator of proximity because the presence of intersections is likely to cause changes in traffic characteristics (Regehr et al. 2006). If there are one or more major intersections between the count and the town boundary, it is unlikely the count location will be significantly influenced by the town travel patterns, and therefore should not be categorized as a town count. If there are no intersections, additional information is required.

Finally, land use in the vicinity of the count (Criterion 7) is used as the final check to determine whether the short duration count should be considered a town count. Inspection of the surrounding land use can reveal if the location of the short duration count is expected to have urban traffic characteristics.

The interrelationship between transportation and land use is complex; however, in this thesis a simple approach is utilized to identify urban land use characteristics. The land use designation at the location of a short-duration count was deemed to be urban if one or more of the following points applied:

- The immediate vicinity of the counter location features single and/or multi-family residences, and/or commercial, industrial, or institutional businesses.

- The roadway the count is located on directly connects areas which contain residences or businesses.

The satellite and street view features of Google Maps are used to explore the land use characteristics at each short-duration count location.

Decision Algorithm

A decision algorithm is developed to assist in applying Criteria 3 through 7, which is ultimately the procedure to select which short duration counts should be town counts. Each of the five questions in the decision algorithm are based on a single criterion, starting with Question 1: "Does the count occur within a defined town boundary?" relating to Criterion 3, and the remaining pairings continuing in ascending order. Figure 2 displays the decision algorithm.
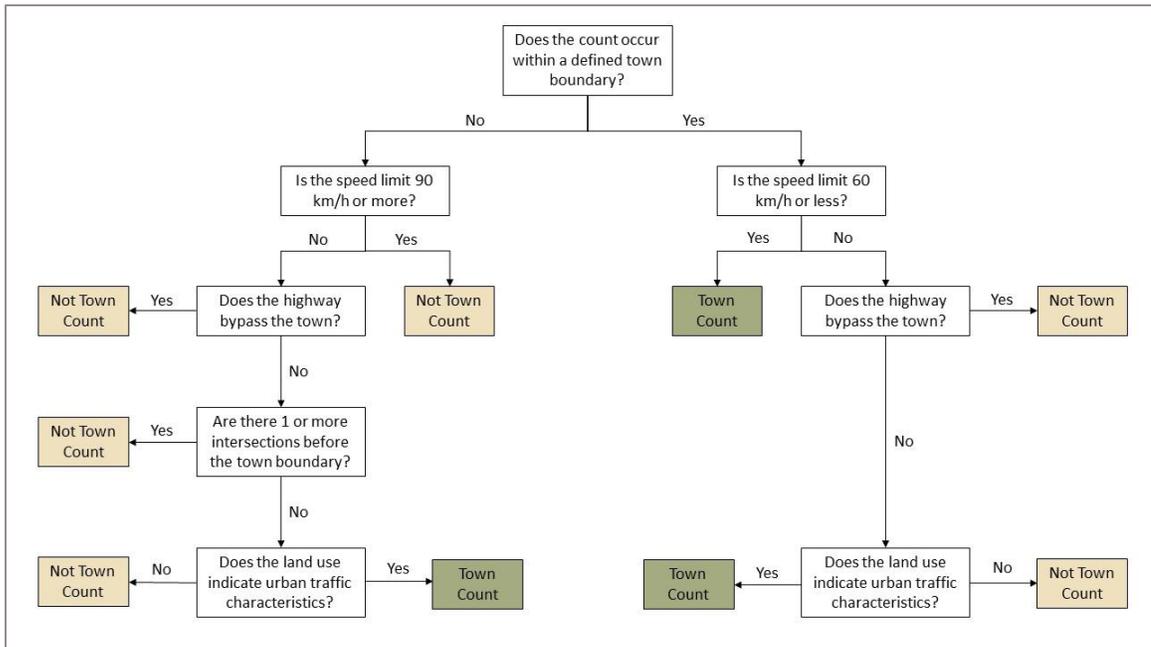
Figure 2: Decision algorithm to determine which counts are town counts

The decision algorithm is applied in two stages. The first considers all current town counts and uses the questions in the algorithm to evaluate their categorization. The

second examines short-duration counts within or nearby the 55 identified towns in Manitoba and determines their categorization. It is not necessary to review all short-duration counts because if the count is not located within or nearby a geographical location defined as a town, there is no possibility for it to be classified as a town count.

3.1.2 Spatial Data Sources

Three categories of spatial data are used in the GIS analysis: (1) speed limit data, (2) traffic count station data, and (3) boundary information.

Speed limit data was obtained from MI in 2018. The shapefile consists of 1953 polylines of various length, each with a speed limit and associated regulation information. A linear referencing system is used in this dataset. Speed limits range from 30 km/h to 110 km/h. Figure 3 shows a map of speed limits on provincial roadways in Manitoba. Most roadways have speed limits of 90 km/h or 100 km/h, as expected on a provincial highway. There are two notable exceptions. First, the western section of the Trans-Canada Highway (PTH 1) and the southern section of PTH 75 near the Pembina-Emerson border crossing have a speed limit of 110 km/h. Second, there are numerous short highway sections with speed limits between 50 km/h and 80 km/h; these mostly occur in or near populated areas. In instances where speed limit data on a section of roadway is not provided, the street view feature of Google Maps is used to detect speed limit signs. If no signs are visible, the speed limit is recorded as unknown.
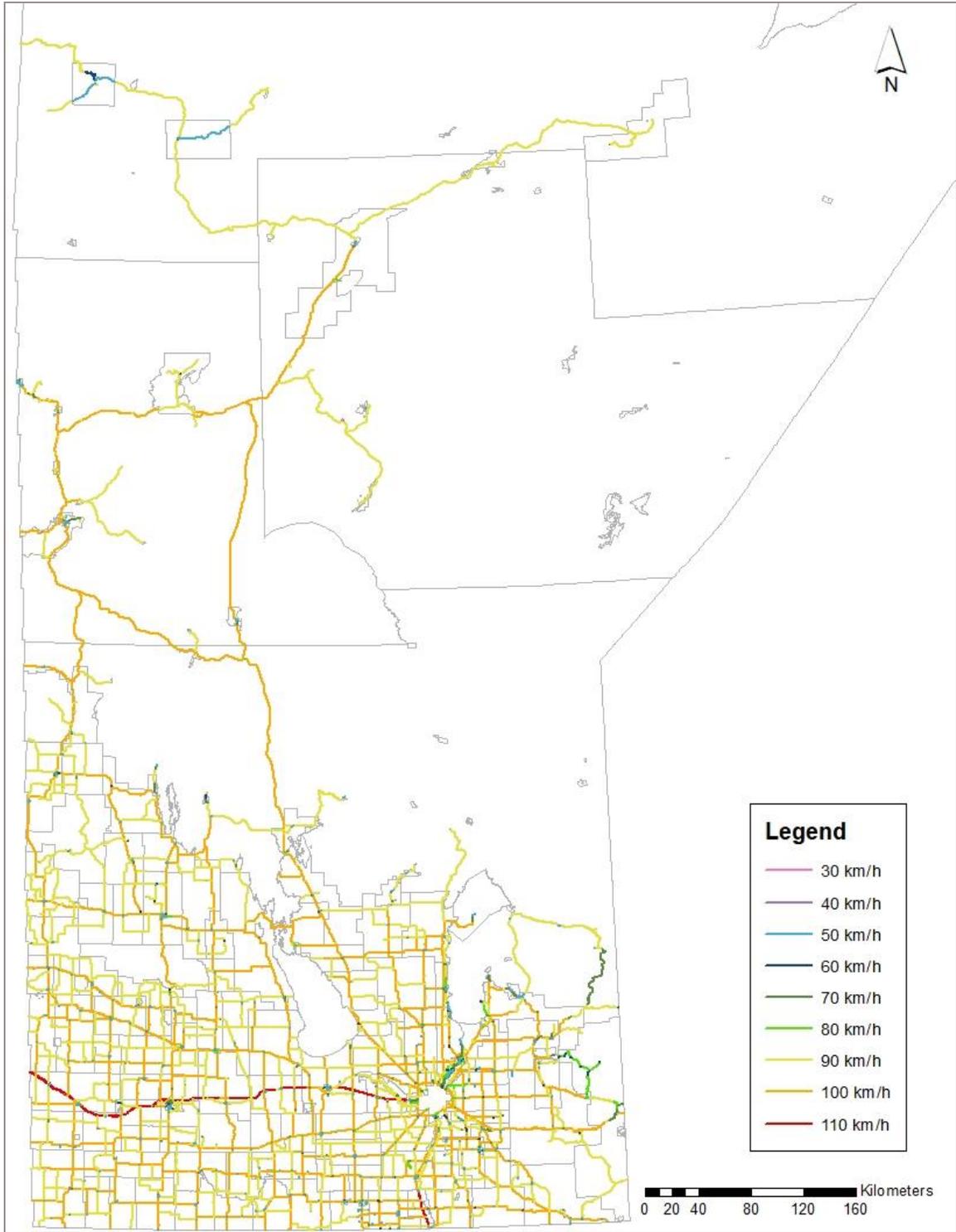
Figure 3: Speed Limits on Manitoba Provincial Trunk Highways, Provincial Roads, and Provincial Access Roads, 2018

Traffic count station data was obtained from MHTIS in 2018. The shapefile consists of

85 continuous count stations, 1683 coverage counts, and 327 current town counts.

These totals indicate the current distribution of count type before conducting the analysis

described in Section 3.1.1. Figure 4 shows the locations of the traffic counters in

Manitoba by type of count.
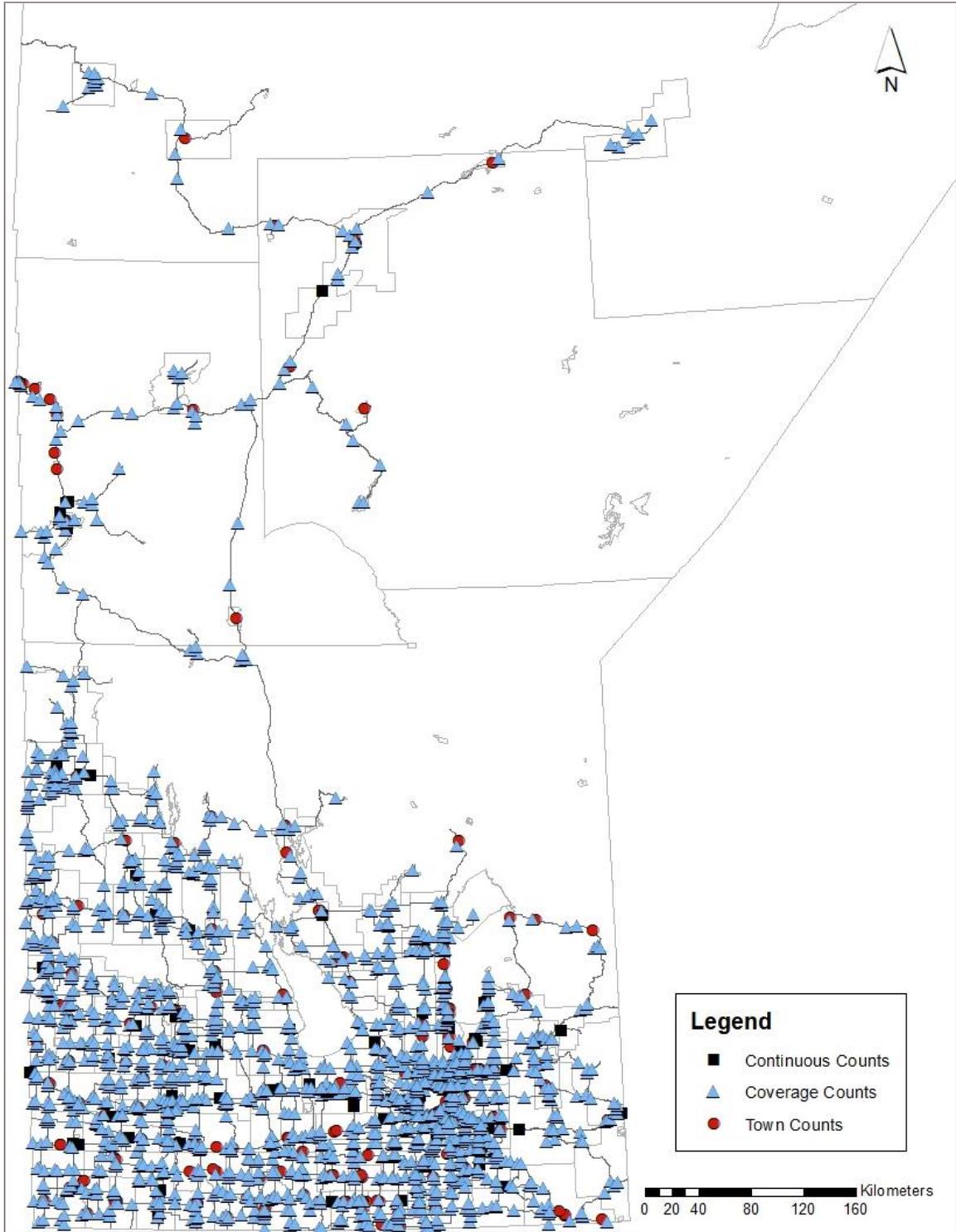
Figure 4: Traffic count stations in Manitoba, 2018

Boundary data was obtained from two publicly available sources: Census Canada and the Manitoba Government's ArcGIS Geoportal. The data from Census Canada includes three datasets: (1) census subdivision boundaries, (2) census population centre boundaries, and (3) census designated places boundaries. The Manitoba Government dataset containes Manitoba's municipal boundaries. Table 9 provides a summary of important information for each dataset. Note that the "number of towns" column indicates how many of the selected 55 towns that exist within the corresponding dataset.

Table 9: Summary of boundary data sources

Dataset	Description	Geometry Type	Number of Towns	Last Updated
Census Subdivision (CSD)	An area of a municipality as determined by provincial / territorial legislation OR an area deemed to be equivalent to a municipality for statistical purposes. 54 types (Statistics Canada, 2018a).	Polygon	28	2016 Census
Census Population Centre (PC)	An area with a population of at least 1000 people and a population density of 400 persons/km^2. Classified into three groups based on size of population (Statistics Canada, 2018c).	Polygon	49	2016 Census
Census Designated Places (DPL)	An area, normally a small community or settlement that is not considered a CSD or PC. Criteria to be met include: area $\leq$ 10 km^2, does not overlap the area of a PC, follows previous census block structure as much as possible (Statistics Canada, 2018b).	Polygon	12	2016 Census
Manitoba Municipal (MM)	Areas represent descriptions in the Municipal Status and Boundaries Regulation (567/88R) and subsequent amendments. Three types: cities, towns and villages, and rural municipalities (Government of Manitoba, 2016).	Polygon	27	Current to most recent regulation amendments

As shown in Table 9, some identified towns exist in multiple datasets. In order to proceed with the analysis, a single boundary needed to be selected. The overarching goal to determine which boundary to use, is to be the least restrictive and most descriptive as possible. The following steps are used to select the boundary.

1. If the town is in only one dataset, select the boundary from that dataset.
2. If the town is in multiple datasets but only satisfies the population and population density requirements for one dataset, select the boundary from the dataset that satisfies the requirements.
3. If the town is in multiple datasets and the population and population density requirements are satisfied in multiple datasets, select the boundary from the dataset with the larger population.
   3.1. If the CSD dataset has the larger population and the town is also in the MM dataset, select the boundary from the MM dataset. The MM data source is updated more frequently and was deemed to be more reliable in the event of inconsistencies between these two datasets. Note that in many cases these datasets were the same or nearly identical.
   3.2. If the town is in two datasets with identical data, select the boundary from the dataset with the more descriptive geographic type. For example, PC data only indicates the relative size (small, medium, large), where the CDS, DPL, and MM datasets all indicate geographic type (city, LUD, town, UUC, village).

To illustrate, consider the cases of Flin Flon, Dauphin, and Blumenort.

- Flin Flon exists in the MM, CSD, and PC datasets. The population and population density requirements are met in the PC dataset, but the density requirement is not met in the CSD or MM dataset. Therefore, as a result of Step 2, the PC boundary is selected for Flin Flon.

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- Dauphin also exists in the MM, CSD, and PC datasets. All three datasets meet the population and density requirements, but the CSD population is greater than the PC population. However, because the town is in both the MM and CDS datasets, the MM boundary is selected for Dauphin based on Step 3.1.

- Blumenort exists in the PC and DPL datasets. Population and population density are identical in both datasets and meet the minimum requirements. Therefore, as a result of Step 3.2, the DPL boundary is selected for Blumenort.

Table 10 shows which towns are in the four datasets and which boundary was selected. A single check indicates that it is in the specified dataset, and a double check indicates the boundary dataset that was selected for use. Figure 5 shows the final selected boundaries of the 55 towns within Manitoba. Appendix A provides magnified boundaries for each town.

Table 10: Summary of boundary information for each selected town

Town Name	Manitoba Municipal (MM)	Census Subdivision (CSD)	Census Population Centre (PC)	Census Designated Place (DPL)
Altona	✓✓	✓	✓	
Arborg	✓✓	✓	✓	
Beausejour	✓✓	✓	✓	
Blumenort			✓	✓✓
Boissevain			✓✓	
Brandon	✓✓	✓	✓	
Carberry	✓	✓	✓✓	
Carman	✓✓	✓	✓	
Chemawawin 2		✓✓		
Cross Lake 19A			✓✓	
Dauphin	✓✓	✓	✓	
Deloraine				✓✓
Flin Flon	✓	✓	✓✓	
Gimli			✓✓	
Grunthal			✓	✓✓
Ile des Chênes			✓	✓✓
Killarney			✓✓	
La Salle			✓✓	✓

Town Name	Manitoba Municipal (MM)	Census Subdivision (CSD)	Census Population Centre (PC)	Census Designated Place (DPL)
Lac du Bonnet	✓✓	✓	✓	
Landmark			✓	✓✓
Lorette			✓	✓✓
MacGregor				✓✓
Melita	✓✓	✓		
Minnedosa	✓	✓	✓✓	
Mitchell			✓✓	✓
Moose Lake			✓✓	✓
Morden	✓✓	✓	✓	
Morris	✓	✓	✓✓	
Neepawa	✓	✓	✓✓	
Niverville	✓✓	✓	✓	
Oak Bluff			✓✓	
Oakbank			✓✓	
Pinawa			✓✓	
Portage la Prairie	✓✓	✓	✓	
Rivers			✓✓	
Roblin			✓✓	
Russell			✓✓	
Selkirk	✓✓	✓	✓	
Shilo CFB-BFC			✓✓	
Souris			✓✓	
St. Adolphe			✓✓	
St. Theresa Point			✓✓	
Ste. Anne	✓✓	✓	✓	
Ste. Rose du Lac				✓✓
Steinbach	✓✓	✓	✓	
Stonewall	✓✓	✓	✓	
Stony Mountain			✓✓	
St-Pierre-Jolys	✓✓	✓	✓	
Swan River	✓✓	✓	✓	
Teulon	✓	✓	✓✓	
The Pas	✓	✓	✓✓	
Thompson	✓✓	✓	✓	
Tyndall (Tyndall-Garson)				✓✓
Virden	✓	✓	✓✓	
Winkler	✓✓	✓	✓	
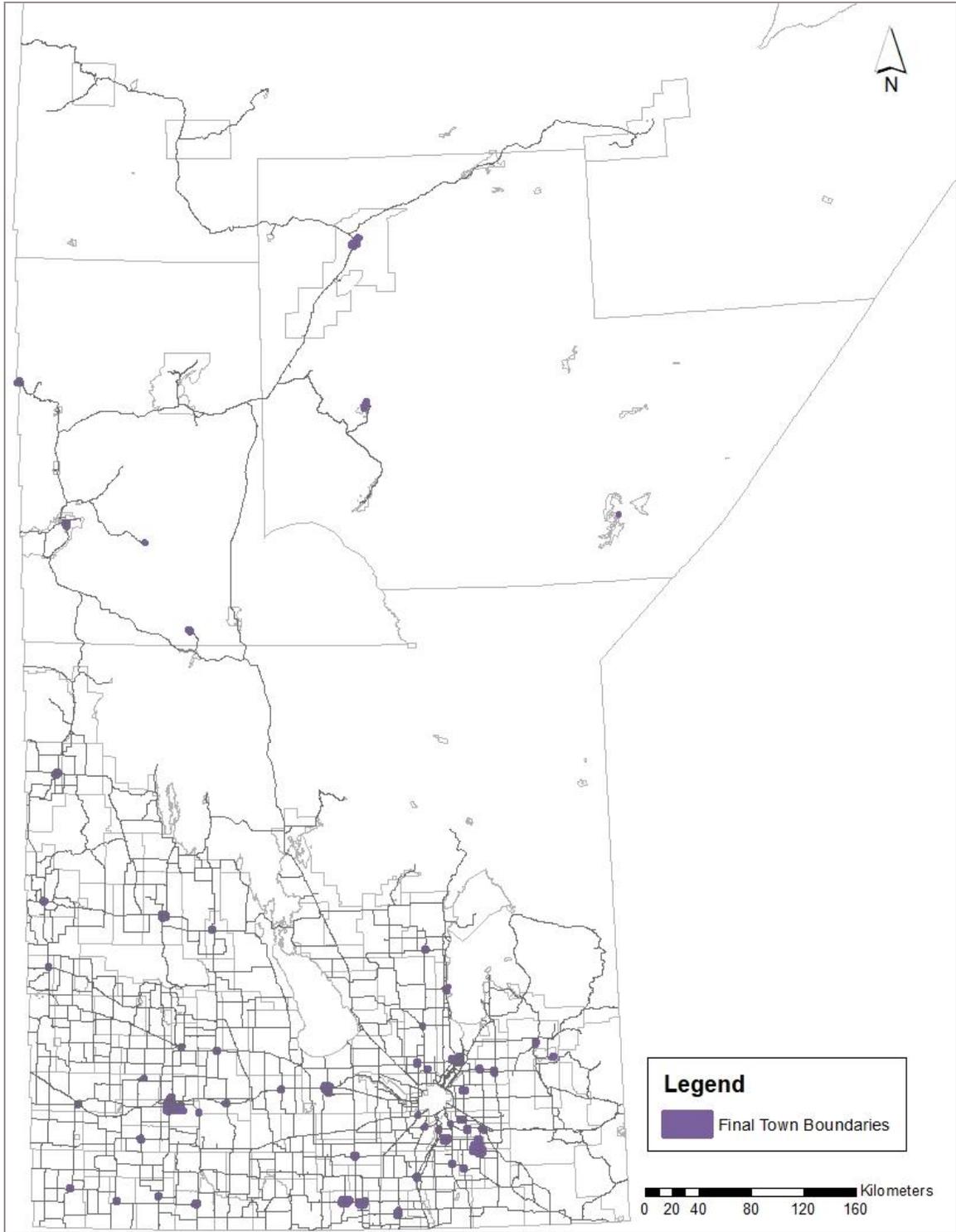
Figure 5: Boundaries of the 55 Manitoba locations identified as towns

3.2 DETERMINATION OF AADT FROM TOWN COUNTS

This section outlines the procedure to determine AADT from counts identified as town counts (i.e., Objective 2 of the research). It presents details of the data collection framework and the data analysis procedures.

3.2.1 Data Collection

The data collection framework comprises three elements:

1. The data collection plan, which states what data to collect and why to collect it.

2. The selection of sample sites, which identifies where to collect the data.

3. The data collection procedure, which describes how, when and by whom the data is collected.

Data Collection Plan

Determining AADT from town counts begins with developing a method to study the temporal patterns at these locations. The method established involves collecting hourly volume data for seven consecutive days at a representative sample of short-duration count locations two times during Manitoba's 2019 coverage count program. The intent is for this data to demonstrate a typical week at the sample site. This data enables the development of the following three temporal traffic volume patterns at the sample sites:

1) Hourly distribution

2) DOW distribution

3) Simplified monthly distribution (using monthly ratios of the two installations)

However, due to missing data, monthly distributions could not be explored in this thesis.

Identifying the traffic periodicities at the sample sites allows these patterns to be compared to the average periodicities known to exist in Manitoba, which are categorized through the TPGs. Detecting which TPG most closely matches the traffic periodicities

observed at short-duration counts identified to be town counts enables the 2-day

volumes collected at these sites to be expanded into AADT estimates, in the same way

they are for non-town short-duration counts in Manitoba.

Table 11 summarizes the traffic volume and geographical characteristics for each of the

seven TPGs in Manitoba. Appendix B provides detailed information about the traffic

periodicities experienced in 2019 for each TPG.

Table 11: Summary of hourly, DOW, and seasonal traffic patterns and geographic attributes for each TPG in Manitoba. Adapted from "*Traffic on Manitoba Highways 2019,*" by Olfert et al.

TPG	Hourly Patterns	DOW Patterns	Seasonal Patterns	Geographic Characteristics
TPG 1	• High morning and afternoon peaks on weakdays.	• Steady weekday traffic. • Moderate Friday peak. • Lower weekend volume.	• Low seasonal variations.	• Routes near major urban centres of Winnipeg and Brandon.
TPG 2	• Steady traffic that increases and decreases throughout the day on weekdays and weekends.	• Steady weekday traffic. • Moderate Friday peak. • Lower weekend volume. • Similar to TPG1.	• Moderate seasonal variations.	• Routes not adjacent to population centres. • Routes serve longer-trip purposes.
TPG 3	• Weekday afternoon peaks higher than weekday morning peaks.	• Weekday traffic lower than weekend traffic. • High Friday and Sunday peaks.	• Very high summer peak.	• Routes not adjacent to population centres. • Routes serve longer-trip purposes and lead to recreational destinations.
TPG 4	• Weekday afternoon peaks higher than weekday morning peaks.	• Steady weekday traffic. • Moderate Friday peak. • Lower weekend volume. • Similar to TPG1.	• Low seasonal variations. • Similar to TPG 1.	• Routes lie adjacent to rural population centres.
TPG 5	• Weekday afternoon peaks higher than weekday morning peaks (similar to TPG 4). • Steady increase in weekend traffic throughout the day.	• Steady weekday traffic. • Moderate Friday and Sunday peaks.	• High summer peak.	• Routes lie adjacent to population centres. • Routes lead to recreational destinations.

TPG	Hourly Patterns	DOW Patterns	Seasonal Patterns	Geographic Characteristics
TPG 6	• Very high daytime weekend traffic compared to daytime weekday traffic.	• Weekday traffic lower than weekend traffic. • High Friday and Sunday Peaks. • Similar to TPG 3.	• Very high summer peak. • Similar to TPG 3.	• Routes lead to recreational destinations such as provincial parks.
TPG 7	• Weekday afternoon peaks higher than weekday morning peaks. • Similar to TPG 4.	• Steady weekday traffic. • Moderate Friday peak. • Lower weekend volume. • Similar to TPG 1.	• High summer peak. • Similar to TPG 5.	• Routes are located in northern Manitoba (north of the intersection of PTH 6 and PTH 60). • Routes have some commuter traffic. • Routes lead to recreational destinations.

Selection of Sample Sites

The next step is to select a representative sample of short-duration town counts to study.

The data collection was planned for the summer months of 2019, and during this count

period, 115 of Manitoba's 327 current town counts (prior to conducting the analysis

described in Section 3.1.1) were scheduled to be surveyed. However, it was not realistic

to collect data at all 115 locations. Through correspondence with MI's traffic monitoring

staff, it was concluded that collecting hourly data for seven consecutive days at between

10 and 15 count sites was realistic within the 2019 coverage count program.

Twelve of the 115 counts are located on roadways with unknown speed limits, and as a

result they are removed from the list of possible sample locations. The remaining 103

count sites are evaluated to select a list of sites that satisfy the following requirements:

- Counts on roadways with a variety of speed limits.

- Counts located in towns of varying population.

- Counts located at different places within a town such as, town centre, on a

   highway leading to/from a town, or on a highway bypassing a town.

- Counts on PTHs, PRs, and PARs.

- Preference given to towns with multiple counters to demonstrate:

  o The impacts of speed reduction.

  o The impacts of different roadside environments.

In total, 13 count stations, in six towns, are selected for data collection. Table 12 provides a summary of the important attributes for each selected sample site.

Table 12: Characteristics of the 13 selected sample sites

Station Number [a]	Town	Town Population (2016)	Town Size	Speed Limit	Highway Number	Highway Orientation
5049 (c)	Beausejour	3219	Small	70	PR 215	Leading to/from town
5051 (e/w)				50	PR 215	Town centre
5055 (c)				100	PTH 44	Bypass town
2469 (c)	Brandon	48,859	Large	60	PAR 800	Leading to/from town
5123 (n/s)				50	PTH 1A	Town centre
5135 (n/s)				70	PTH 1A	Town centre
5139 (e/w)				80	PTH 1	Bypass town
5220 (c)	Deloraine	978	Very small	50	PAR 618	Town centre
5222 (c)				90	PAR 618	Leading to/from town
5518 (c)	Melita	1042	Very small	40	PAR 644	Town centre
5942 (c)	Souris	1876	Small	50	PTH 2	Town centre
6013 (e/w)	Thompson	13,678	Medium	70	PR 391	Town centre
6016 (e/w)				50	PR 391	Town centre

[a] This column specifies whether the data collected at the station is directional (east/west or north/south) or combined (c).

The following six subsections provide a description of each town, descriptions of the individual count locations within the town, and the specific reasons each count location is selected.

Beausejour Sites

Beausejour (population: 3219), an incorporated town surrounded by the Rural
Municipality of Brokenhead, is located 46 kilometres northeast of Winnipeg, Manitoba's
capital city. It is en route to popular recreational destinations, including Whiteshell
Provincial Park. Given its proximity to these recreational areas, tourism is a major
economic driver in the town. In addition, the economy relies heavily on agriculture,
specifically grain production. The town also acts as a commercial area for surrounding
populations.

As shown in Figure 6, the major highway routes servicing Beausejour are as follows:

- PTH 44 and PR 215 from the west

- PTH 44 from the east

- PTH 12 from the north

- PR 302 from the south

PTH 44, PR 215, and PR 302 intersect at the east side of the town.

Figure 6 identifies (using an asterisk) the three selected count sites in Beausejour:
Station 5049, Station 5051, and Station 5055.
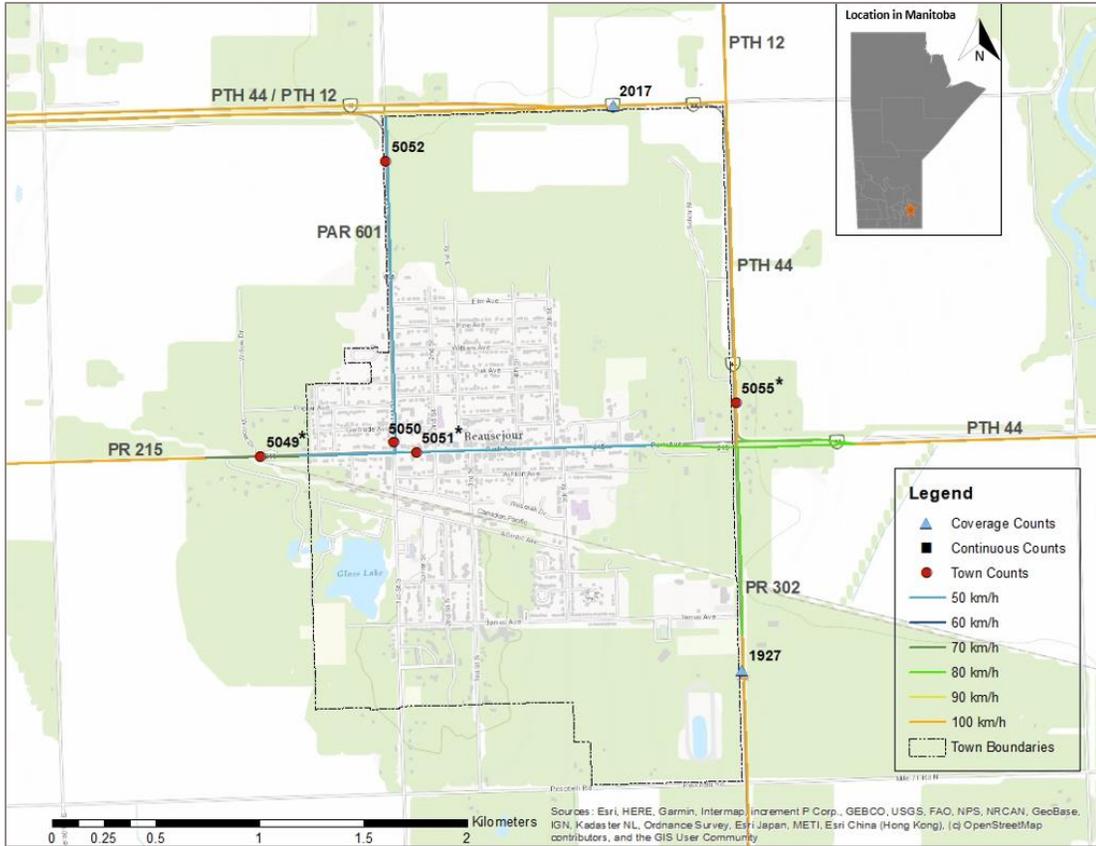
Figure 6: Town counts in Beausejour, Manitoba

Figure 7, Figure 8, and Figure 9 show the roadside environment at each of the three
count sites, Station 5049, Station 5051, and Station 5055, respectively.

- Station 5049: At this site, PR 215 is a two-lane highway with gravel shoulders
  and a speed limit of 70 km/h. This count is located just west of Beausejour's town
  boundary where the roadside consists of a field to the north and vegetation to the
  south. Accesses to private residences are provided at this location.

- Station 5051: This site is also located on PR 215, but is in the town centre. At this
  location, PR 215 is a two-lane roadway with angled parking and sidewalks on
  both sides and a speed limit of 50 km/h. The roadside environment comprises
  small businesses and accesses to business parking lots and local roadways.

- Station 5055: This site is located on PTH 44, at the eastern edge of the town boundary. At this location, PTH 44 is a two-lane highway that bypasses Beausejour, has a speed limit of 100 km/h, and has gravel shoulders. An access road on the west side connects the highway to a small commercial business area. The east side of PTH 44 mainly consists of fields.

Figure 7: Roadside environment at Station 5049

Figure 8: Roadside environment at Station 5051

Retrieved from: Street View, *GoogleMaps*
Image capture: Oct 2018
Image accessed: March 2021
Facing: South

Figure 9: Roadside environment at Station 5055

The counts in Beausejour were selected for the following reasons:

- Station 5049 and Station 5051 were selected to demonstrate the impacts of different speed limits within a small town.

- Station 5055 was selected to study traffic patterns evident on a bypass highway.

- Lastly, the intent of selecting three count stations with different roadside characteristics was to reveal the associated impacts on traffic patterns.

Brandon Sites

Brandon (population: 48,859) is the second largest city in Manitoba. It is situated in the southwest portion of the province and is approximately 200 kilometres west of Winnipeg and 120 kilometres east of the Saskatchewan border. Brandon was incorporated as a city in 1882 and is the primary hub of trade and commerce for the Westman Region of Manitoba. The economy is predominantly associated with agriculture but is also largely centered in healthcare, manufacturing, food processing, education, business services, and transportation sectors. Four post-secondary institutions operate in Brandon. The Western Hockey League's Wheat Kings call Brandon home. The city has its own transit network that provides daily service, seven days a week, via 10 bus routes.

As shown in Figure 10, the major highway routes servicing Brandon are as follows:

- PTH 1, PTH 1A, and PR 459 from the west

- PTH 1, PTH 110, PR 457, PAR 800 from the east

- PTH 10 and PTH 1A from the north

- PTH 10 from the south

Brandon is uniquely situated adjacent to the Trans-Canada Highway (PTH 1), a transcontinental federal-provincial highway system that travels through all ten provinces in Canada. As a result, the provincial road network through Brandon is more complex than most other populated areas in Manitoba. PTH 1A is an alternate spur of PTH 1 and is known as 1st Street north-south and Victoria Avenue east-west inside the city limits. The current alignment of PTH 1 allows through traffic to bypass Brandon.

PTH 110 is also known as the Brandon Eastern Access Route. It connects PTH 1 to PTH 10 south of Brandon. It has two intended functions: 1) to allow through traffic to bypass the city and 2) to provide access, mainly for commercial trucks, to the industrial areas located on the east side of Brandon without having to travel through the city.

Figure 10 identifies (using an asterisk) the four selected count sites in Brandon: Station 2469, Station 5123, Station 5135, and Station 5139.
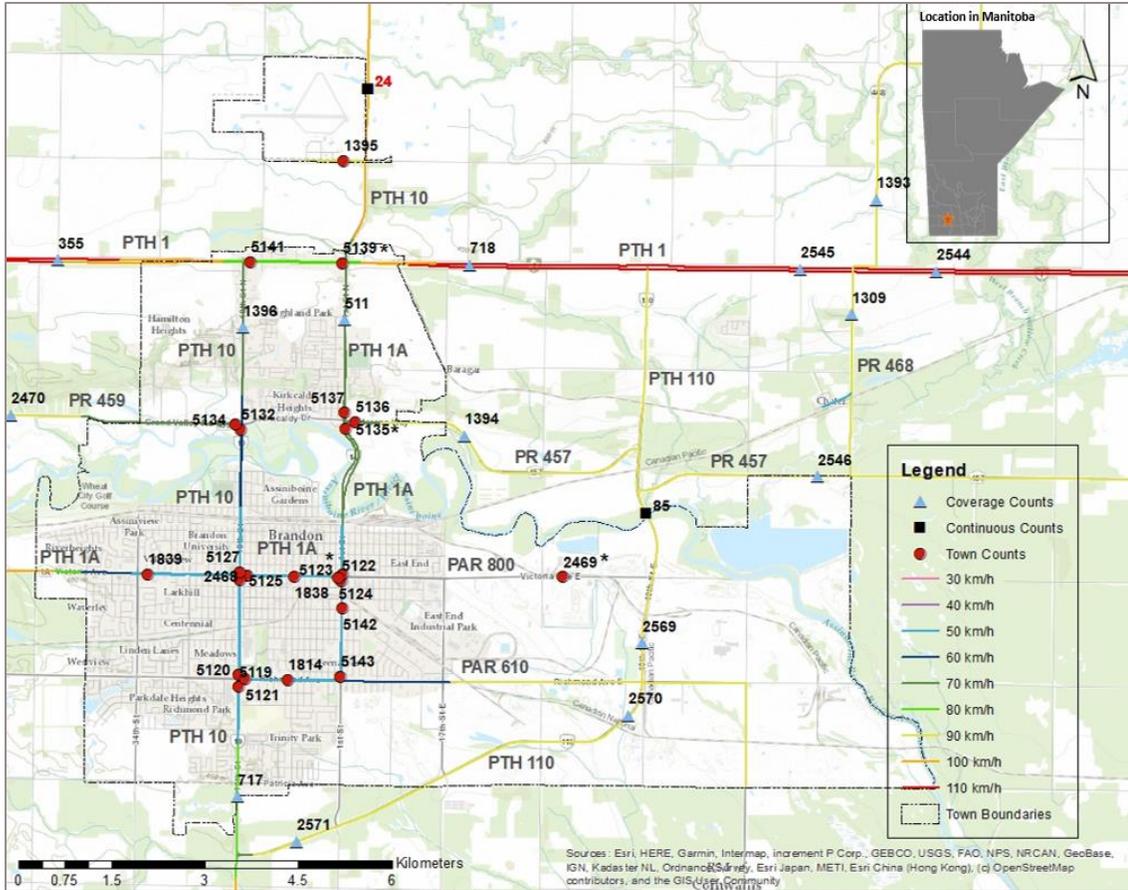
Figure 10: Town counts in Brandon, Manitoba

Figure 11, Figure 12, Figure 13, and Figure 14 show the roadside environment at each of the four count sites, Station 2469, Station 5123, Station 5135, and Station 5139, respectively.

- Station 2469: This station is located on PAR 800, where the speed limit is 60 km/h). At this location, PAR 800 is a two-lane roadway with no shoulder. Brandon's Manitoba Hydro generating station is located on the north side of the roadway in addition to of a group of parallel railways. The south side of PAR 800 contains the Eastview Landfill.

- Station 5123: At this site, PTH 1A (Victoria Avenue) is a four-lane divided arterial with sidewalks on the north and south sides and a speed limit of 50 km/h.

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Storage lanes for left and right turns are provided for northbound traffic. This count is located in a predominantly residential neighbourhood, with accesses to small commercial businesses. The Brandon Regional Health Centre is nearby.

- Station 5135: This station is also located on PTH 1A, but at this location it is called 1st Street. Here PTH 1A is a four-lane divided roadway, with paved shoulders and a speed limit of 70 km/h. Left and right turn storage lanes are provided for northbound traffic approaching the intersection with PR 457. Limited access is provided to PTH 1A at this location and the roadside mainly consists of vegetation, with the Assiniboine River on the west, and an active transportation path and field on the east.

- Station 5139: This station is located on PTH 1, at the northern edge of Brandon's boundary. At this location, PTH 1 is a four-lane divided highway with paved shoulders and a speed limit of 80 km/h. This roadway functions as a bypass of Brandon, and as a result limited access is provided. Parallel access roads provide local access to businesses on the north and south sides of the roadway.

Retrieved from: Street View, *GoogleMaps*
Image capture: Sept 2018
Image accessed: March 2021
Facing: West

Figure 11: Roadside environment at Station 2469

Figure 12: Roadside environment at Station 5123

Figure 13: Roadside environment at Station 5135

Figure 14: Roadside environment at Station 5139

The counts in Brandon were selected for the following reasons:

- Station 2469 was selected because it is one of few counts on a roadway with a speed limit of 60 km/h.

- Station 5123 and Station 5135 were selected to demonstrate the impacts of different speed limits and roadside characteristics in a large town.

- Station 5139 was selected because it is one of few counts on a roadway with a speed limit of 80 km/h and to study traffic patterns evident on a bypass highway.

- Lastly, the intent of selecting four count stations with different roadside qualities in the same town was to reveal the associated impacts on traffic patterns.

Deloraine Sites

Deloraine (population: 978) is an unincorporated urban centre in the Municipality of Deloraine-Winchester. It was incorporated as a town from 1907 to 2015, at which time it amalgamated with the Municipality of Winchester, relinquishing its town status. Located near the Turtle Mountains, in the southwest corner of Manitoba, Deloraine is approximately 100 kilometres south of the city of Brandon and 25 kilometres north of the Canada-United States border. Agriculture and tourism are the driving forces of Deloraine's economy, in addition to its function as a service centre for surrounding communities.

As shown in Figure 15, the highway routes servicing Deloraine are as follows:

- PAR 618, which connects to PTH 3/PTH 21 from the west
- PAR 618, which connects to PTH 3 from the south

The south intersection of PTH 3 and PTH 21 occurs just southwest of Deloraine.

Figure 15 identifies (using an asterisk) the selected count sites in Deloraine: Station 5220 and Station 5222.
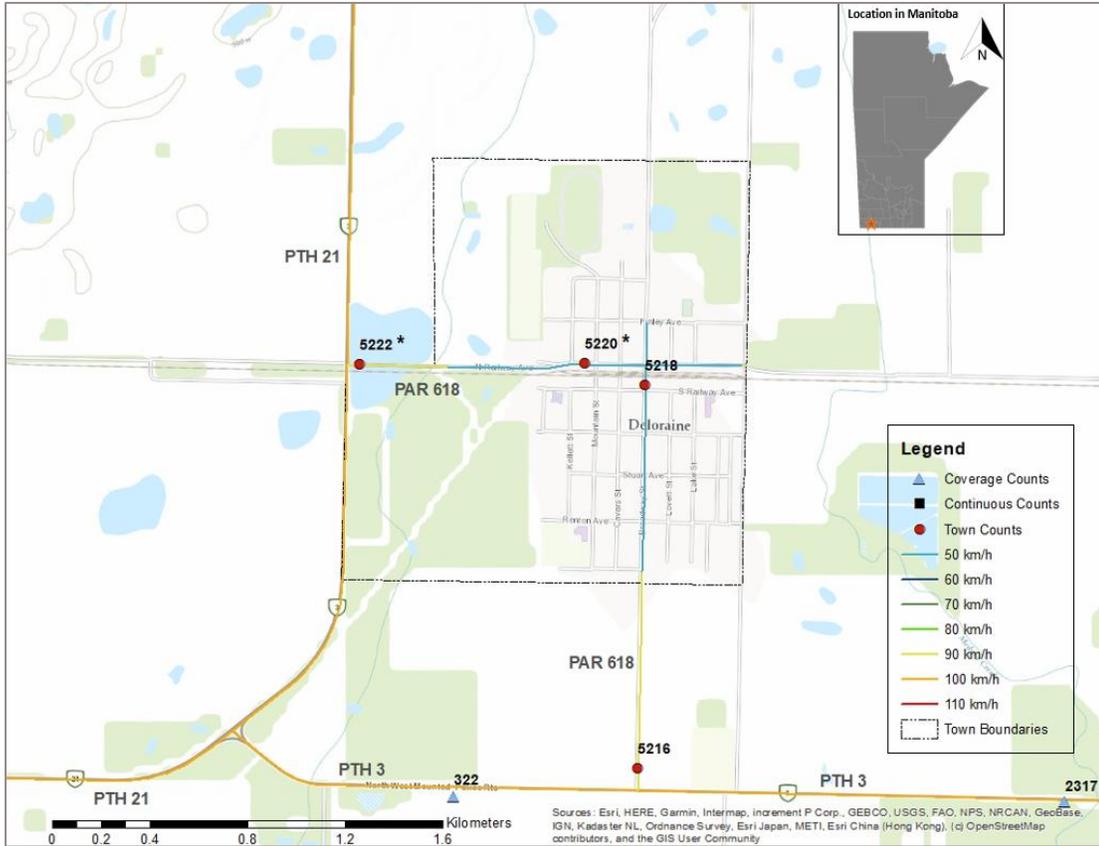
Figure 15: Town counts in Deloraine, Manitoba

Figure 16 and Figure 17 show the roadside environment at Station 5220, and Station 5222, respectively.

- Station 5220: This station is located on PAR 618, near the town centre. At this location, PAR 618 has a speed limit of 50 km/h and is a four-lane roadway with a parking lane and sidewalks on the north side of the road. The north side of the road provides access to residential lots and local roadways. The south side of PAR 618 consists of vacant land, a parallel railway, and local roadways crossing the railway.

- Station 5222: At this location, PAR 618 is a two-lane road with narrow paved shoulders and a speed limit of 90 km/h. This station is located approximately 200 metres east of the two-way stop-controlled intersection connecting PAR 618 to

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PTH3/PTH 21. The roadside consists mainly of agricultural fields, with a parallel railway to the south.

Retrieved from: Street View, *GoogleMaps*
Image capture: Aug 2013
Image accessed: March 2021
Facing: East

Figure 16: Roadside environment at Station 5220

Retrieved from: Street View, *GoogleMaps*
Image capture: Aug 2013
Image accessed: March 2021
Facing: East

Figure 17: Roadside environment at Station 5222

The counts in Deloraine were selected for the following reasons:

- Station 5220 and Station 5222 were selected to demonstrate the impacts that different speed limits and roadside characteristics have on traffic patterns within a very small town.

- Station 5222 was selected to study traffic patterns evident on a high-speed route leading to/from a town.

Melita Site

Melita (population: 1042) is an incorporated town in the southwestern corner of
Manitoba, surrounded by the Municipality of Two Borders. The town is located
approximately 320 kilometres southwest of the City of Winnipeg, 40 kilometres north of
the Canada-United States border and is about 40 kilometres northwest of Deloraine.
Melita is a service hub for the Southwest corner of Manitoba, with agriculture and the oil
industry providing most of the economic opportunity.

As shown in Figure 18, the major highway routes servicing Melita are as follows:

- PR 445 from the west

- PTH 3 and PTH 83 from the east

- PTH 83 from the north

- PTH 3 from the south

The north junction of PTH 3 and PTH 83 exists at the south side of the town.

Figure 18 shows (using an asterisk) the selected count site in Melita: Station 5518. This
station is located on PAR 644, approximately 40 metres west of the junction of PTH 83
and PAR 644. At this location, PAR 644 is a two-lane roadway and has a speed limit of
40 km/h. The north side of the road features sidewalks and accesses to residential lots
and local roadways. On the south side of PAR 644, there is a parallel railway and a
small park featuring Melita's historic landmark.

Figure 19 displays the roadside environment at Station 5518.
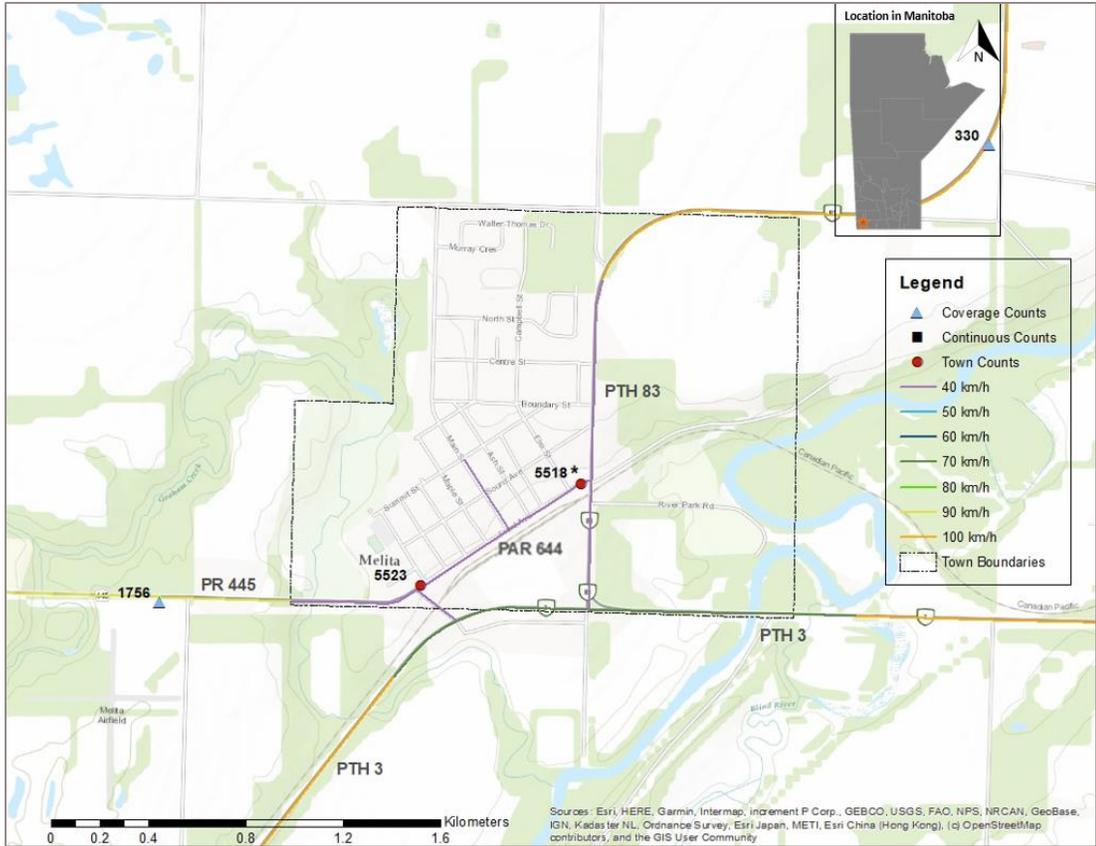
Figure 18: Town counts in Melita, Manitoba

Figure 19: Roadside environment at Station 5518

The count in Melita was selected to study the effects of a 40 km/h speed limit. This was

the only site scheduled to be surveyed in 2019 with this characteristic.

Souris Site

Souris (population: 1876) is an unincorporated urban centre in the Municipality of Souris-Glenwood. In 1904, it was incorporated as a town, surrounded by the former Rural Municipality of Glenwood, until its amalgamation with the rural municipality in 2015. Located in southwestern Manitoba, Souris is approximately 40 kilometres southwest of Brandon, and about 250 kilometres southwest of Winnipeg. The economic drivers of Souris are agriculture, education, and healthcare.

As shown in Figure 20, the major highway routes servicing Souris are as follows:

- PTH 2 from the west and east
- PR 250 from the north
- PTH 22 from the south

Souris is unique in the sense that a primary provincial highway, PTH 2, runs directly through the town and functions as Souris's main street, called First Avenue. PTH 2, PTH 22, and PR 250 intersect in the town centre.

Figure 20 identifies (using an asterisk) the selected count site in Souris: Station 5942. At this station, PTH 2 transitions from a two-lane roadway to the four-lane undivided roadway present at the junction of PTH 2, PTH 22, and PR 250. There are sidewalks on both sides of the road and the speed limit is 50 km/h. The roadside consists of accesses to residential and small commercial lots.

Figure 21 displays the roadside environment at Station 5942.
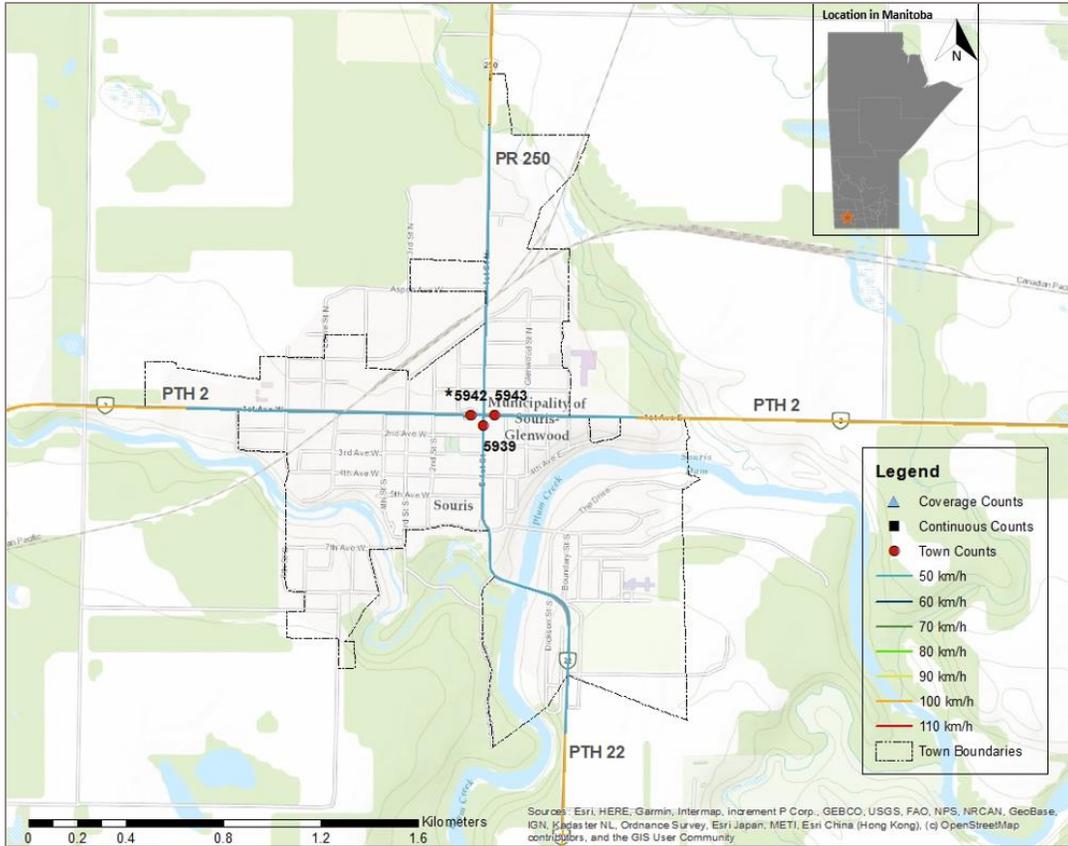
Figure 20: Town counts in Souris, Manitoba

Figure 21: Roadside environment at Station 5942

The count in Souris was selected to study the traffic patterns evident on a primary

provincial highway running through a small town, rather than bypassing the town.

Thompson Sites

Thompson (population: 13,678) is a city located in the Northern Region of Manitoba, approximately 760 kilometres north of Winnipeg. Founded in 1956 as a mining town, Thompson was incorporated as a town in 1967 and gained city status in 1970. As the largest community in northern Manitoba, Thompson primarily serves as a hub to provide goods and services to the surrounding communities. Thompson's nickel mining industry remains one of the City's largest economic sectors. Other major economic drivers include healthcare, accommodation and food services, education, and retail. Additionally, the untouched nature in the area and proximity to Paint Lake Provincial Park attracts outdoor enthusiasts and recreational visits.

As shown in Figure 22, the major highway routes servicing Thompson are as follows:

- PR 391 from the north
- PTH 6 from the south

The junction of PTH 6 and PR 391 occurs at the southern edge of the City of Thompson. In addition to highways, transport by railroad and air also provide connections between Thompson and Winnipeg.

Figure 22 identifies (using an asterisk) the two selected count sites in Thompson: Station 6013 and Station 6016.
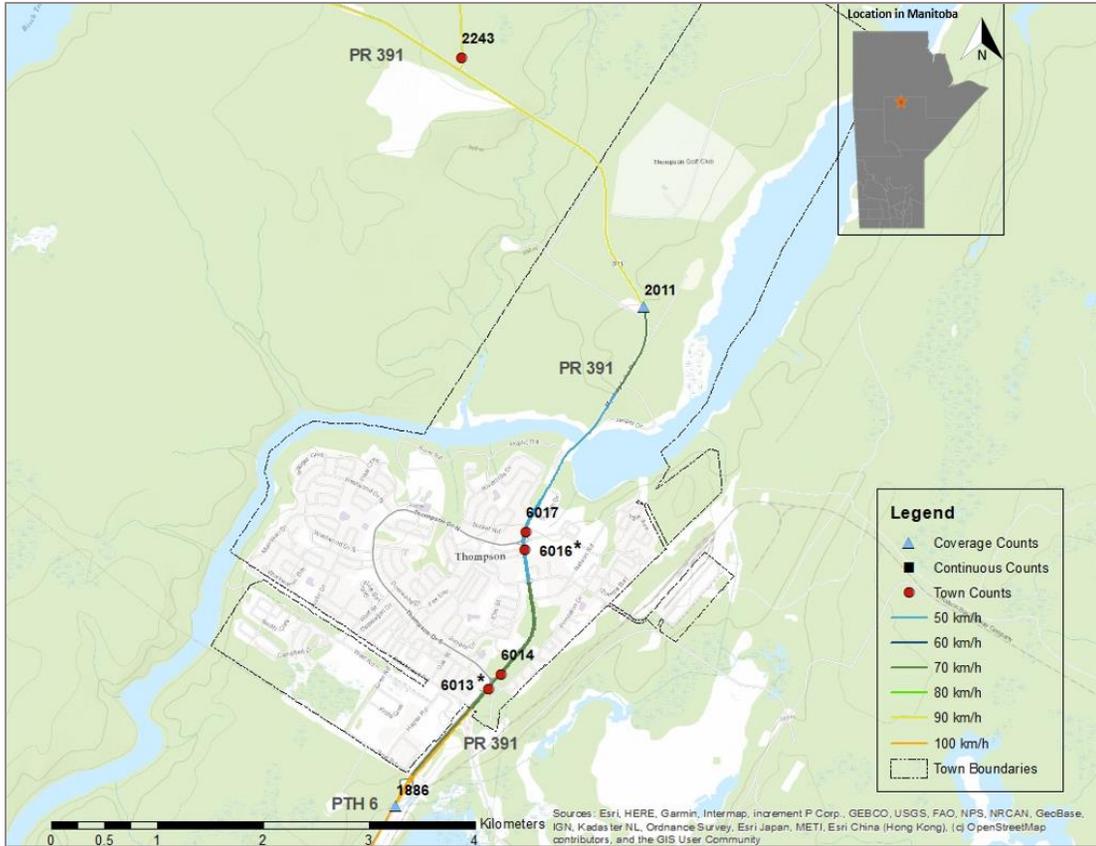
Figure 22: Town counts in Thompson, Manitoba

Figure 23 and Figure 24 show the roadside at Stations 6013, and 6016, respectively.

- Station 6013: This station is located on PR 391, near the southern boundary of Thompson. At this location, PR 391 is a four-lane divided roadway with a left turn storage lane for northbound vehicles, paved shoulders, and a speed limit of 70 km/h. Limited access is provided to PR 391 at this location and the roadside mainly consists of vegetation.

- Station 6016: At this station, PR 391 is a two-lane divided road with a speed limit of 50 km/h and multiple access points for northbound and southbound vehicles. In the northbound direction there are left and right turn storage lanes. There are sidewalks on both sides of the roadway and a pedestrian crosswalk with overhead flashing beacons exists on PR 391 approximately 60 metres south of

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the location of Station 6016. On the east side of PR 391 there is a mall, and to the west there are many smaller commercial businesses.

Figure 23: Roadside environment at Station 6013

Figure 24: Roadside environment at Station 6016

The counts in Thompson were selected for the following reasons:

- Station 6013 and Station 6016 were selected to demonstrate the impacts that different speed limits and roadside characteristics have on traffic patterns within a medium sized town.

- The roadside environment at Station 6016 is much more complex than other count locations scheduled to be surveyed in the 2019 count program.

Data Collection Procedure

Data collection at the 13 sample sites occurred in the summer months of 2019. The installations were scheduled and completed by MI's Traffic Monitoring Program staff in conjunction with their 2019 coverage count program. Count data was collected using a single pneumatic tube connected to a Traffic Tally 6, which is a portable road tube time-interval counter manufactured by Diamond Traffic Products. The counter can be set to record vehicle volumes at a variety of intervals (15 minutes, 30 minutes, 1 hour, 6 hours, 12 hours, 1 day) and has the capability of being set to automatically stop counting after a specified number of days (Diamond Traffic Products, 2019). This configuration is only able to record vehicle volume; it can not classify vehicles. The tubes are secured to the pavement on each side of the roadway using a strap surrounding the tube and nails. The tube is then connected to the counter box, and any excess tube and the counter box are secured to a nearby fixed object such as a post or tree with a chain and lock. For stations with directional counts, each direction uses its own tube and counter. Figure 25 shows the installation of a tube. Figure 26 shows the installation of a counter.

Installing securing strap | Tube secured at side without counter | Tube secured at side with counter

Figure 25: Installation of a traffic tube

Figure 26: Installation of a traffic counter

To collect data for this thesis, the counters were set to record vehicle volume at 1-hour intervals for a total run time of 7 days. This ensured the hourly and DOW analyses could be completed appropriately. Once the data was collected, MI staff retrieved the data from the counters and provided a summary of the volume information for each installation via a spreadsheet. Two 1-hour on-site manual counts were performed in Beausejour to verify that the equipment could obtain accurate count data.

In total, 33 installations were scheduled across the 13 sample site stations. This included the two expected installations at each count location as well as a third installation at some locations due to data errors during the first installation. Locations with a scheduled third installation included Beausejour, Melita, Deloraine, and Souris. Table 13 shows the time period of each installation at each of the count sites. A dash indicates the scheduled survey was not completed. Since multiple surveys were counted at a single site, from this point on, an individual survey will be denoted as "Station Number-Installation Number" (e.g., the second installation at Station 5055 will be denoted as 5055-2).

Table 13: Summary of installation dates for each count station

Station Number	Town	Installation 1	Installation 2	Installation 3
5049	Beausejour	May 27 to June 3[a]	July 16 to July 23	Aug 12 to Aug 19
5051		May 27 to June 3[a]	July 16 to July 23	Aug 12 to Aug 19
5055		July 4 to July 11	July 16 to July 23	Aug 12 to Aug 19
5518	Melita	June 3 to June 10[a]	July 29 to Aug 5	-
5220	Deloraine	June 4 to June 10[a]	July 29 to Aug 5	-
5222		June 4 to June 10[a]	July 29 to Aug 5	-
5942	Souris	-	Aug 29 to Sept 5	-
6013	Thompson	-	-	
6016		-	-	
2469	Brandon	June 25 to July 2	Aug 6 to Aug 13	
5139		June 25 to July 2	Aug 7 to Aug 14	
5123		June 25 to July 2	Aug 7 to Aug 14	
5135		June 25 to July 2	Aug 7 to Aug 14	

[a] Hourly volume unavailable; these surveys recorded daily rather than hourly volumes.

To illustrate the equipment setup, Figure 27 shows the installation at each of the three count stations in Beausejour: Station 5049, Station 5051, and Station 5055. Station 5051 records directional volume and therefore uses a two-counter configuration as shown.

Figure 27: Equipment installations in Beausejour, 2019

3.2.2 Data Analysis

The data analysis consists of three parts:

1. The data screening procedure, which identifies and addresses data errors.

2. The assignment of town counts to TPGs by matching temporal distributions.

3. The results validation, which confirms the chosen assignments.

Data Screening Procedure

The first step in the data analysis is to screen data in each survey for abnormalities or other concerns, and subsequently fix or remove the errors. The surveys are intended to represent a typical week at the sample site, so it is important to identify any irregular patterns to ensure the data used in the statistical analysis meet this requirement. The criteria used to detect abnormalities, explanations of the potential causes of these concerns, and the decision process to fix or remove the errors are explained in detail. Table 14 describes the five criteria that are used to identify abnormal data.

Table 14: Descriptions of the five criteria used to detect abnormal data

Criterion ID	Criterion Description
1	Survey not conducted.
2	Survey with missing data.
	2.1 – More than 24 hours of missing data.
	2.2 – More than 0 but less than 24 hours of missing data
3	Survey that occurs during an event expected to cause irregular changes/patterns in traffic volume[a]
4	Survey with abnormal hourly volumes[b]
	4.1 – A single hourly volume that has more than a 100% difference relative to the same hour in another day of the week. Hourly volumes before and after the abnormal value are also reviewed to determine if the change was abrupt or gradual.
	4.2 – A single hourly volume that has more than a 100% difference relative to the previous or next hour in the current day. Steady increases and decreases in volume are expected.

Criterion ID	Criterion Description
5	Survey with abnormal daily volumes.
	5.1 – A daily volume that has more than a 25% difference relative to the next or previous day.
	5.2 – A peak daily volume on an unexpected day of the week, such as Wednesday.

ª Example: a long weekend or the start of school.
ᵇ Extra scrutiny was given to hourly volumes less than 15 vehicles/hour due to the uncertainty associated with very low volumes.

After the abnormalities are identified, the next step is to determine the cause of the concern and pinpoint how many hours are impacted by the concern. This step is particularly important for surveys with abnormal hourly or daily volumes because the decision to accept or reject the survey relies heavily on the cause of the data abnormality. It is also important to identify the cause of missing data because if the counter malfunctioned, data leading up to the missing values could be inaccurate.

Questions to aid in identifying the cause of the concern follow:

- Did the missing data occur due to equipment failure? Do the volumes before the missing data make sense?

- Was there an intra-town event, such as a festival that could result in the abnormal hourly or daily volumes observed? Is it clear how many hours are affected by the event?

- How many hours in the survey are affected by the event expected to cause irregular volume patterns? If it is less than 24 hours, those "irregular" hours can be treated as "abnormal" hourly volumes (criterion 4) instead.

- Did the daily volume difference of more than 25% occur between a weekday daily volume and weekend daily volume? If so, this may be normal.

- If there are two or more complete surveys at the same location, do both surveys experience the abnormality? It is possible it is a result of the count location?

Finally, based on the cause of the concern, the survey can be:

1. Accepted without changes
2. Accepted with changes
3. Rejected

A survey is accepted without changes if any of the following situations apply:

- A survey that has no abnormal data identified.

- A survey with more than 24 hours affected by an event that caused irregular patterns in traffic volume at the sample location that would also be expected to affect traffic volume patterns at continuous count stations. Such events include a long weekend or the start of school. These surveys qualify for an Equivalent Week Analysis (EQWA), which is described further in the Assignment of Sample Sites to TPGs.

A survey is accepted with changes if any of the following situations apply:

- A survey that has a single hour of missing or abnormal data. It is assumed the missing data in this situation can be reliably imputed using data from the survey.

- A survey that is missing between 2 and 24 hours of data. It is assumed the missing data in this situation can be reliably imputed if a second survey at the same location exists.

- A survey that has between 2 and 24 consecutive hours of abnormal hourly volumes. It is assumed these hours can be reliably imputed if a second survey at the same location exists.

A survey is rejected if any of the following situations apply:

- A survey that is missing more than 24 hours of data. It is assumed this much missing data could not be reliably imputed.

- A survey with abnormal hourly volumes prior to the missing data, such that the total consecutive number of abnormal and missing data hours is more than 24. It is assumed this much missing and abnormal data could not be reliably imputed.

- A survey that occurs during an intra-town event. These events are localized to the town, and therefore are not expected to affect volume patterns at continuous count stations. Additionally, it is difficult to identify all the hours impacted by the intra-town event; therefore, the abnormal data can not be reliably imputed.

- A survey that has less than 24 hours of missing or abnormal data but does not meet the requirements for imputation.

In situations where data imputation is reasonable, the method of imputing data is based on how many hours require imputation, and whether a second survey at the same location is available. If more than 1 hour of imputation is required, a second survey at the same location is necessary to perform the imputation method described below. If a second survey is unavailable, other methods of imputation could be considered. However, if the data can not be reliably imputed, the survey should be rejected.

In cases where there is a single abnormal or missing hourly volume, the value in question should be replaced by calculating the average of the volume for the hour prior to and the volume for the hour after the unusual value.

In cases where there are multiple consecutive abnormal or missing hourly volumes, these unusual values can be calculated using the volume relationship between the day with unusual data, and another day of the week that is expected to have similar hourly volume patterns. To explain this process, consider the following example. Two surveys are completed at location A (call them survey 1 and survey 2). Survey 1 does not have any abnormal data. Survey 2 is missing data for hours 11 through 15 on Monday. Equation 2 demonstrates how the missing volume for hour 11 is calculated.

Equation 2

$$Hour\ 11_{Mon\ @\ Survey\ 2} = Hour\ 11_{Tues\ @\ Survey\ 2} \times \frac{Daily\ Volume_{Mon\ @\ Survey\ 1}}{Daily\ Volume_{Tues\ @\ Survey\ 2}}$$

Table 15 summarizes the outcomes of the data screening procedure. Of the 33 scheduled surveys, 9 were unable to be performed due to resource limitations. Of the 24 conducted surveys, 11 are accepted without changes, of which four qualify for EQWA, three are accepted with changes, and 10 are rejected. The high rejection rate is mainly attributed to large amounts of missing data and unexpected intra-town events.

Table 15: Outcomes from the data screening procedure

Survey		Abnormal Data Concerns	Cause of Concern	Decision
BEAUSEJOUR	5049-1[a]	N/A	No abnormal data identified.	Accept without changes
	5051-1[a]	N/A	No abnormal data identified.	Accept without changes
	5055-1	N/A	No abnormal data identified.	Accept without changes
	5049-2	1. Criterion 2.2 2. Criterion 4.1	1. Data missing for last 22 hours. 2. Intratown event – Manitoba Gospel Jamboree. Affects up to 72 hours.	Reject
	5051-2	1. Criterion 2.2 2. Criterion 4.1, 4.2, 5.1	1. Data missing for last 22 hours. 2. Intratown event – Manitoba Gospel Jamboree. Affects up to 72 hours.	Reject
	5055-2	1. Criterion 2.1	1. 46 hours of missing data.	Reject
	5049-3	1. Criterion 2.2	1. Data missing for last 23 hours.	Accept with changes
	5051-3	N/A	No abnormal data identified.	Accept without changes
	5055-3	1. Criterion 4.1	1. No cause identified. Pattern not shown in first survey.	Accept with changes
MELITA	5518-1[a]	1. Criterion 2.1	1. 120 hours of missing data.	Reject
	5518-2	1. Criterion 3, 5.1	1. August long weekend, up to 72 hours affected.	Accept without changes: Equivalent Week Analysis
	5518-3	1. Criterion 1	1. Survey not conducted.	N/A

	Survey	Abnormal Data Concerns	Cause of Concern	Decision
DELORAINE	5220-1[a]	1. Criterion 2.1	1. 120 hours of missing data.	Reject
	5222-1[a]	1. Criterion 2.1	1. 120 hours of missing data.	Reject
	5220-2	1. Criterion 3	1. August long weekend, up to 60 hours affected.	Accept without changes: Equivalent Week Analysis
	5222-2	1. Criterion 3	1. August long weekend, up to 60 hours affected	Accept without changes: Equivalent Week Analysis
	5220-3	1. Criterion 1	1. Survey not conducted.	N/A
	5222-3	1. Criterion 1	1. Survey not conducted.	N/A
SOURIS	5942-1	1. Criterion 1	1. Survey not conducted.	N/A
	5942-2	1. Criterion 3 2. Criterion 5.1, 5.2	1. September long weekend, up to 72 hours affected. 2. First day of school (September 4th) begins on day 7 of survey.	Accept without changes: Equivalent Week Analysis
	5942-3	1. Criterion 1	1. Survey not conducted.	N/A
THOMPSON	6013-1	1. Criterion 1	1. Survey not conducted.	N/A
	6016-1	1. Criterion 1	1. Survey not conducted.	N/A
	6013-2	1. Criterion 1	1. Survey not conducted.	N/A
	6016-2	1. Criterion 1	1. Survey not conducted.	N/A
BRANDON	2469-1	1. Criterion 2.1	1. 141 hours of missing data.	Reject
	5123-1	1. Criterion 3, 5.1 2. Criterion 4.1, 4.2	1. Canada day long weekend, up to 72 hours affected. 2. Intratown event – Canada Day fireworks. Patterns not shown in second survey.	Reject
	5135-1	1. Criterion 3, 5.1 2. Criterion 4.1	1. Canada day long weekend, up to 72 hours affected. 2. Intratown event – Canada Day fireworks. Patterns not shown in second survey.	Reject
	5139-1	1. Criterion 2.1 2. Criterion 3	1. 53 hours of missing data. 2. Canada day long weekend, up to 35 hours affected.	Reject
	2469-2	N/A	No abnormal data identified.	Accept without changes
	5123-2	1. Criterion 4.2, single hour	1. No cause identified. Pattern not shown in first survey.	Accept with changes
	5135-2	N/A	No abnormal data identified.	Accept without changes
	5139-2	N/A	No abnormal data identified.	Accept without changes

[a] Hourly volume unavailable; these surveys recorded daily rather than hourly volumes.

Assignment of Sample Sites to TPGs

The second step in the data analysis is to identify the TPG that most closely matches the hourly and DOW distributions observed at each sample site. A modified cluster analysis is applied to accomplish this task. This section explains the components of a cluster analysis and describes how this method is applied.

A cluster analysis is a statistical tool used to identify groups in a dataset containing multivariate data objects. Clustering methods accomplish this by arranging the data in a way that objects in the same group (called a cluster) are similar to each other and are meaningfully different from the objects in other clusters. In the context of traffic monitoring, clustering techniques are commonly used to develop TPGs (Hasan and Oh, 2020; Madanu *et al.*, 2016; Regehr, *et al.*, 2015; Reimer and Regehr, 2014).

A clustering procedure can be divided into two fundamental steps: 1) choice of proximity measure and 2) choice of clustering algorithm (Härdle and Simar, 2019). Proximity measures quantify the closeness of two data objects. Many proximity measures exist and despite the existence of comparative studies, it can be difficult to select the optimal measure. The factors to consider when selecting a proximity measure are the nature of the data, the scale of the data, and the choice of clustering algorithm. Euclidean distance, formally known as the L_2 norm, is the most common distance measure for continuous variables (Everitt *et al.*, 2011). Clustering algorithms use the proximity results to form clusters. Many clustering techniques have been developed, and similar to proximity measures, there is no objectively correct clustering algorithm. Although all algorithms have the same objective, each one accomplishes this task differently. The three traditional clustering methods are: agglomerative hierarchical models, divisive hierarchical models, and partitioning models (Härdle and Simar, 2019).

In this thesis, a modified form of a cluster analysis is performed since it is only necessary to identify which existing cluster (TPG) the sample site is most similar to, not actually add it to the cluster. To accomplish this, the analysis only considers the first fundamental step: measuring proximity. Additionally, there is added risk in performing a clustering procedure with this data because it is possible that two TPGs may be the most similar objects.

The proximity measure selected is the Euclidean distance because the proportion of traffic volume experienced in an hour or single day of the week are continuous variables, and this proximity measure is the most commonly used for this variable type. Equation 3 shows the general form of the formula used to calculate Euclidean distance, along with how the variables apply to the data in this thesis. The formula can be interpreted as the physical distance between two p-dimensional points in Euclidean space.

Equation 3

$$d_{ij} = \left[\sum_{k=1}^{p} (x_{ik} - x_{jk})^2 \right]^{1/2}$$

Where:

d the measured distance between objects i and j

i object one (i.e., the temporal distribution from the sample site survey)

j object two (i.e., the temporal distribution from the selected TPG)

k index of the *kth* distribution value ($k = 1, \dots p$)

p number of dimensions in the distribution
            • for hourly distributions $p = 24$
            • for DOW distributions $p = 7$

x distribution value (i.e., the proportion of traffic volume experienced in that hour or day)

The Euclidean distance formula measures the distance between the traffic pattern distributions (hourly and DOW) experienced at the sample site survey and each of the seven TPGs. The goal of this analysis is to determine which TPG has the most similar hourly and DOW traffic volume distributions to the sample site survey. For each of the two distribution types, the distances between the sample site survey and each TPG are ranked from smallest (1) to largest (7). A rank of 1 identifies the TPG that has the most similar hourly or DOW traffic patterns to the survey. The ranks from the two distributions are then equally weighted and added together. This determines which TPG is most similar when both hourly and DOW patterns are considered together. In the event that multiple TPGs receive the smallest weighted rank, or the most similar TPG does not make logical sense, engineering judgement and the descriptions of the characteristics for each TPG are applied to determine the appropriate TPG for the sample site.

The following paragraphs outline the steps to develop the hourly and DOW distributions at the sample site surveys and at the TPGs, and explain how the EQWA differs from the general clustering analysis.

The hourly and DOW distributions at the sample sites are developed for each accepted survey using the corresponding hourly volume data. Surveys with directional volumes are combined before developing the distributions. For sample sites with multiple accepted surveys, distributions are also developed for the average of the surveys.

To calculate the hourly distributions at sample site surveys:
1. Calculate the **average volume for each hour** for the survey by taking the average of hourly volumes for each hour over the 7-day count period.
2. Calculate the **hourly distribution (hourly % of 7-day ADT)** for the survey by dividing the average volume for each hour by the 7-day ADT.

The result is a vector comprising the 24 hour-of-day ratios for each survey.

To calculate DOW distributions at sample site surveys:

1. Calculate the **total volume for each day** for the survey by taking the sum of hourly volumes for each day over the 7-day count period.

2. Calculate the **DOW distribution (daily % of 7-day ADT)** for the survey by dividing the total volume for each day by the 7-day ADT.

The result is a vector comprising the 7 DOW ratios for each survey.

The hourly and DOW distributions at each TPG are developed using MI's 2019 continuous count data and the existing TPG assignments. The current assignment, completed in 2006, assigned most continuous count stations to one of seven TPGs (Regehr *et al.*, 2006). In 2019, AADT was unavailable at 17 of the 85 continuous counters in Manitoba (Olfert *et al.*, 2020). As a result, these stations were not included in the calculation of TPG distributions for this thesis. Of the remaining 68 continuous count stations, 18 do not belong to a TPG and were therefore also not included. Hourly volume data from the remaining 50 continuous counters are used to develop the hourly and DOW distributions at each TPG.

To calculate the 2019 hourly distributions at each TPG:

1. Identify those continuous counters associated with the TPG.

2. Calculate the **average volume for each hour** for the associated continuous counters by taking the average of hourly volumes for each hour.

3. Calculate the **hourly distribution (hourly % of AADT)** for the associated continuous counters by dividing the average volume for each hour by the continuous counter's 2019 AADT.

4. Calculate the **hourly distribution (hourly % of AADT)** for the TPG by taking the average of all associated continuous counter's hourly % of AADTs.

The result is a vector comprising the 24 hour-of-day ratios for each of the seven TPGs.

Similarly, to calculate the 2019 DOW distributions at each TPG:

1. Identify those continuous counters associated with the TPG.

2. Calculate the **total volume for each day** for the associated continuous counters by taking the sum of hourly volumes for each day.

3. Calculate the **average volume for each day of the week** for the associated continuous counters by taking the average of total volume for each day for each of the seven days of the week.

4. Calculate the **DOW distribution (daily % of AADT)** for the associated continuous counters by dividing the average volume for each day of the week by the continuous counter's 2019 AADT.

5. Calculate the **DOW distribution (daily % of AADT)** for the TPG by taking the average of all associated continuous counter's daily % of AADTs.

The result is a vector comprising the 7 DOW ratios for each of the seven TPGs.

The EQWA procedure works in the same way as the cluster analysis described, with the only difference being the values used to calculate the hourly and DOW distributions for each TPG. The general cluster analysis uses an entire year of volume data at the continuous count stations to calculate the average hourly and DOW distributions at each TPG. This method works well for surveys that occur during a typical week at the sample location. However, in cases where the survey is completed during an event such as a long weekend, the hourly and DOW volume patterns experienced at the survey are likely not the same as those of a typical week. Comparing a survey of this nature to the

average hourly and DOW distributions at each TPG could result in an incorrect match. The EQWA approach is developed to account for this.

The EQWA uses only one week of volume data (the same week as the survey) at the continuous count sites to calculate the "equivalent week" hourly and DOW distribution ratios at each TPG. It is not favourable to perform the EQWA for all surveys because calculating the TPG distributions using only one week of continuous count data could amplify unknown biases in that week of data. The average hourly and DOW distributions remove this bias because they average all weeks over an entire year. Therefore, this method should only be used if the survey is conducted during an occasion that is expected to alter the volume patterns at both the survey and the continuous counters.

Validation of Results

The third and final step in the data analysis is to validate the results obtained from step two to ensure the TPG selected for each sample site is reasonable. This section describes the two validation procedures performed:

1. Visual validation of the distribution graphs and geographical characteristics.
2. Statistical validation using a tolerance interval analysis.

The first validation procedure involves visual inspection of the distinct characteristics of each sample site survey and a comparison to the selected TPG[6]. The visual validation procedure consists of three steps:

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[6] The four sample site surveys that qualify for the EQWA are also compared to their individual equivalent week temporal distribution graphs from the selected TPG in addition to the general characteristics of the selected TPG.

1. Graphically compares the hourly distributions obtained from each sample site survey with the hourly distribution at the selected TPG for that site, and qualitatively evaluates the degree to which these distributions match.

2. Graphically compares the DOW distributions obtained from each sample site survey with the DOW distribution at the selected TPG for that site, and qualitatively evaluates the degree to which these distributions match.

3. Assesses whether the geographic location of each sample site matches the geographic characteristics of the selected TPG for that site.

Statistical validation using a tolerance interval analysis is employed as the second validation procedure to confirm the chosen TPG assignments for each sample site. A tolerance interval is a statistical interval that is developed to contain at least a specified proportion, p, of a distribution with a specified level of confidence, α (Meeker, Hahn and Escobar, 2017). In other words, for example, you can be 95% confident that 90% of the distribution's population is within the calculated tolerance limits. This interval can be referred to as the (90%, 95%) tolerance interval.

In this thesis, two-sided tolerance intervals are developed for each of the 24 hour-of-day ratios, and seven DOW ratios for each of the seven TPGs[7]. Then, the hour-of-day and DOW ratios from each survey are compared to the corresponding hour-of-day or DOW tolerance interval for the TPG identified as matching most closely with the survey. Lastly, the number of ratios in each survey that fall within the tolerance limits for the matching TPG are used to determine the likelihood that the survey comes from the same population as the TPG.

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[7] Specific equivalent week tolerance intervals were developed for the four sample site surveys that qualify for the EQWA.

Equation 4 shows the general form of the formula that calculates the lower and upper

tolerance limits for a two-sided tolerance interval.

Equation 4

$$Y_L = \bar{y} - k_2 s \,; \; Y_U = \bar{y} + k_2 s$$

Where:

Y_L is the lower limit of the tolerance interval.

Y_U is the upper limit of the tolerance interval.

$\bar{y}$ is the sample mean for the specified hour-of-day or DOW ratio calculated using 2019 continuous count data from the specified TPG.

s is the sample standard deviation for the specified hour-of-day or DOW ratio calculated using 2019 continuous count data from the specified TPG.

k_2 is a factor calculated so that the two-sided tolerance interval covers at least a proportion p of the population with confidence α.

Equation 5 shows the general form of the formula that calculates the approximate value

of k_2, the k-factor for a two-sided tolerance interval (Howe, 1969). It is assumed that the

hourly and DOW ratios calculated from the sites comprising each TPG are normally

distributed.

Equation 5

$$k_2 = z_{(1+p)/2} \sqrt{\frac{\left(1 + \frac{1}{n}\right)}{x^2{}_{1-\alpha,v}}}$$

Where:

$x^2{}_{1-\alpha,v}$ is the critical value of the chi-square distribution with degrees of freedom v that is exceeded with probability α.

$z_{(1+p)/2}$ is the critical value of the normal distribution associated with cumulative probability, $(1 + p)/2$.

n is the sample size.

v degrees of freedom used to estimate the standard deviation.

Notably, each TPG is created using a different number of continuous counters, which means the sample sizes used to develop the tolerance intervals for each TPG are different. As a result, the tolerance intervals for each TPG are not necessarily created equally. And because of this, it is not appropriate to compare the number of distribution ratios in a survey that fall within the tolerance limits for one TPG to the number of distribution ratios from the same survey that fall within the tolerance limits of another TPG.

4 RESULTS AND DISCUSSION

This chapter presents and discusses the results obtained from the two phases of this research as identified in the methodology: (1) the procedure to identify town counts, and (2) the procedure to estimate AADT for town counts. This chapter also summarizes the limitations of this research and considerations for implementing a short-duration town count program.

4.1 DECISION ALGORITHM RESULTS

This section reveals the outcomes of the decision algorithm and GIS analysis which together determined which short-duration counts should be categorized as town counts (i.e., Objective 1 of the research).

Four examples are provided to illustrate the application of the criteria and the use of the decision algorithm as shown in Figure 2 for the four different count type scenarios.

1. Currently a town count → should be a town count.
2. Currently a town count → should not be a town count.
3. Currently not a town count → should be a town count.
4. Currently not a town count → should not be a town count.

The first example considers Station 5443, located in Killarney on PTH 18. Figure 28 displays the location of this count site within the road network. In this example, the short-duration count currently defined as a town count is confirmed to be a town count as a result of question 5 in the decision algorithm ("Does the land use indicate urban traffic characteristics?"). Table 16 provides the answers to the five decision algorithm questions for this station and the reasoning behind each answer.
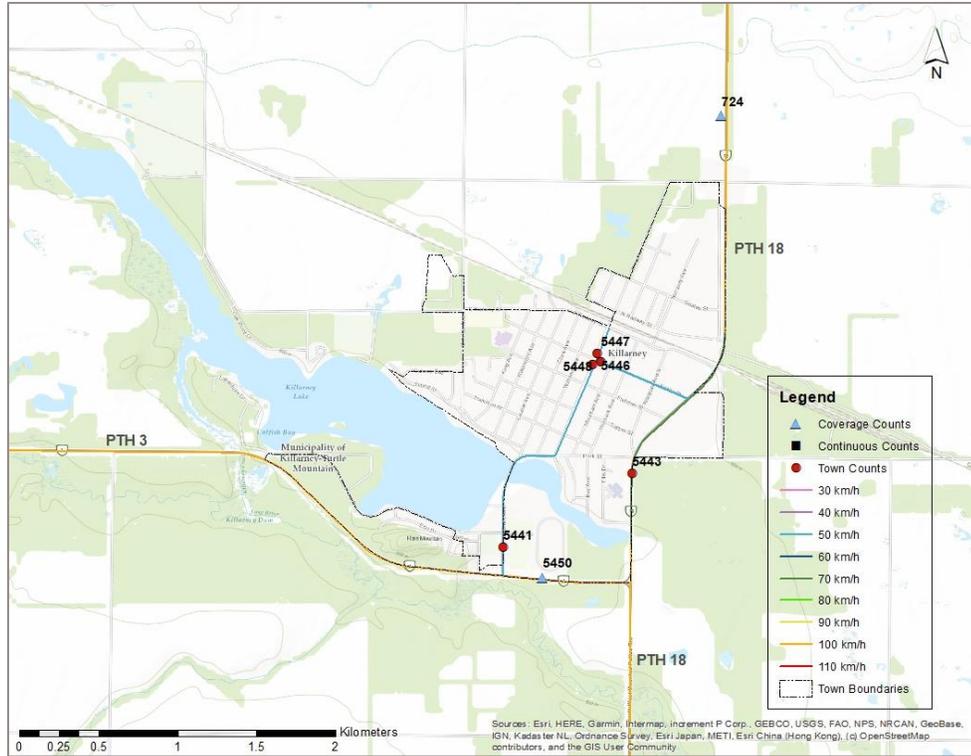
Figure 28: Location of Station 5443, an example of scenario 1 (currently a town count and should be a town count)

Table 16: Decision algorithm question outcomes for Station 5443, an example of scenario 1 (currently a town count and should be a town count)

Question	Answer	Reasoning
1	Yes	Within Killarney town boundary.
2	No	Speed limit is 70 km/h, which is greater than 60 km/h.
3	No	This roadway does not bypass the town. Although the count is located on a major highway, this roadway provides direct access to businesses and residential areas in Killarney.
4	Not applicable	This count is within a town boundary.
5	Yes	Surrounded by and leads to various residential and commercial properties.

The second example considers Station 5013, located near Amaranth on PTH 50. Figure

29 displays the location of this count site within the road network. In this example, the

short-duration count currently defined as a town count is redefined to not be a town

count as a result of question 4 in the decision algorithm ("Are there 1 or more
intersections before the town boundary?"). Table 17 provides the answers to the five
decision algorithm questions for this station and the reasoning behind each answer.
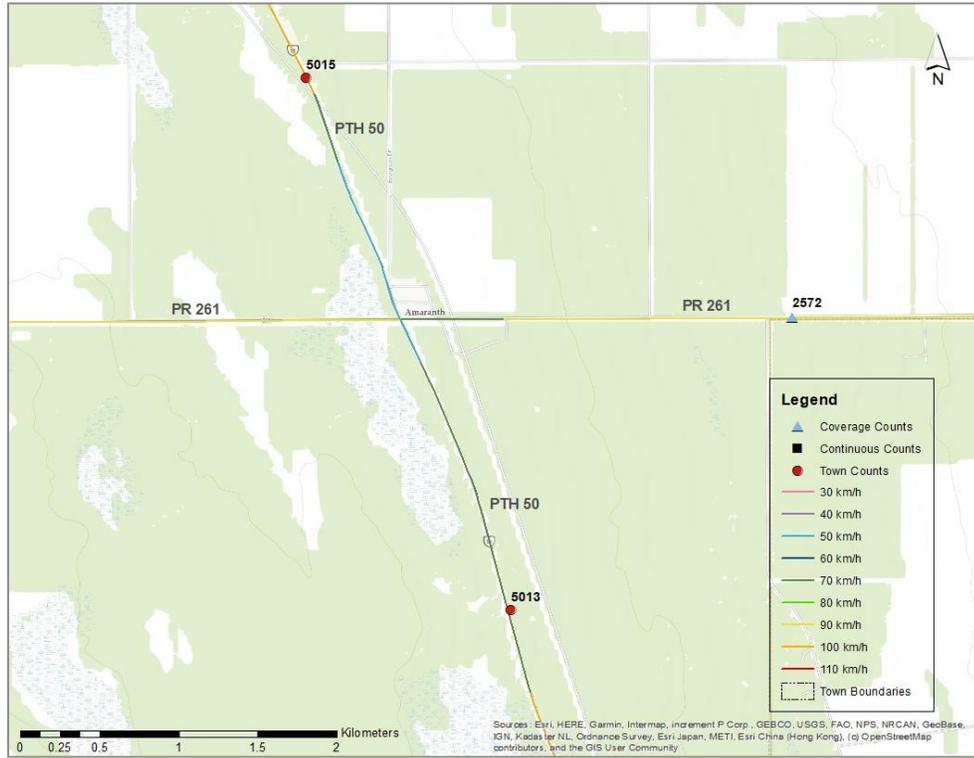
Figure 29: Location of Station 5013, an example of scenario 2 (currently a town count but should not be a town count)

Table 17: Decision algorithm question outcomes for Station 5013, an example of scenario 2 (currently a town count but should not be a town count)

Question	Answer	Reasoning
1	No	Located near Amaranth, which was not identified as one of the 55 towns.
2	No	Speed limit is 70 km/h, which is less than 90 km/h.
3	No	This roadway does not bypass the area, it runs directly through Amaranth.
4	Yes	There is more than one intersection between this count and the nearest town boundary of St. Rose du Lac.
5	Not applicable	Question 4 resulted in a decision.

The third example considers Station 950, located in Morden on PR 432. Figure 30 displays the location of this count within the road network. In this example, the short-duration count currently defined as not a town count is redefined to be a town count as a result of question 2 in the decision algorithm ("Is the speed limit 60 km/h or less?"). Table 18 presents the answers to the five decision algorithm questions for this station and the reasoning behind each answer.
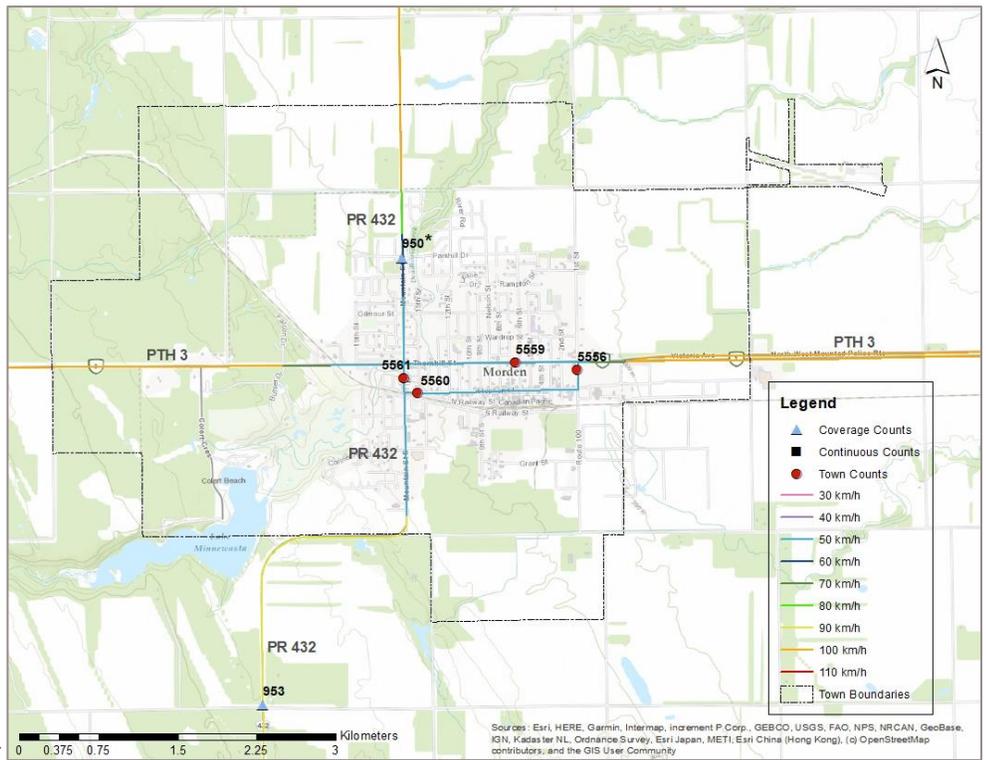
Figure 30: Location of Station 950, an example of scenario 3 (currently not a town count but should be a town count)

Table 18: Decision algorithm question outcomes for Station 950, an example of scenario 3 (currently not a town count but should be a town count)

Question	Answer	Reasoning
1	Yes	Within Morden town boundary.
2	Yes	Speed limit is 60 km/h, which is equal or less than 60 km/h.
3	Not applicable	Question 2 resulted in a decision.
4	Not applicable	Question 2 resulted in a decision.
5	Not applicable	Question 2 resulted in a decision.

The fourth example considers Station 5456, located in Lac du Bonnet on PTH 11. Figure 31 displays the location of this count within the road network. In this example, the short-duration count currently defined as not a town count is confirmed to not be a town count as a result of question 3 in the decision algorithm ("Does the highway bypass the town?"). Table 19 provides the answers to the five decision algorithm questions for this station and the reasoning behind each answer.
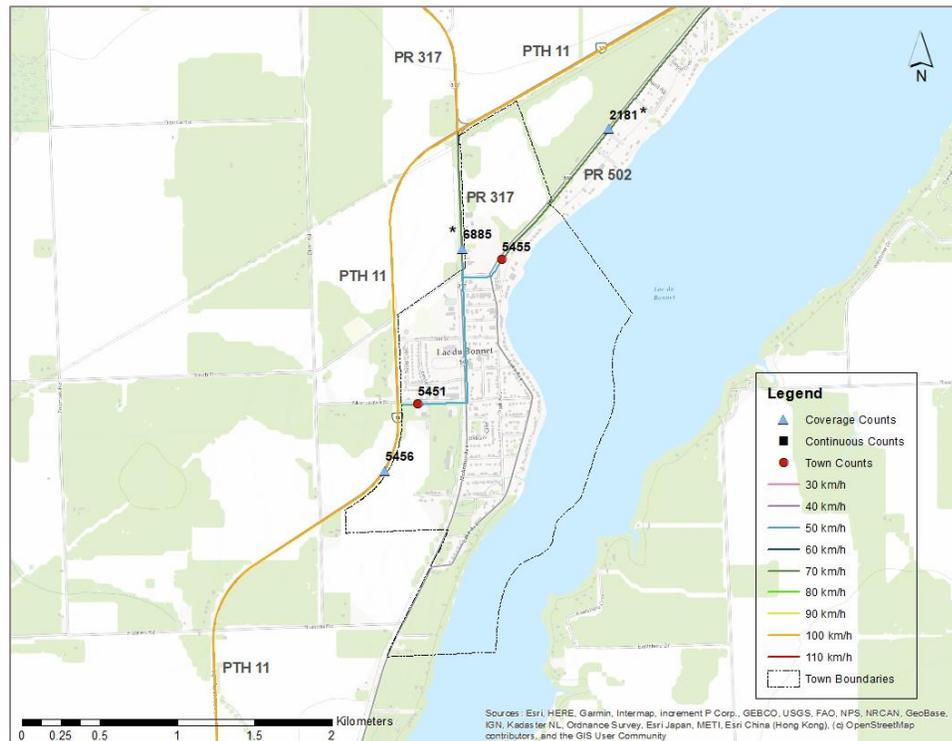
Figure 31: Location of Station 5456, an example of scenario 4 (currently not a town count and should not be a town count)

Table 19: Decision algorithm question outcomes for Station 5456 which displays scenario 4, currently not a town count and should not be a town count

Question	Answer	Reasoning
1	Yes	Within Lac du Bonnet town boundary.
2	No	Speed limit is 100 km/h, which is greater than 60 km/h.
3	Yes	This roadway funcitons as a bypass of the town of Lac du Bonnet.
4	Not applicable	Question 3 resulted in a decision.
5	Not applicable	Question 3 resulted in a decision.

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In total, 478 count stations were evaluated, the 327 current town counts, and 151 short-duration counts that are located within or nearby the 55 towns. No town counts were identified in nine of the 55 towns. A total of 241 count stations kept their initial definitions, and 237 count stations were redefined. Eight of the evaluated count stations were expected to exhibit town like travel characteristics despite the decision algorithm classifying them as not town counts. As a result, two types of exceptions to the decision algorithm were acknowledged:

- Count stations located just outside the town boundary on a PAR leading directly into the town where there are zero major intersections between the count and the town boundary, and the speed limit is 90 km/h or greater. The decision algorithm determines that a short-duration count station located outside a town boundary where the speed limit is 90 km/h or greater should not be considered a town count. However, in this rare occurrence where the count is located on a PAR with the sole function of accessing the town, it is expected that the traffic on the roadway will be influenced by the town-like travel behaviours in the same way as town counts, despite the high speed limit. The three count stations determined to be town counts as a result of this exception to the decision algorithm are 7734 in Altona, 5216 in Deloraine, and 5969 in Stony Mountain.

- Count stations located just outside the town boundary where there is one major intersection between the count and the town boundary but a case can be made that the intersection does not confine the town-like travel behaviours that exist within the town boundary and the speed limit is 60 km/h or less. The decision algorithm determines that a short-duration count located outside a town boundary with one or more intersections between the count and the town boundary should not be considered a town count. However, in some instances, an intersection

between the count and the town boundary was determined to not change the
town-like travel patterns. Examples include situations where there is a nearby
suburb of the town as is the case for Portage la Prairie (Southpoint) and Selkirk
(East Selkirk), or situations where a portion of the town's commercial area is
outside the town boundary, as is the case for Virden. The five count stations
determined to be town counts due to this exception of the decision algorithm are
2558 in Portage la Prairie, 569, 5881 and 5882 in Selkirk, and 6045 in Virden.

Table 20 summarizes how many count stations belong to each count type scenario.
Appendix C summarizes the decision algorithm outcome for all evaluated count stations.

Table 20: Summary of decision algorithm outcomes for each count type scenario

Scenario	Initial Count Type	Decision Algorithm Outcome	Number of Count Stations
1	Town count	Town count	131
2	Town count	Not town count	196
3	Not town count	Town count	41
4	Not town count	Not town count	110
		SUM	478

4.2   ASSIGNMENT AND VALIDATION RESULTS

This section presents the findings of the assignment procedure that determined which
TPG most closely matched each sample site, enabling the estimation of AADT from
these counts (i.e., Objective 2 of the research). It also provides the results of the
assignment validation procedures.

4.2.1 Assignment to TPGs: Results

As described in the methodology, assigning the eleven sample sites to a TPG occurred
in two steps. The first step developed the hourly and DOW vectors for the sample site
surveys and the TPGs. These vectors indicate the proportion of ADT or AADT observed

in each hour or DOW for the survey or TPG. The second step calculated and compared the Euclidean distances between the hourly and DOW vectors at the sample site survey with the corresponding vectors for each TPG.

An example using data from Station 5051 is provided to illustrate both steps. This count site is located in the town centre of Beausejour where the speed limit is 50 km/h. A detailed description of the characteristics of Station 5051 is provided in the Selection of Sample Sites Section. Table 21 shows the hourly vectors for each TPG, and the single hourly survey completed at Station 5051.

Table 21: Hourly vectors for each TPG and survey 5051-3

Hour	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7	5051-3
0	0.007	0.008	0.010	0.006	0.005	0.005	0.008	0.005
1	0.004	0.005	0.007	0.003	0.003	0.003	0.005	0.003
2	0.003	0.004	0.006	0.002	0.002	0.002	0.004	0.002
3	0.003	0.004	0.006	0.002	0.002	0.001	0.003	0.003
4	0.005	0.005	0.009	0.003	0.004	0.004	0.006	0.008
5	0.015	0.012	0.020	0.011	0.015	0.013	0.012	0.013
6	0.042	0.027	0.034	0.025	0.035	0.027	0.022	0.023
7	0.066	0.045	0.041	0.047	0.044	0.039	0.046	0.035
8	0.059	0.053	0.046	0.059	0.053	0.049	0.050	0.048
9	0.052	0.059	0.055	0.058	0.057	0.057	0.049	0.062
10	0.053	0.063	0.062	0.061	0.064	0.068	0.052	0.071
11	0.056	0.066	0.065	0.066	0.067	0.074	0.058	0.073
12	0.059	0.068	0.066	0.071	0.068	0.077	0.066	0.077
13	0.061	0.071	0.069	0.072	0.070	0.078	0.070	0.081
14	0.066	0.074	0.072	0.074	0.074	0.079	0.073	0.083
15	0.081	0.078	0.076	0.080	0.083	0.084	0.076	0.082
16	0.095	0.081	0.079	0.086	0.090	0.085	0.086	0.078
17	0.080	0.075	0.073	0.078	0.077	0.075	0.078	0.070
18	0.056	0.058	0.060	0.058	0.059	0.059	0.064	0.057
19	0.041	0.045	0.047	0.044	0.043	0.045	0.052	0.046
20	0.035	0.036	0.037	0.035	0.034	0.033	0.043	0.033
21	0.028	0.029	0.029	0.029	0.025	0.023	0.032	0.023
22	0.019	0.021	0.020	0.019	0.016	0.014	0.021	0.016
23	0.012	0.013	0.014	0.011	0.010	0.008	0.013	0.008
SUM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 22 shows the squared difference between the hourly proportion of ADT at survey 5051-3 and the hourly proportion of AADT at each TPG, the sum of the differences, and Euclidean distance (calculated using Equation 3). The table also ranks the Euclidean distances between survey 5051-3 and each TPG, from smallest (1) to largest (7).

Table 22: Comparison of survey 5051-3's hourly vector with each TPG

Hour	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
0	5.0E-06	9.9E-06	2.5E-05	5.4E-07	5.4E-08	2.7E-08	1.0E-05
1	1.6E-06	5.2E-06	1.9E-05	2.0E-07	2.2E-09	6.4E-08	6.0E-06
2	1.9E-06	5.1E-06	2.3E-05	5.0E-07	1.4E-07	9.5E-08	5.0E-06
3	2.8E-07	1.1E-07	1.0E-05	1.6E-06	1.9E-06	3.2E-06	4.5E-08
4	9.9E-06	8.5E-06	1.3E-06	2.0E-05	1.6E-05	1.7E-05	3.9E-06
5	4.2E-06	8.8E-07	5.0E-05	3.2E-06	4.4E-06	2.7E-10	9.0E-07
6	3.9E-04	1.9E-05	1.2E-04	6.3E-06	1.6E-04	2.1E-05	1.8E-07
7	9.6E-04	9.5E-05	3.1E-05	1.4E-04	8.2E-05	1.5E-05	1.1E-04
8	1.2E-04	2.7E-05	4.1E-06	1.1E-04	2.0E-05	1.8E-06	5.2E-06
9	9.3E-05	8.7E-06	4.4E-05	1.4E-05	2.9E-05	2.0E-05	1.6E-04
10	3.3E-04	6.4E-05	9.3E-05	9.9E-05	5.3E-05	9.7E-06	3.6E-04
11	2.9E-04	4.6E-05	6.8E-05	5.2E-05	3.5E-05	2.3E-06	2.3E-04
12	3.3E-04	8.7E-05	1.3E-04	4.5E-05	8.4E-05	8.1E-08	1.4E-04
13	4.1E-04	9.3E-05	1.4E-04	7.8E-05	1.2E-04	9.5E-06	1.3E-04
14	2.9E-04	8.1E-05	1.0E-04	7.8E-05	7.0E-05	1.0E-05	9.0E-05
15	1.4E-06	1.7E-05	2.8E-05	4.2E-06	6.1E-07	4.5E-06	3.2E-05
16	2.8E-04	9.7E-06	1.4E-06	6.1E-05	1.6E-04	4.9E-05	6.6E-05
17	1.1E-04	3.0E-05	1.1E-05	6.2E-05	4.8E-05	2.3E-05	7.2E-05
18	1.7E-06	1.5E-06	9.0E-06	1.4E-06	5.1E-06	5.6E-06	5.2E-05
19	2.3E-05	1.8E-06	1.2E-06	2.9E-06	1.2E-05	1.6E-06	4.1E-05
20	1.6E-06	9.0E-06	1.7E-05	3.4E-06	2.2E-07	2.0E-10	9.3E-05
21	2.8E-05	3.7E-05	3.5E-05	3.6E-05	3.3E-06	8.1E-11	8.0E-05
22	1.3E-05	2.4E-05	1.6E-05	1.4E-05	2.6E-08	2.2E-06	2.9E-05
23	1.1E-05	2.0E-05	2.8E-05	5.9E-06	2.7E-06	7.2E-08	1.8E-05
SUM	0.004	0.001	0.001	0.001	0.001	2.0E-04	0.002
Euclidean Distance	0.061	0.026	0.032	0.029	0.030	0.014	0.042
RANK	**7**	**2**	**5**	**3**	**4**	**1**	**6**

Table 23 shows the DOW vectors for each TPG, the two DOW surveys completed at

Station 5051, and the average of the two DOW surveys at Station 5051. The DOW

vectors begin with the week starting on Sunday (day 1).

Table 23: DOW vectors for each TPG and surveys 5051-1, 5051-3 and 5051-avg

DOW	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7	5051-1	5051-3	5051-avg
1	0.76	0.86	1.12	0.80	0.98	1.10	0.86	0.88	0.80	0.84
2	0.99	0.99	0.96	0.98	0.97	0.94	0.97	0.99	1.04	1.01
3	1.05	1.00	0.85	1.03	0.94	0.87	0.98	0.98	1.01	0.99
4	1.08	1.03	0.89	1.05	0.96	0.87	1.02	1.11	1.04	1.07
5	1.10	1.07	0.95	1.09	1.00	0.93	1.02	1.08	1.06	1.07
6	1.15	1.17	1.22	1.17	1.18	1.22	1.19	1.11	1.18	1.14
7	0.86	0.88	1.04	0.89	0.97	1.10	0.90	0.85	0.88	0.86
AVG	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 24 shows the squared difference between the DOW proportion of ADT at survey

5051-1 and the DOW proportion of AADT at each TPG, the sum of the differences, and

Euclidean distance (calculated using Equation 3). The table also ranks the Euclidean

distances between survey 5051-1 and each TPG, from smallest (1) to largest (7). Similar

tables were developed for survey 5051-3 and the average of the two surveys, survey

5051-avg. Table 25 displays the data for survey 5051-3. Table 26 displays the data for

survey 5051-avg.

Table 24: Comparison of survey 5051-1's DOW vector with each TPG

DOW	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
1	0.014	0.000	0.055	0.007	0.011	0.049	0.001
2	0.000	0.000	0.001	0.000	0.000	0.002	0.000
3	0.005	0.000	0.015	0.003	0.002	0.012	0.000
4	0.001	0.007	0.048	0.004	0.024	0.058	0.009
5	0.000	0.000	0.019	0.000	0.008	0.023	0.004
6	0.002	0.005	0.013	0.004	0.005	0.012	0.007
7	0.000	0.001	0.034	0.002	0.014	0.061	0.002
SUM	0.023	0.014	0.185	0.019	0.064	0.218	0.023
Euclidean Distance	0.150	0.117	0.430	0.138	0.253	0.467	0.151
RANK	3	1	6	2	5	7	4

Table 25: Comparison of survey 5051-3's DOW vector with each TPG

DOW	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
1	0.001	0.004	0.100	0.000	0.034	0.091	0.003
2	0.003	0.003	0.006	0.004	0.005	0.010	0.006
3	0.002	0.000	0.024	0.001	0.005	0.020	0.001
4	0.002	0.000	0.020	0.000	0.006	0.027	0.000
5	0.001	0.000	0.014	0.001	0.005	0.018	0.002
6	0.001	0.000	0.002	0.000	0.000	0.002	0.000
7	0.000	0.000	0.027	0.000	0.010	0.051	0.001
SUM	0.010	0.007	0.192	0.006	0.064	0.218	0.012
Euclidean Distance	0.102	0.082	0.438	0.078	0.253	0.467	0.112
RANK	3	2	6	1	5	7	4

Table 26: Comparison of survey 5051-avg's DOW vector with each TPG

DOW	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
1	0.006	0.000	0.076	0.002	0.020	0.068	0.000
2	0.001	0.001	0.003	0.002	0.002	0.005	0.002
3	0.003	0.000	0.019	0.001	0.003	0.016	0.000
4	0.000	0.002	0.033	0.001	0.014	0.041	0.003
5	0.001	0.000	0.016	0.000	0.006	0.020	0.003
6	0.000	0.001	0.006	0.001	0.001	0.006	0.002
7	0.000	0.000	0.030	0.001	0.012	0.056	0.001
SUM	0.011	0.005	0.183	0.007	0.059	0.212	0.012
Euclidean Distance	0.105	0.068	0.428	0.084	0.242	0.461	0.110
RANK	3	1	6	2	5	7	4

Table 27 shows the equally weighted rank for each TPG when considering each of the three vector combinations available for Station 5051.

Table 27: Comparison of weighted ranks for each hourly and DOW vector combination at survey 5051

Hourly Vector	DOW Vector	Weighted Rank						
		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5051-3	5051-1	5	1.5	5.5	2.5	4.5	4	5
5051-3	5051-3	5	2	5.5	2	4.5	4	5
5051-3	5051-avg	5	1.5	5.5	2.5	4.5	4	5

Determining which TPG most closely matched Station 5051 was not straightforward because the hourly and DOW results pointed to different TPGs. For instance, the hourly data indicated that TPG 6 is the most similar to Station 5051. However, the DOW data from both individual surveys and the average survey showed TPG 6 as being the most different from Station 5051. The DOW data identified TPG 2 and TPG 4 ranking either first or second for all three surveys, with relatively small differences between the Euclidean distances. The hourly data followed suit, ranking TPG 2 second and TPG 4 third, with a difference of only 0.003 between the Euclidean distances.

The equally weighted ranks offered further information by considering both the hourly and DOW results simultaneously. As shown in Table 27, depending on which combination of vectors are used, TPG 2 and TPG 4 are both candidates for the smallest rank, i.e., the best matching TPG.

Ultimately, TPG 4 was selected as most closely matching Station 5051. The following points provide insight into the decision-making procedure:

- The DOW characteristics experienced by TPG 2 and TPG 4 are very similar, so it is not surprising that the calculated Euclidean distances are similar.
- The hourly characteristics experienced by TPG 2 and TPG 4 are also quite similar; however, there is a difference in the weekday vs. weekend patterns. TPG 2 stations experience steady increases and decreases in volume throughout the day on weekdays and weekends, whereas TPG 4 stations experience morning and afternoon peaks on weekdays. Comparing the hourly distribution experienced on weekdays and weekends for survey 5051-3 revealed peaks on weekdays, similar to the characteristics of TPG 4.
- The seasonal characteristics experienced by TPG 2 and TPG 4 are quite different and unfortunately could not be determined with the available data.

However, due to the nature of being within a town, it is expected that this site would have low monthly variation.

For each sample site, Table 28 displays the assigned TPG, the rank of the assigned TPG's Euclidean distance (out of 7) when considering the hourly and DOW distributions separately, and the weighted rank of the assigned TPG. An asterisk is used to emphasize the four sample sites that applied EQWA methods. These locations were compared to the equivalent week distribution vector at each TPG, not the average vector. The ranked Euclidean distances for each survey are provided in Appendix D. Of the eleven sample sites, two stations, 5055 and 5139, displayed considerably different hourly and DOW patterns than the rest. This is further discussed in Section 4.3.

Table 28: Results of the assignment procedure

Station		5049	5051	5055	5518*	5220*	5222*	5942*	2469	5123	5135	5139
Assigned TPG		4	4	5	4	4	4	4	4	4	4	2
Rank of Assigned TPG for:	**Hourly Vector**	5th	3rd	1st	2nd	1st	1st	2nd	3rd	2nd	1st	2nd
	DOW Vector	3rd	2nd	1st	2nd	2nd	2nd	2nd	2nd	2nd	2nd	1st
Weighted Rank for Assigned TPG		4	2	1	2	1.5	1.5	2	2.5	2	1.5	1.5

*Identifies stations that applied EQWA methods

Notably, the assigned TPG is the preliminary assignment for each sample site, and the results from this assessment are subject to the validation procedures to ensure the characteristics of the sample site match those of the assigned TPG. Moreover, as observed, the TPG selected as the "assigned TPG" was not always the TPG that ranked the best relative to the others (i.e., the smallest weighted rank). The decision-making process included the results of the Euclidean distances for the hourly and DOW

distributions, the weighted ranks, as well as logical assessment. In some cases, like Station 5049, the weighted rank of 4 suggests the assigned TPG appears to have performed poorly relative to the other TPGs. However, an examination of the results of the hourly Euclidean distance analysis shows a very small difference (0.003) in the Euclidean distance calculated between the closest matching TPG (TPG 5) and the assigned TPG (TPG 4), which ranked 5th. So, although TPG 4 ranked in 5th place for the hourly distribution, this result was somewhat misleading, because TPG 4 performed very similarly to the best matching TPG, TPG 5. As a result, considering the DOW similarities between TPG 2 and TPG 4 described above, it was determined that it was most sensible to assign Station 5049 to TPG 4.

4.2.2 Validation Results

This section demonstrates the application of the two validation procedures continuing with Station 5051 as an example. The results of both validation procedures for all stations are also provided.

Visual Validation Results

The first validation procedure was a visual comparison between the hourly and DOW patterns observed at each survey with the characteristics of the TPG assigned to that sample site. The validation procedure occurred in three steps. The four sample site surveys that qualified for EQWA were visually compared to the temporal distribution graphs containing only the equivalent week of data at their assigned TPG in addition to the general characteristics of the assigned TPG. Station 5051 was matched with TPG 4 in the assignment procedure, so the example provided compares each survey completed at Station 5051 with the characteristics of TPG 4. For reference, characteristics of the seven TPGs can be found in Table 11.

1. **Compare the hourly patterns at the sample site surveys with the hourly patterns at the selected TPG.**

Figure 32 shows the comparison of the hourly ratios (as percentages of the 7-day ADT) at survey 5051-3 with the hourly ratios (as percentages of AADT) at TPG 4.
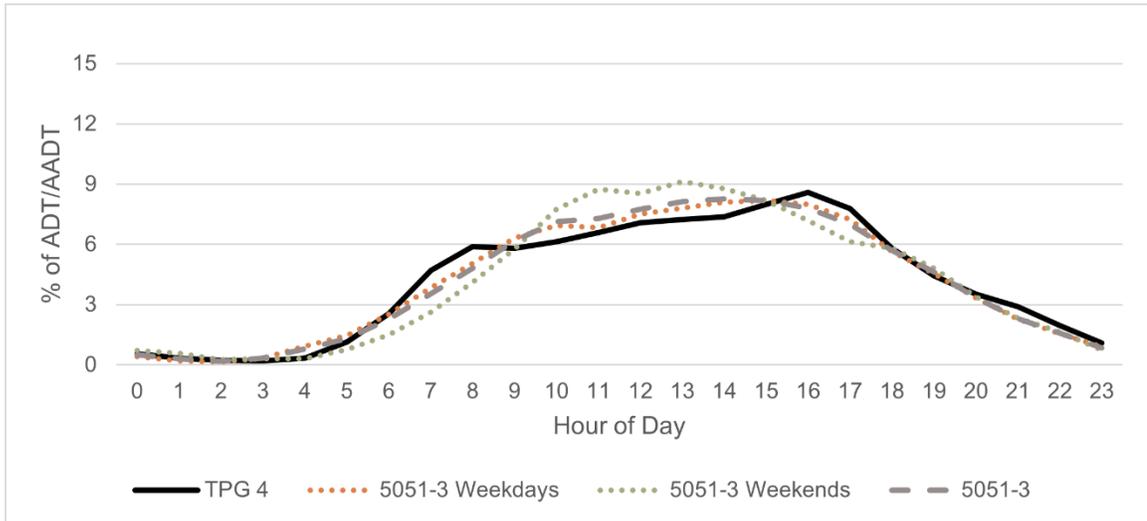
Figure 32: Comparison of hourly patterns at survey 5051-3 with TPG 4

A visual inspection of Figure 32 reveals that the average hourly patterns observed during the seven days of data collected at Station 5051 show similarities to the hourly patterns at TPG 4 continuous count stations. Although the peaks experienced at Station 5051 are not as evident as those for TPG 4, they do exist, particularly in the afternoon on weekdays. A qualitative comparison with the description of hourly variation provided for TPG 4 further reinforces the finding that Station 5051 has similar hourly characteristics to TPG 4. In particular, the weekday afternoon peaks are higher than the morning peaks.

2. **Compare the DOW patterns at the sample site surveys with the DOW patterns at the selected TPG.**

Figure 33 shows the comparison of the DOW ratios (as percentages of the 7-day ADT) at each of the three surveys conducted at Station 5051 with the DOW ratios (as percentages of AADT) at TPG 4.
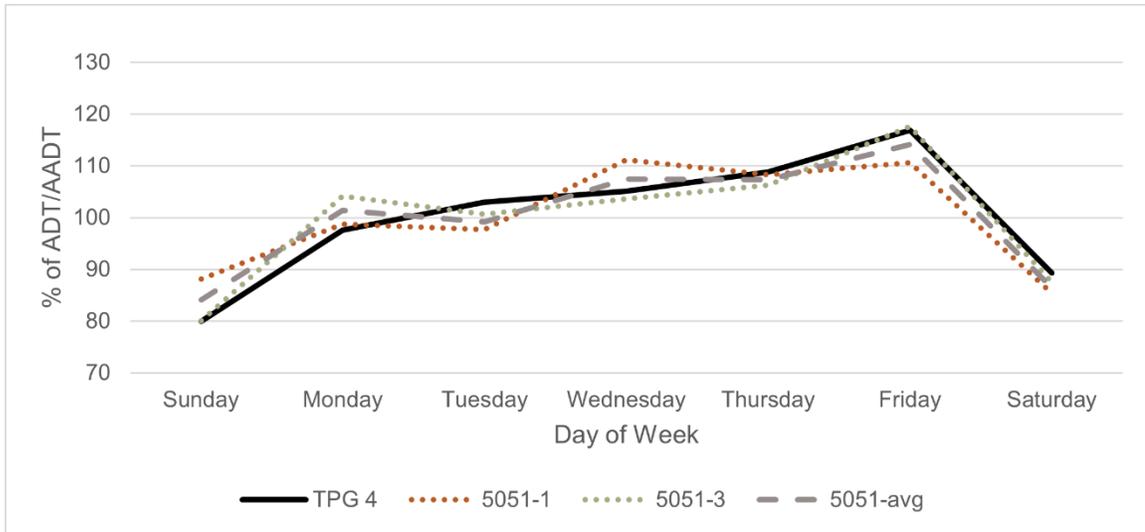
Figure 33: Comparison of DOW patterns for all surveys at Station 5051 with TPG 4

A visual inspection of Figure 33 illustrates that the DOW patterns observed at each of the two surveys completed at Station 5051, as well as their average, match closely to the DOW patterns at TPG 4 continuous counter stations. Notably, the TPG patterns are an average over an entire year, whereas the surveys display only one week out of the year and as a result, the patterns displayed are more susceptible to a single random event in that week. A qualitative comparison to the description provided for TPG 4 further strengthens the finding that Station 5051 has similar characteristics to TPG 4. Most notably, Station 5051 surveys have a moderate peak on Friday, lower weekend volumes and relatively steady weekday volumes, matching the DOW characteristics at TPG 4 stations.

3. **Assess whether the geographic location of the sample site matches the geographic characteristics of the selected TPG**.

TPG 4 comprises stations that exist on routes lying adjacent to rural population centres. Station 5051 is located within the town of Beausejour, and as a result shares the geographic characteristics of TPG 4 sites.

To summarize, the following tables provide the results of the visual validation procedure for all surveys. Table 29 compares the hourly volume patterns for the 13 hourly surveys (12 individual surveys and one average survey) completed at the eleven sample sites with their assigned TPG. Table 30 compares the DOW volume patterns for the 17 DOW surveys (14 individual surveys and three average surveys) completed at the eleven sample sites with their assigned TPG. Table 31 compares the geographic characteristics of the eleven sample sites with their assigned TPG.

Table 29: Comparison of hourly volume patterns with assigned TPG

Survey	Assigned TPG	Hourly Characteristics of Assigned TPG	Hourly Characteristics of Survey Compared to Assigned TPG	Matches TPG?
5049-3	TPG 4	• Afternoon peak higher than morning peak	• Slightly smaller weekday morning and afternoon peaks	Yes
5051-3			• Slightly smaller weekday morning and afternoon peaks	Yes
5518-2			• Similar weekday morning and afternoon peak • Additional peak around noon on weekdays and weekends	Yes
5220-2			• Nearly identical distribution observed	Yes
5222-2			• Nearly identical distribution observed	Yes
5942-2			• Nearly identical distribution observed	Yes
2469-2			• Slightly larger morning and afternoon peaks	Yes
5123-2			• Nearly identical distribution observed	Yes
5135-2			• Nearly identical distribution observed	Yes
5055-1	TPG 5	• Steady increase in weekend traffic throughout the day • Weekday afternoon peak higher than morning peak	• Slight weekday morning peak • Similar weekday afternoon peaks • Steady increase and decrease on weekends, no peaks. • Both surveys experience very similar hourly variation to eachother	Yes
5055-3				
5055-avg				

Survey	Assigned TPG	Hourly Characteristics of Assigned TPG	Hourly Characteristics of Survey Compared to Assigned TPG	Matches TPG?
5139-2	TPG 2	• Steady increases and decreases throughout the day on weekdays and weekends	• Nearly identical distribution observed	Yes

Table 30: Comparison of DOW volume patterns with assigned TPG

Survey	Assigned TPG	DOW Characteristics of Assigned TPG	DOW Characteristics of Survey Compared to Assigned TPG	Matches TPG?
5049-1	TPG 4	• Steady weekday traffic • Moderate Friday peak • Lower weekend volume	• Slightly higher porportion of traffic on Sunday • Similar patterns for the rest of the week	Yes
5049-3				
5049-avg				
5051-1			• Average survey is nearly identical aside from slightly lower Tuesday and higher Wednesday propotions	Yes
5051-3				
5051-avg				
5518-2			• Similar distribution • Slightly higher weekday and lower weekend proportion	Yes
5220-2			• Similar distribution • Slightly higher weekday and lower weekend proportion	Yes
5222-2			• Similar distribution • Slightly higher weekday and lower weekend proportion	Yes
5942-2			• Nearly identical distribution observed	Yes
2469-2			• Similar distribution • Slightly higher weekday and lower weekend proportion	Yes
5123-2			• Nearly identical distribution observed	Yes
5135-2			• Nearly identical distribution observed	Yes
5055-1	TPG 5	• Steady weekday traffic • Moderate Friday and Sunday peaks	• Nearly identical distribution observed	Yes
5055-3				
5055-avg				
5139-2	TPG 2	• Steady weekday traffic • Moderate Friday peak • Lower weekend volume	• Nearly identical distribution observed	Yes

Table 31: Comparison of geographic characteristics with assigned TPG

Station	Selected TPG	Geographic Characteristics of Assigned TPG	Geographic Characteristics of Survey	Matches TPG?
5049	TPG 4	• Adjacent to rural population centres	• On PR leading to the town of Beausejour	Yes
5051			• On PR in Beausejour's town centre	Yes
5518			• On PAR in Melita's town centre	Yes
5220			• On PAR in Deloraine's town centre	Yes
5222			• On PAR leading to the town of Deloraine	Yes
5942			• On PTH in Souris' town centre	Yes
2469			• On PAR leading to the town of Brandon	Yes
5123			• On PTH in Brandon's town centre	Yes
5135			• On PTH in Brandon's town centre	Yes
5055	TPG 5	• Adjacent to rural population centres • Lead to recreational destinations	• On PTH bypassing the town of Beausejour	Yes
5139	TPG 2	• Not adjacent to population centres • Serve longer-trip purposes	• On the Trans-Canada Highway, bypassing the city of Brandon	Yes

Tolerance Interval Validation Results

The tolerance interval analysis was the second validation procedure applied. The

development of each hour-of-day and DOW tolerance interval can be broken down into

four steps. Once the tolerance intervals for each ratio are developed, the ratio observed

at each survey is compared with the corresponding tolerance interval for the selected

TPG. For the four sample site surveys that qualified for the EQWA, tolerance intervals

were developed using only the equivalent week data from the assigned TPG. Since

Station 5051 was matched with TPG 4 in the assignment procedure, the example

provided for each of the four steps uses Sunday data from TPG 4's continuous count

stations.

1. **Define the specified proportion, p, of the distribution and the specified level of confidence, α.**

For each distribution ratio, a (90%, 95%) tolerance interval was developed. In this example, this interval is 95% likely to contain 90% of the possible values for the Sunday DOW ratio at count stations that belong to TPG 4.

2. **Calculate the mean and standard deviation for the specific ratio.**

In 2019, a total of eight continuous counters were used to develop the distributions for TPG 4. The mean and standard deviation for the Sunday DOW ratio are calculated using the average Sunday DOW ratio observed at each of the eight continuous counters.

$$\bar{y} = \frac{\sum Y}{n} = \frac{0.81 + 0.72 + 0.77 + 0.71 + 0.85 + 0.74 + 0.91 + 0.90}{8} = 0.80$$

$$s = \sqrt{\frac{\sum (Y - \bar{y})^2}{n - 1}} = 0.079$$

3. **Calculate the k-factor for a two-sided tolerance interval (k_2).**

The critical value of the chi-square distribution, x^2, is determined from the chi-square distribution table, using a level of significance less than 0.05, and 7 degrees of freedom.

$$x^2{}_{1-\alpha,v} = x^2{}_{0.05\,,\,7} = 2.167$$

The critical value of the normal distribution, z, that contains 90% of observations is:

$$z_{(1+p)/2} = z_{0.95} = 1.645$$

These two values, along with the sample size, $n = 8$, are used in Equation 5 to calculate the k_2 factor as follows:

$$k_2 = z_{(1+p)/2} \sqrt{\frac{(1 + 1/n)}{x^2_{1-\alpha,v}}} = 1.645 \sqrt{\frac{1 + 1/8}{2.167}} = 3.14$$

4. Calculate the lower and upper tolerance limits.

Lastly, the (90%, 95%) tolerance limits can be calculated using Equation 4.

$$Y_L = \bar{y} - k_2 s = 0.80 - 3.14 \times 0.079 = 0.553$$

$$Y_U = \bar{y} + k_2 s = 0.80 + 3.14 \times 0.079 = 1.047$$

Table 32 shows the lower and upper tolerance limits for each of the seven DOW ratios for TPG 4, starting on Sunday (day 1). With 95% confidence, each DOW interval contains 90% of the possible proportions of AADT for that DOW at TPG 4 count stations.

Table 32: The (90%, 95%) lower and upper tolerance limits for each DOW ratio for TPG 4 stations

DOW	Y_L	Y_U
1	0.553	1.047
2	0.872	1.079
3	0.858	1.201
4	0.887	1.215
5	0.964	1.213
6	1.108	1.231
7	0.614	1.171

Now that the tolerance intervals for each of TPG 4's DOW ratios have been developed, the DOW ratios for each of the three surveys completed at Station 5051 can be compared to them. Table 33 shows the results of this comparison, where a 1 indicates the ratio is within the interval and a 0 indicates it is outside the interval. For reference, Table 33 also provides the DOW vectors for each of the three surveys at Station 5051.

Table 33: Results of comparing the ratios observed at Station 5051 surveys to the TPG 4 DOW tolerance intervals

DOW	5051-1	5051-3	5051-avg	5051-1	5051-3	5051-avg
1	0.882	0.801	0.841	1	1	1
2	0.987	1.041	1.014	1	1	1
3	0.977	1.007	0.992	1	1	1
4	1.112	1.036	1.074	1	1	1
5	1.083	1.063	1.073	1	1	1
6	1.106	1.176	1.141	0	1	1
7	0.854	0.875	0.864	1	1	1
			SUM	6	7	7

A shown by Table 33, all but one of the DOW ratios observed during the three surveys completed at Station 5051 fall within TPG 4's (90%, 95%) tolerance interval for each corresponding DOW ratio. These results justify the conclusion that Station 5051 follows similar DOW patterns to TPG 4 count stations.

To summarize, the following tables provide the results of the tolerance interval validation procedure for all surveys, where a 1 indicates the ratio is within the interval and a 0 indicates it is outside the interval. Table 34 shows the days of the week that fell within the TPG 4 DOW tolerance intervals for all surveys that matched with TPG 4 in the assignment procedure. Similarly, Table 35 shows the days of the week that fell within the TPG 2 or TPG 5 DOW tolerance intervals for the surveys that matched with those TPGs in the assignment procedure. Table 36 shows the hours of the day that fell within the TPG 4 hourly tolerance intervals for all surveys that matched with TPG 4 in the assignment procedure. Similarly, Table 37 shows the hours of the day that fell within the TPG 2 or TPG 5 hourly tolerance intervals for the surveys that matched with those TPGs in the assignment procedure.

Table 34: Results of comparing surveys assigned to TPG 4 to the TPG 4 DOW tolerance intervals

DOW	2469-2	5123-2	5135-2	5942-2	5220-2	5222-2	5518-2	5049-1	5049-3	5049-avg	5051-1	5051-3	5051-avg
1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	0	1	1	1	1
6	1	1	1	1	1	1	1	0	1	1	0	1	1
7	0	1	1	1	1	1	1	1	1	1	1	1	1
SUM	5	7	7	7	7	7	7	6	6	7	6	7	7
% of 7	71%	100%	100%	100%	100%	100%	100%	86%	86%	100%	86%	100%	100%

Table 35: Results of comparing surveys assigned to TPG 2 and TPG 5 to the corresponding DOW tolerance intervals

DOW	TPG 2	TPG 5		
	5139-2	5055-1	5055-3	5055-avg
1	1	0	1	1
2	1	0	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	0	0	0
SUM	7	4	6	6
% of 7	100%	57%	86%	86%

Table 36: Results of comparing surveys assigned to TPG 4 to the TPG 4 hourly tolerance intervals

Hour	2469-2	5123-2	5135-2	5942-2	5220-2	5222-2	5518-2	5049-3	5051-3
0	1	0	1	1	0	1	1	0	1
1	1	0	1	1	1	1	0	1	1
2	1	0	1	1	0	0	1	0	1
3	1	1	1	1	1	1	0	0	1
4	0	1	1	1	1	1	1	0	0
5	1	1	1	1	1	1	1	0	1
6	0	1	1	1	1	1	1	0	1
7	0	1	1	1	1	1	0	1	1
8	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	0	1	1
11	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	0	1	1
13	1	1	1	1	0	1	1	1	1
14	1	1	1	1	0	0	1	1	1
15	0	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	0	1
17	0	1	1	1	1	1	0	0	1
18	0	1	1	1	1	1	1	0	1
19	0	1	1	1	1	1	1	0	1
20	0	1	1	1	1	1	1	0	1
21	1	1	1	1	1	1	1	0	1
22	1	0	1	1	1	1	1	0	1
23	1	0	1	1	1	1	0	0	1
SUM	**16**	**19**	**24**	**24**	**20**	**22**	**17**	**10**	**23**
% of 24	67%	79%	100%	100%	83%	92%	71%	42%	96%

Table 37: Results of comparing surveys assigned to TPG 2 and TPG 5 to the corresponding hourly tolerance intervals

Hour	TPG 2	TPG 5		
	5139-2	5055-1	5139-2	5055-avg
0	1	0	1	1
1	1	0	1	1
2	1	0	1	1
3	1	1	1	1
4	0	1	1	0
5	1	1	1	1
6	0	1	1	1
7	0	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	0	1	1	1
16	1	1	1	1
17	0	1	1	1
18	0	1	1	1
19	0	1	1	1
20	0	1	1	1
21	1	1	1	1
22	1	0	1	1
23	1	0	1	1
SUM	16	19	24	23
% of 24	67%	79%	100%	96%

4.3   DISCUSSION OF RESULTS

This section begins by discussing the results of the two foregoing analyses. Although the analyses were completed independently, given their interrelationship, the discussion presented herein considers the results simultaneously. The section then identifies the limitations relevant to this research. Lastly, implementation considerations for short-duration volume counting within towns are discussed.

4.3.1 Assessment of Results

As demonstrated in the results sections, two main analyses were conducted to respond to the two research objectives. The first was the decision algorithm and GIS analysis, which had the goal of determining which short-duration counts should be labelled as town counts. The second was the study of the hourly and DOW traffic patterns at a sample of town count sites to enable the estimation of AADT from this type of count. The quantitative nature of the second analysis allowed for a relatively simple validation of the results. However, the qualitative method used in the first analysis was more difficult to substantiate. Nonetheless, the results of these two analyses corroborated each other.

The decision algorithm analysis revealed four key findings. First, many of the current short-duration town counts occur in and/or around geographic areas with population and population densities less than the limits established by this research to define a town. A particular challenge with these short-duration counts is their low volumes. Previous surveys at these locations often report below 1000 vehicles/day, many with less than 500 vehicles/day. Developing AADT estimates on low volume roadways presents unique challenges, specifically in that accuracy of the AADT estimates can be reduced due to the high variability of low volume counts (Sharma *et al.*, 2001; FHWA 2016). However, because there are many count locations that fall within this group, this finding demonstrates the need to conduct further analysis on this group of counts.

Second, the decision algorithm nearly always appropriately classified sites as town counts. The few exceptions were reasonable and emphasize the value of expert judgement when applying the decision algorithm. It is important to know and understand the highway network and overall characteristics of the system.

Third, nine of the 55 towns identified currently have no town counts within them. This is recognized as a gap in the current program and an opportunity to provide additional data

to data customers. The nine towns are: Chemawawin 2, Mitchell, Moose Lake, Niverville, Oakbank, Pinawa, Shilo CFB-BFC, St. Adolphe, and St. Theresa Point.

Last, the motivation for this research arose in part from previous work by Ominski (2018; 2021), on attributing traffic volume data to a rural highway network. That work developed a list of redundant count sites and identified 26 short-duration count stations located within a city or town boundary in Manitoba. Because these 26 stations were located within a town boundary but not designated as town counts, Ominski (2018) advised they be removed, moved, or redesignated as a town count. Application of the decision algorithm developed in this research to those 26 count stations revealed that:

- 18 of the short-duration count sites should be redesignated as town counts, as these locations are likely to experience urban traffic periodicities;

- 6 of the short-duration count sites should remain non-town coverage counts, as these locations are not likely to experience urban traffic periodicities despite the fact the count stations are located within a town boundary; and

- 2 of the short-duration count sites were not evaluated as they are located in towns with population and/or population density lower than the limits this thesis uses to define a town.

Regarding the second analysis, the use of the Euclidean distance to identify the closest matching TPG to each sample site helped to determine the best fit, however, it lacked the ability to identify the degree of closeness between the sample site and the selected TPG. For example, the TPG with the smallest Euclidean distance may in fact be the closest, but still not be a good fit for the sample site. The two validation procedures performed, visual inspection and tolerance interval analysis, allowed for the closeness between the TPG and the sample site to be qualitatively and quantitatively examined.

The results of these two validation procedures identified that the TPGs selected for each sample site through the assignment procedure were valid matches for the sample sites.

The results of the two validation procedures not only validated the results of the assignment procedure but also strengthened the defensibility of the selected TPG for each sample site. Therefore, it appears that the TPGs selected for each sample site are the best fit, given the current TPG groupings.

The selection of sample sites and the initial analysis of their traffic periodicities occurred prior to the completion of the decision algorithm analysis that determined which counts should be town counts. The sites selected intended to provide a representative sample of Manitoba's town counts by considering factors such as town population, roadway speed, highway type, and orientation. The expectation was that studying hourly and DOW patterns for a set of counts with varying characteristics could be used to detect which characteristics were more likely to result in urban traffic patterns. The sample locations were selected under the assumption that stations currently categorized as town counts were likely town counts. However, as shown in Table 28, two of the sampled stations, Station 5055 and Station 5139, experienced considerably different patterns from the others. These differences can be pragmatically explained as follows:

- Station 5055 is located on a high-speed road (speed limit of 100 km/h), which bypasses a town (Beausejour), and is near recreational destinations. For these reasons, it makes sense that this site best matches the patterns of TPG 5.
- Station 5139 is located on a high-speed road (speed limit of 80 km/h), which bypasses a town (Brandon), and serves primarily long-distance trips (despite its proximity to Brandon). For these reasons, it makes sense that this site best matches the patterns of TPG 2.

The development of the decision algorithm criteria occurred independently of the traffic

pattern analysis. The criteria selection was based on factors known or expected to

influence traffic patterns, in particular, those that could indicate urban travel

characteristics at the location of the short-duration count. As discussed in the

methodology, the criteria included: population and population density of a geographic

area, the legal bounds of that area, speed limit, roadway orientation, land use, and for

counts outside the legal boundary, the number of intersections between the count and

the boundary. Table 38 provides the answers and reasoning for each of the five decision

algorithm questions and the outcome (town count or not town count) for the eleven

sample sites studied within the second analysis. For reference, the decision algorithm

questions are provided in Figure 2. An asterisk is used to identify the decision algorithm

question that was ultimately responsible for the decision outcome.

Table 38: Decision algorithm analysis of the eleven sample sites examined in the second analysis

| Count Station | Decision Algorithm Question | | | | | Decision |
	1	2	3	4	5	
5049	Yes – in Beausejour town boundary	No – speed limit 70 km/h	No – does not bypass	n/a	Yes – urban features*	Town count
5051	Yes – in Beausejour town boundary	Yes – speed limit 50 km/h*	n/a	n/a	n/a	Town count
5118	Yes – in Melita town boundary	Yes – speed limit 40 km/h*	n/a	n/a	n/a	Town count
5220	Yes – in Deloraine town boundary	Yes – speed limit 50 km/h*	n/a	n/a	n/a	Town count
5222	Yes – in Deloraine town boundary	No – speed limit 90 km/h	No – does not bypass	n/a	Yes – urban features*	Town count

Count Station	Decision Algorithm Question					Decision
	1	2	3	4	5	
5942	Yes – in Souris town boundary	Yes – speed limit 50 km/h*	n/a	n/a	n/a	Town count
2469	Yes – in Brandon town boundary	Yes – speed limit 60 km/h*	n/a	n/a	n/a	Town count
5123	Yes – in Brandon town boundary	Yes – speed limit 50 km/h*	n/a	n/a	n/a	Town count
5135	Yes – in Brandon town boundary	No – speed limit 70 km/h	No – does not bypass	n/a	Yes – urban features*	Town count
5055	Yes – in Beausejour town boundary	No – speed limit 100 km/h	Yes – does bypass*	n/a	n/a	Not town count
5139	Yes – in Brandon town boundary	No – speed limit 80 km/h	Yes – does bypass*	n/a	n/a	Not town count

Considering the outcomes of both analyses together supports the results of the decision algorithm, and in turn supports the results of the assignment procedure. Although validation of the decision algorithm was not the focus of the second analysis, the results of the assignment procedure corroborate the findings from applying the algorithm. The two sample sites that the decision algorithm determined not to be town counts, did in fact exhibit considerably different hourly and DOW traffic patterns than the other nine sample sites, which the decision algorithm identified as town counts. Additionally, the nine sample sites identified as town counts experienced traffic periodicities similar to each other, and to the TPG (TPG 4) that by definition contains continuous count stations located adjacent to population centres. Specifically, the results demonstrate that TPG 4

can be used to develop reliable AADT estimates at town count stations, using the existing estimation procedures.

Finally, this research relies on the current state of the practice which uses a hybrid analytical approach that blends statistical inputs while also understanding the value in expert judgement of the transportation network to ensure decisions make intuitive sense. The hybrid approach is evident in the work done for both analyses. The first analysis recognized eight short-duration counts to be categorized as town counts, despite the decision algorithm identifying them as not town counts. The second analysis relied on the site-specific characteristics of the sample sites in addition to the findings of the Euclidean distance analysis to distinguish the closest matching existing TPG. Although this is the process undertaken in this research the critiques of a hybrid approach have been acknowledged, specifically that a purely data-driven assignment method has the potential to reduce mean absolute errors in AADT estimates (Grande, Paramita and Regehr, 2021).

4.3.2 Research Limitations

The analysis results are subject to limitations concerning data collection, data screening and quality control, and certain analytical assumptions.

Data Collection

The following points summarize research limitations related to data collection:

- To fully understand traffic characteristics at town count sites, it would be valuable to obtain data from every location. Unfortunately, limited time and data collection equipment to conduct the counts resulted in the selection of 13 sample locations.
- Selecting a representative sample of count locations from the list of 327 existing town count locations was imperfect. First, the list of possible locations was

restricted to approximately 33%, as short-duration counts are conducted on a

three-year return period in Manitoba and only counts being conducted in 2019

were eligible to be sampled. Secondly, even though various characteristics were

considered when selecting sample count locations, not all possible scenarios

could be accounted for. This is because the population and layout of towns vary.

- As a result of limited resources, some data that was scheduled to be collected at

  the 13 sample sites, could not be gathered, and therefore was excluded from the

  analysis. No data was collected at two of the sample sites: Station 6013 and

  6016, both located in Thompson. Additionally, five individual surveys, one each

  at Stations 5220, 5222, 5518, and two at Station 5942 could not be performed.

  This missing data contributed to the inability to examine monthly traffic patterns

  at the sample sites.

Data Screening and Quality Control

The following points summarize research limitations related to data screening and

quality control:

- From the 24 surveys that were conducted at the 13 sample sites, a large

  proportion, nearly 42%, were rejected by the data screening procedure. The

  rejections were mainly attributed to large amounts of missing data (greater than

  24 hours over a 7-day period), and a few unexpected intra-town events. Although

  portions of these surveys were unaffected by missing data or the event, it was

  deemed best to reject the entire survey, since at least one complete 7-day survey

  existed at each of the count locations where a survey was rejected. This strict

  data screening procedure ensured the data that was analysed was of high

  quality, but also contributed to the inability to examine monthly traffic patterns at

  the sample sites.

- There was limited ability to control the specific dates during which traffic data collection occurred. Unfortunately, some surveys occurred over long weekends or during intra-town events. These situations resulted in irregular traffic characteristics, different from those of a typical week at the sample site. Some patterns could be accounted for, such as long weekends using EQWA methods, but some could not, such as intra-town events. Future similar research should ensure that no scheduled events coincide with data collection periods; this will help reduce the number of surveys rejected.

Analytical Constraints and Assumptions

The following points summarize research limitations related to analytical constraints and assumptions:

- A result of some of the data collection and data screening limitations was that monthly ratios could not be developed for the sample sites and subsequently compared to the monthly patterns observed at the TPGs. The monthly patterns provide useful information about the travel behaviour at a location and this data would have been valuable to examine.

- The temporal characteristics experienced at each sample site were compared to the existing 7 TPGs in Manitoba. Developing new traffic pattern groups was outside the scope of this research.

- An important factor to consider when interpreting the results of the assignment procedure is that the TPGs themselves are not purely statistical constructs; they are subject to judgement (Regehr et al., 2006). Although the core of their development is based on a cluster analysis, they were developed using a hybrid approach which included manual regrouping of sites based on expert judgement and experience. The regrouping refined the statistical results by considering the

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geographic distribution of stations and professional knowledge about the traffic conditions at specific stations. Application of professional engineering judgement and experience is recommended when developing TPGs because groups can be pragmatically defined and as a result it is easier to assign short-duration counts to the groups (FHWA, 2016).

4.3.3 Implementation Considerations

Including town counts within a traffic monitoring program improves the ability for a jurisdiction to develop systemwide estimates of traffic statistics, such as AADT. However, there are challenges associated with implementing and performing short-duration town counts. This section summarizes implementation considerations relating to program design, data collection, and program evaluation.

Program Design

The design of a program that monitors traffic within a town environment may differ from one that focuses on mainly rural traffic monitoring. Consideration should be given to the following:

- One difference is that urban environments see increased levels of non-motorized traffic. As a result, there may be added value in classifying vehicles, or more broadly, roadway users at the location of town counts. This could mean that the jurisdiction requires additional counting equipment for their town count program.
- Another difference is that the road network is more complex within an urban environment. This can make selecting an appropriate location for traffic counting equipment within a town challenging.
- The locations of town counts should be selected to provide AADT estimates on all sequences identified to have homogeneous traffic flow. However, segmenting

the roadways within an urban area can be challenging due to the dense road network. Moreover, urban environments often experience stop and go traffic. This type of movement needs to be minimized at the location of the town count to reduce the likelihood that vehicles are counted multiple times.

Data Collection

Collecting short-duration count data within a town presents its own challenges as well, from equipment selection to physically conducting the counts.

- The first consideration is the type of equipment used to collect the short-duration count data. Pneumatic tubes, as used in this research, are a common type of equipment used for short-duration counting. Installation of this equipment requires: (1) that the traffic counter be secured to a permanent object such as a tree, signpost, light standard or other pole, or a guy-wire; and (2) that the tube be secured to the pavement. These needs can constrain data collection locations.

- In the case of the current location of Station 5051 in Beausejour, angled parking was observed to result in vehicles driving over the tube twice while leaving the parking spot – once while backing up and a second time while driving forward. A possible solution to this would be to block off affected parking stalls during the counting duration or selecting a different location for the survey. Other count locations may face other site-specific challenges.

- Installing traffic counting equipment can be more dangerous for the installation technician in an urban environment due to increased vehicle volumes. Appropriate training and safety measures should be developed and enforced to ensure safety of the technicians.

Program Evaluation

Towns are dynamic, and over time, their boundaries, and demographics change. This can result in changes to the traffic patterns at the location of the town count. As with any traffic monitoring program, consistent evaluation of the program is essential. Evaluation is recommended to occur at least every five (Regehr *et al.*, 2017), or six (FHWA, 2016) years. For a program that includes town counts, this should include an evaluation of:

- population and population densities of all inhabited areas to identify new towns or remove existing towns that no longer meet the minimum population and population density requirements; and
- new and existing town boundaries to identify if any short-duration town counts should be added, removed, or reassigned, as necessary.

Evaluation of these elements of the town count program will ensure the program provides adequate traffic volume data to decision makers.

5 CONCLUSION

This chapter summarizes the key findings and recommendations of this research, outlines opportunities for future work, and provides closure to the thesis.

5.1 SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS

This research establishes a methodology to estimate AADT from short-duration counts in towns, which are referred to as town counts. The methodology comprises (1) a procedure to systematically define a town count, and (2) a procedure to identify the best matching TPG for town counts, which enables the estimation of AADT from town counts. The research demonstrates and validates the methodology in the context of the province of Manitoba.

The findings presented in this thesis contribute to traffic monitoring research and practice as follows:

- On its own, a town's legal boundary is unlikely able to differentiate town counts from non-town counts from a traffic pattern perspective. Incorporating characteristics of the town such as population and population density, and characteristics of the road environment at the location of the count station such as speed, highway orientation, number of intersections, and land use, in addition to the town's legal boundary, provides a better ability to identify the locations that are likely to experience town-like traffic periodicities and therefore should be recognized as town counts.

- Short-duration count stations located in towns where the population and population density are less than 1000 residents and 400 residents per square kilometre, respectively, often report volumes below 500 vehicles/day. There is additional risk involved in estimating AADT on low volume roadways due to the

high variability present in low volumes. If historical data is available, it should be considered while identifying town counts if the purpose of identification is to estimate AADT.

- A simplified cluster analysis, using only Euclidean distance, paired with the visual and tolerance interval validation procedures facilitates the detection of an appropriately representative TPG for a short-duration count. The identification of this "best matching" TPG then allows AADT to be estimated from data collected at the short-duration count. This approach partially relies on expert knowledge of the transportation network and professional judgement.

- Selecting an appropriate location for counts within towns can be challenging but is necessary when developing a town count program. For example, as experienced during manual verification counts, angled parking in the vicinity of counting equipment can result in double and even triple counting a single vehicle depending on where the equipment is placed. Unique site-specific challenges may arise and need to be mitigated.

- Evaluation of the program is a vital component of counting within towns. The dynamic nature of towns needs to be considered in order to provide valuable data to the traffic monitoring program.

More specifically, the findings presented in this thesis support practical decisions and activities relevant to Manitoba's traffic monitoring program:

- The decision algorithm identified 172 "town count" short-duration count stations on Manitoba's provincial highway network. This includes 131 of the 327 count stations currently defined as town counts and 41 count stations currently defined as non-town short-duration count stations. The research suggests the remaining 196 count stations currently defined as town counts should continue to report

ADT estimates only. These counts exist in populated areas that do not meet the thresholds used to define a town in this thesis. The patterns experienced at these locations are unknown and the low volumes previously recorded at these count stations are subject to increased error during AADT estimation due to the high variability that exists at low volume sites.

- The assignment procedure and the subsequent validation procedures of the chosen assignments reveal that Manitoba's TPG 4 can be used to develop reliable AADT estimates at the 172 identified town count stations. TPG 4 sites are described as being located adjacent to rural population centres. Their distinguishing characteristics are steady weekday traffic with afternoon peaks higher than morning peaks, moderate volume peaks on Fridays, lower weekend (vs weekday) volumes, and low seasonal variation. AADT estimates from town counts can be developed using the existing estimation procedures that are used to develop AADT estimates from other short-duration count sites in Manitoba.

- Of the 55 towns identified, nine currently do not have any town counts in their vicinity. The nine towns are: Chemawawin 2, Mitchell, Moose Lake, Niverville, Oakbank, Pinawa, Shilo CFB-BFC, St. Adolphe, and St. Theresa Point. The addition of new town count stations within these nine towns should be prioritized as resources become available.

- Manitoba's inventory of short-duration count stations should be evaluated as new Census Canada data containing town population and population density becomes available. This will allow the town count portion of the traffic monitoring program to remain up-to-date, thereby providing practitioners with the best available traffic volume data in Manitoba's towns.

5.2 OPPORTUNITIES FOR FUTURE RESEARCH

This research revealed the following future research needs:

- Evaluate the benefit and feasibility of estimating AADT at short-duration count stations that exist in populated areas where the population and population density are lower than the thresholds used to define a town in this thesis. This research identified 196 current short-duration count stations in this category. The historical data from many of these counts report extremely low volumes and the value and practicality of estimating AADT at these locations is unknown.

- Conduct an in-depth review of each of the 55 towns identified in this research, specifically focusing on the current locations of their town counts. Develop a list new town count stations with the goal of providing reliable AADT estimates on all homogenous roadway sections in each town. While the current 172 town counts provide adequate coverage of the network, this work will add to the overall value of the town count program in Manitoba.

- Analyze the feasibility of integrating turning movement counts into the short-duration count program in Manitoba by developing AADT estimates from turning movement counts. Currently, Manitoba collects turning movement data (typically for 14-hour durations) at various locations in the province, and specifically, within many towns. In complex town environments this information is particularly valuable, as it eliminates the need for multiple short-duration counts on each leg of a major intersection. Turning movement data could be used to reduce the number of traditional short-duration town count stations needed, or, to supplement data collected from traditional short-duration counts within towns.

- Analyze the feasibility of using passive data collection technology to develop AADT estimates on roadways within towns. Currently, passive data is not able to

provide accurate AADT estimates on all roads, but as this technology continues

to develop and evolve, this is expected to change. Additionally, the use of

emerging commercially available traffic volume datasets (e.g., StreetLight Data),

which utilize machine learning algorithms to estimate AADT, should be

considered and formally evaluated.

- Further investigate the traffic periodicities, in particular the monthly patterns,

  present in town environments by installing continuous count stations within

  towns. Currently, in Manitoba, continuous count stations exist in exclusively rural

  settings. The addition of continuous count stations in towns in Manitoba will

  identify whether TPG 4, despite being the closest matching to short-duration

  town counts, is truly the best TPG to use to estimate AADT from town count data.

- If installing continuous count stations in towns is not feasible, further investigation

  of the traffic periodicities present in town environments can be accomplished by

  conducting similar research as was done in this thesis, over the course of one

  year. Collecting a week of hourly volume data from each sample site every

  month of the year will allow monthly traffic patterns, and a better representation

  of the average hourly and average DOW traffic patterns to be incorporated in the

  decision of best matching TPG.

5.3   CLOSURE

To close, this research develops and applies a decision algorithm to identify which short-

duration counts should be considered town counts and develops and validates a

methodology to estimate AADT from town counts using the characteristics of existing

TPGs and their temporal adjustment factors. Developing AADT estimates on roadways

within a town environment makes use of existing traffic volume data that is collected by

traffic monitoring agencies in towns, thereby improving an agency's ability to provide

systemwide estimates of traffic statistics. Specifically, developing AADT estimates from

town counts will provide decision makers with the ability to make informed decisions

related to transportation infrastructure, maintenance, safety, and policy within towns.

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APPENDIX A: TOWN BOUNDARY MAPS

This appendix provides maps of the 55 towns within Manitoba, in alphabetical order. Each figure shows the town boundary, provincial roadways and their speed limits, and the locations of traffic count stations within and around each town. The count type indicated reflects the current situation, i.e., before conducting the decision algorithm analysis described in Section 3.1.1. An asterisk is used to identify the traffic count stations that changed their designation as a result of the decision algorithm analysis.
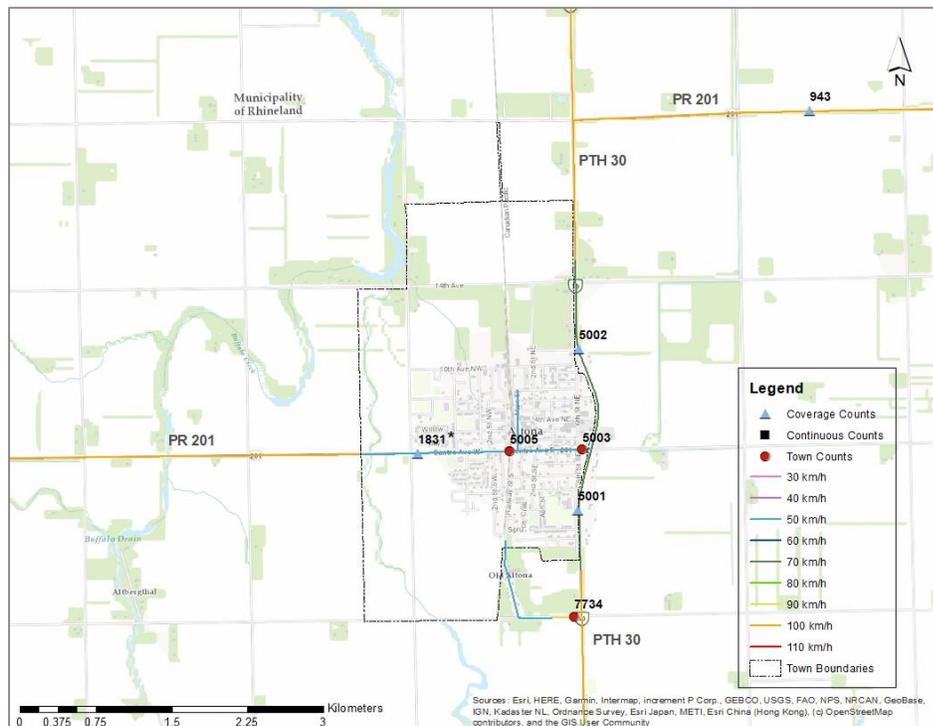
Figure 34: Town boundary of Altona and surrounding area

Figure 35: Town boundary of Arborg and surrounding area

Figure 36: Town boundary of Beausejour and surrounding area

Figure 37: Town boundary of Blumenort and surrounding area

Figure 38: Town boundary of Boissevain and surrounding area

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Figure 39: Town boundary of Brandon and surrounding area
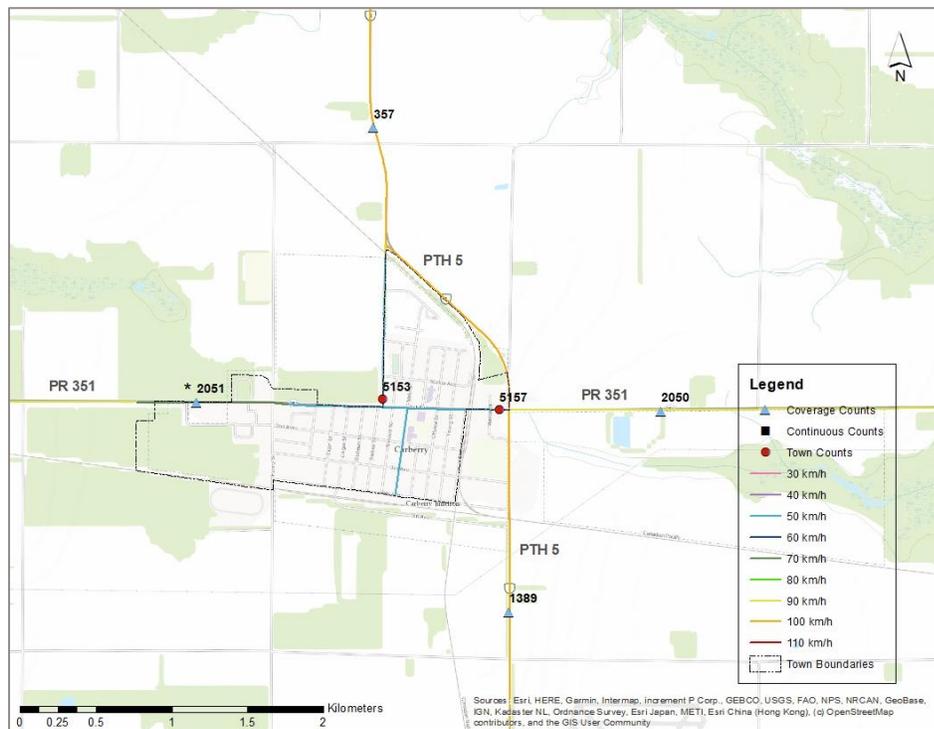
Figure 40: Town boundary of Carberry and surrounding area

Figure 41: Town boundary of Carman and surrounding area

Figure 42: Town boundary of Chemawawin 2 and surrounding area

A-5

Figure 43: Town boundary of Cross Lake 19A and surrounding area

Figure 44: Town boundary of Dauphin and surrounding area
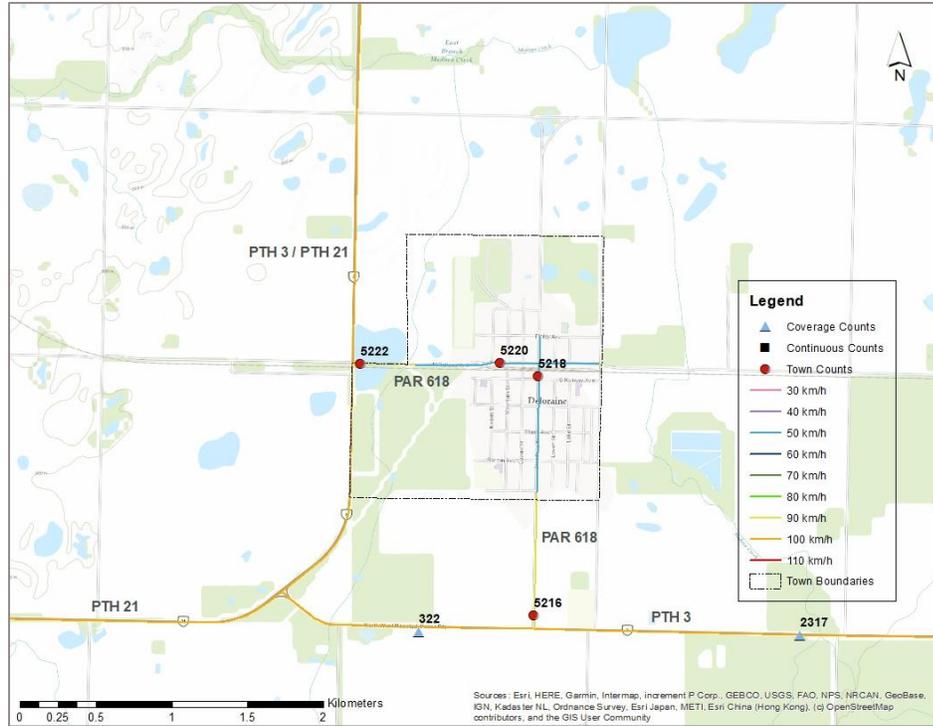
Figure 45: Town boundary of Deloraine and surrounding area
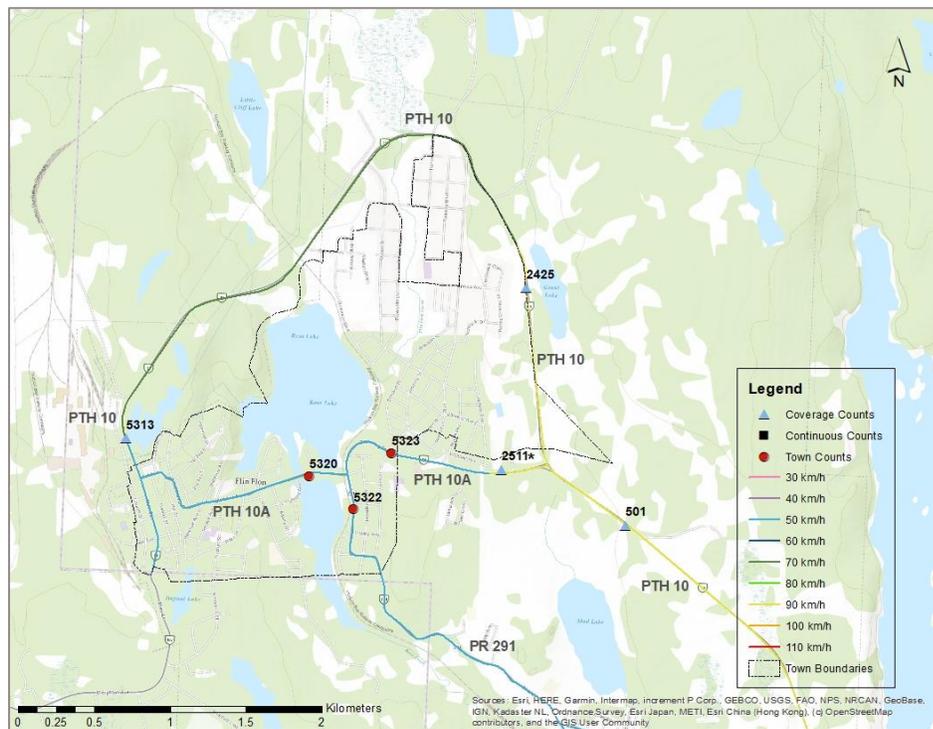
Figure 46: Town boundary of Flin Flon and surrounding area
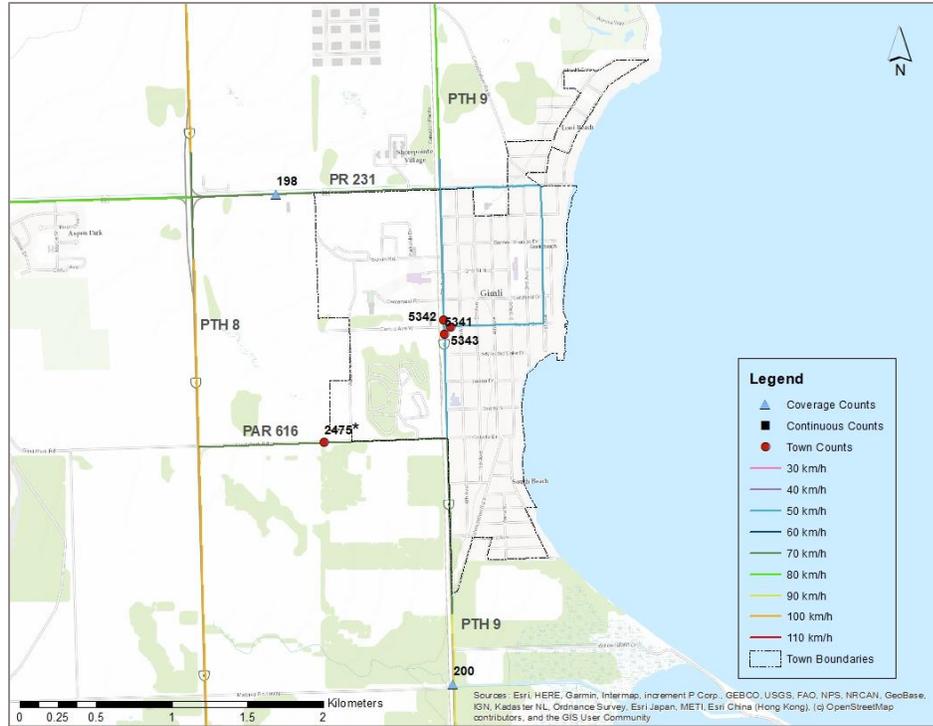
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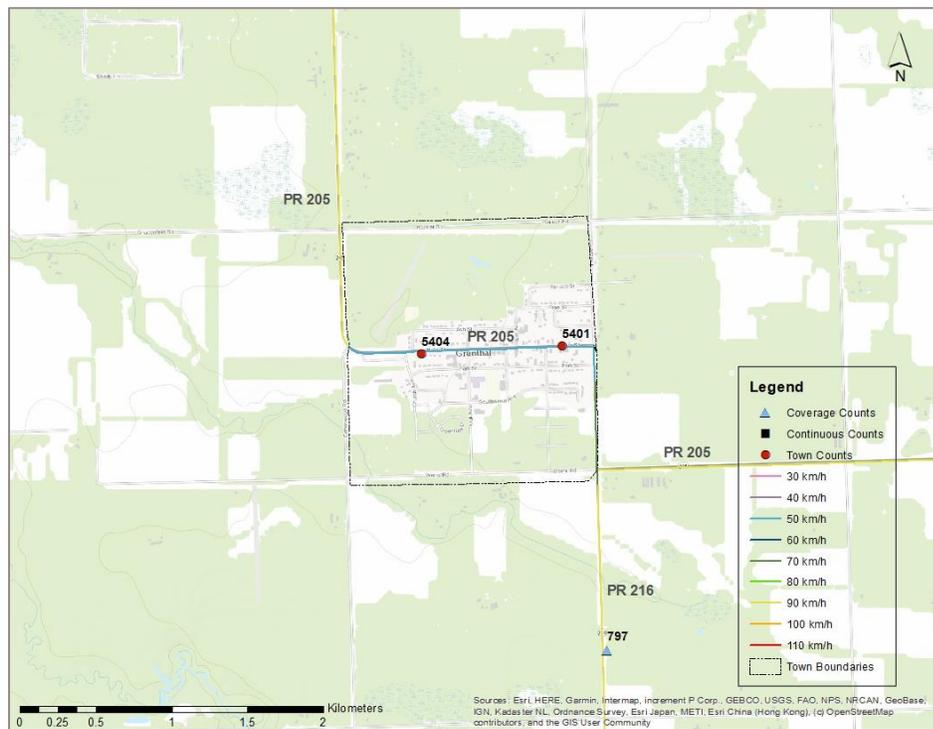
Figure 48: Town boundary of Grunthal and surrounding area

A-8
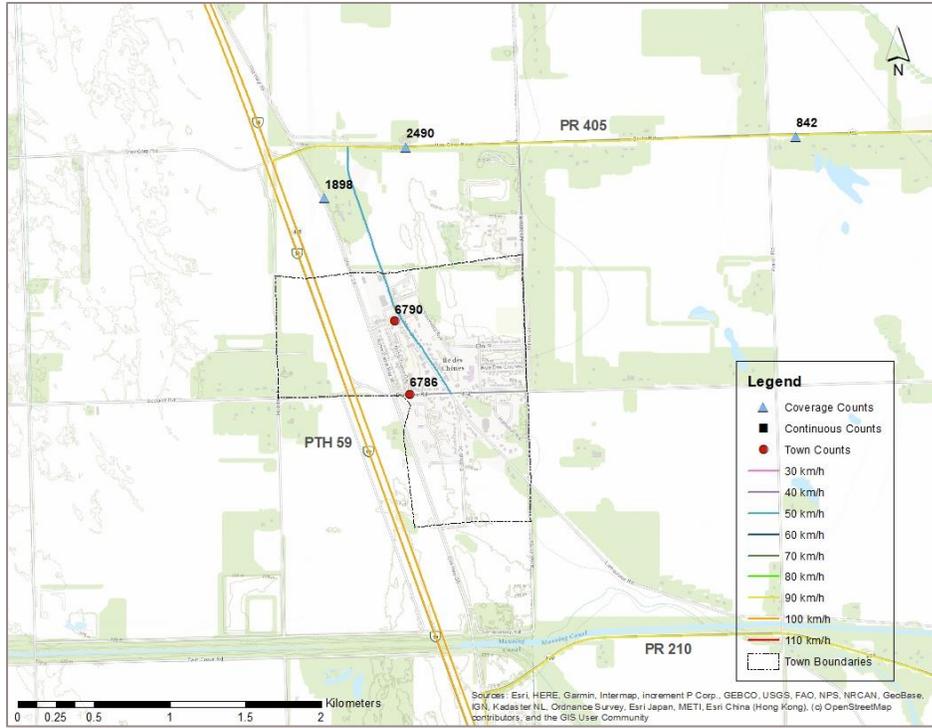
Figure 49: Town boundary of Ile des Chênes and surrounding area
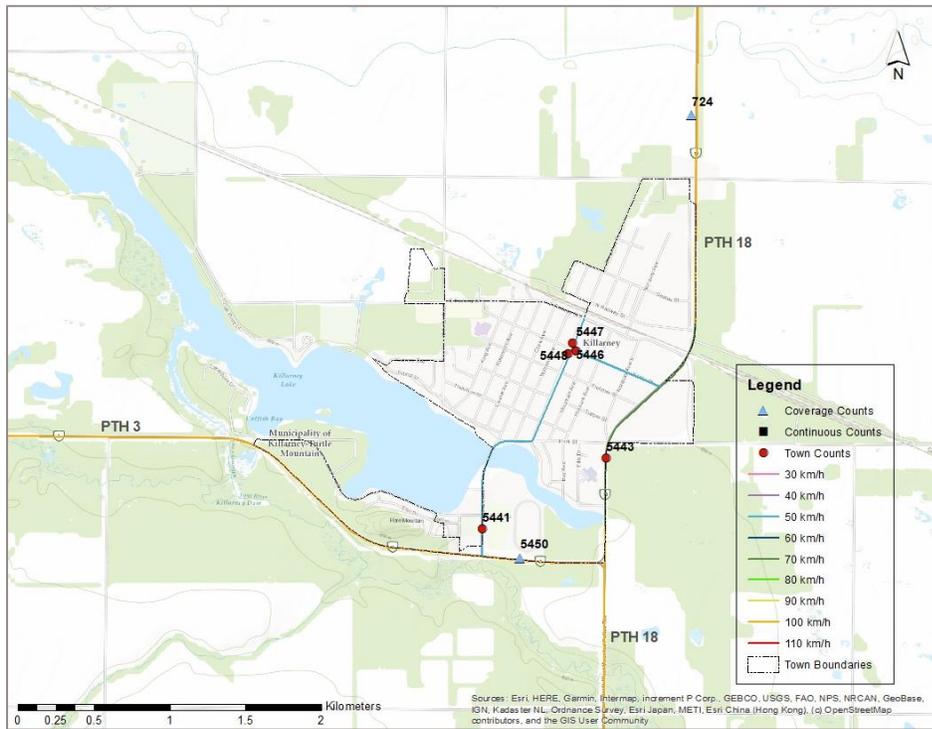
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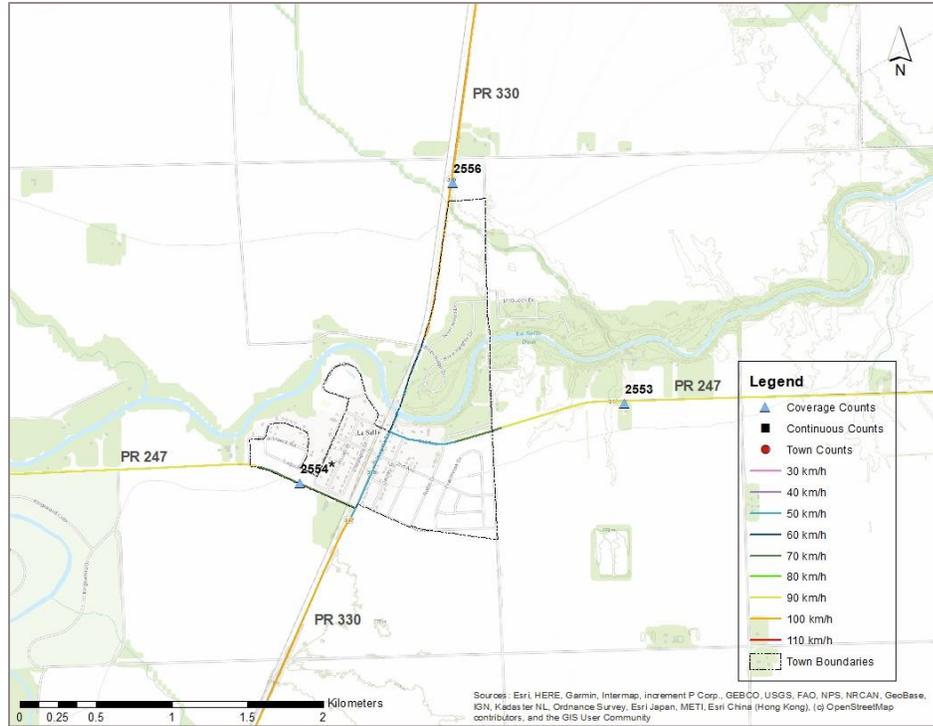
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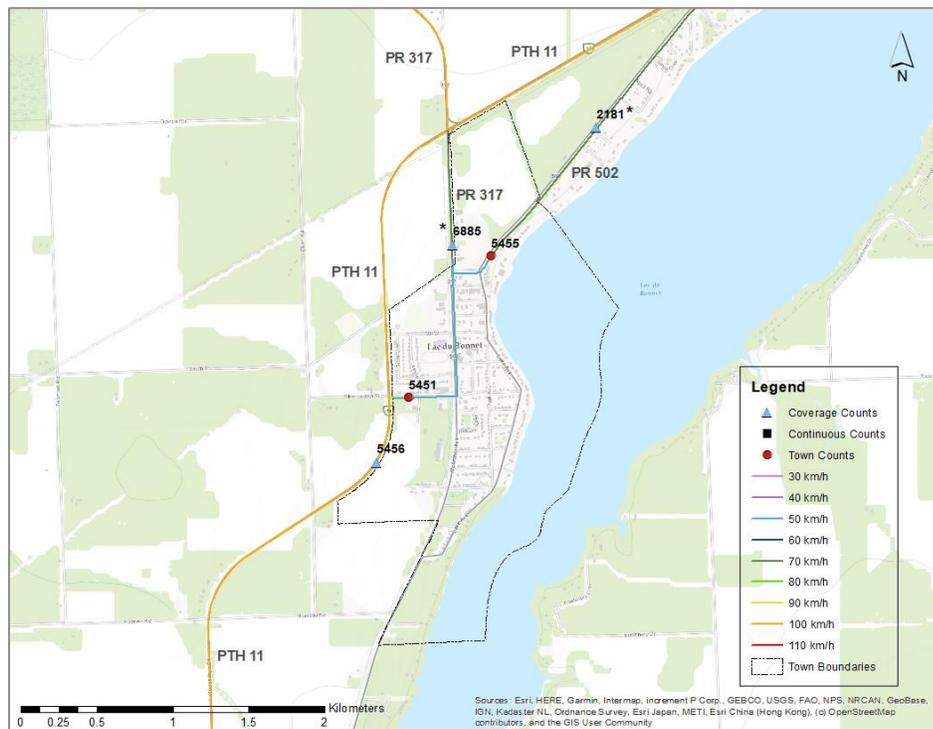
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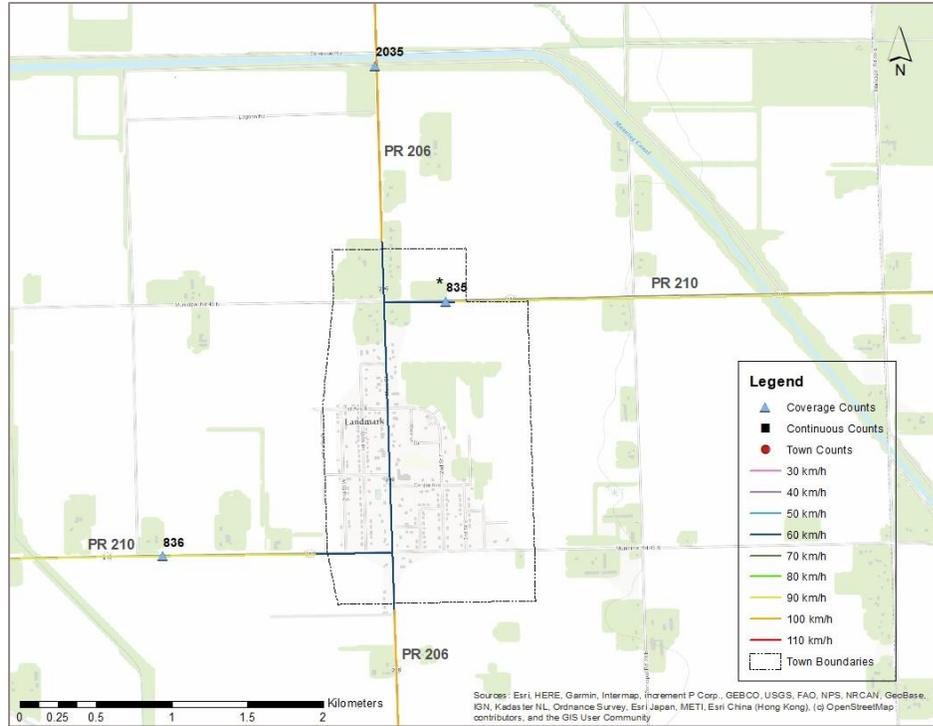
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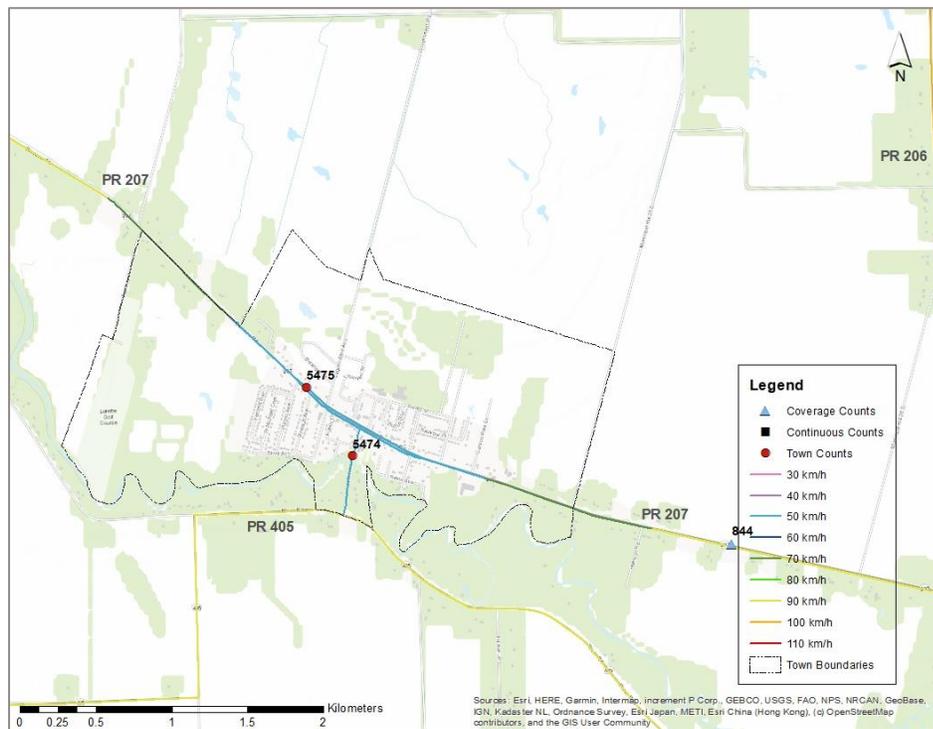
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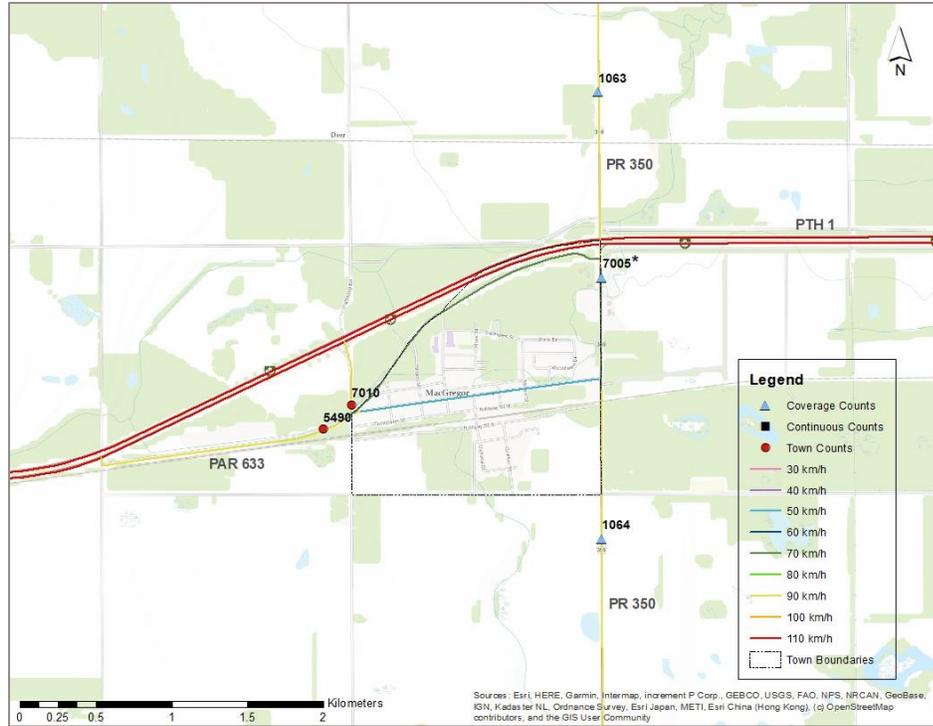
Figure 55: Town boundary of MacGregor and surrounding area
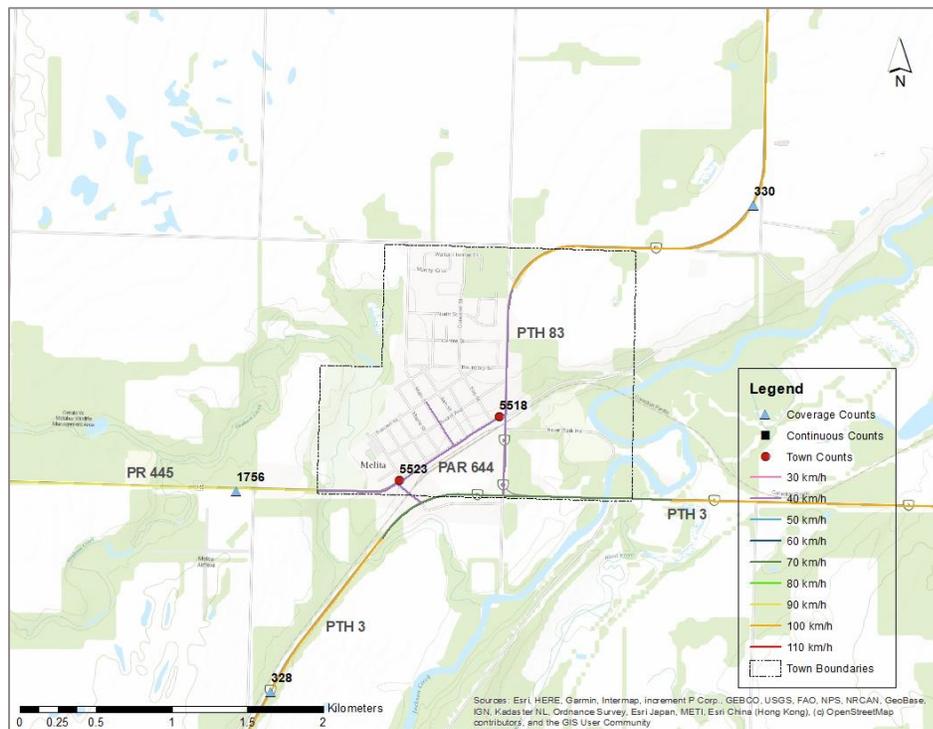
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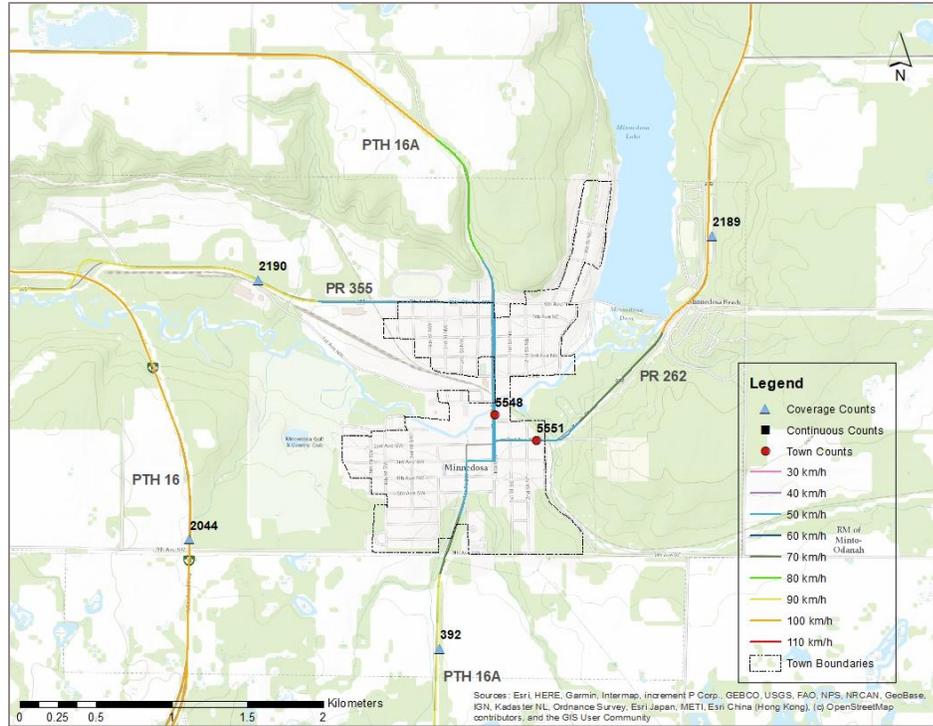
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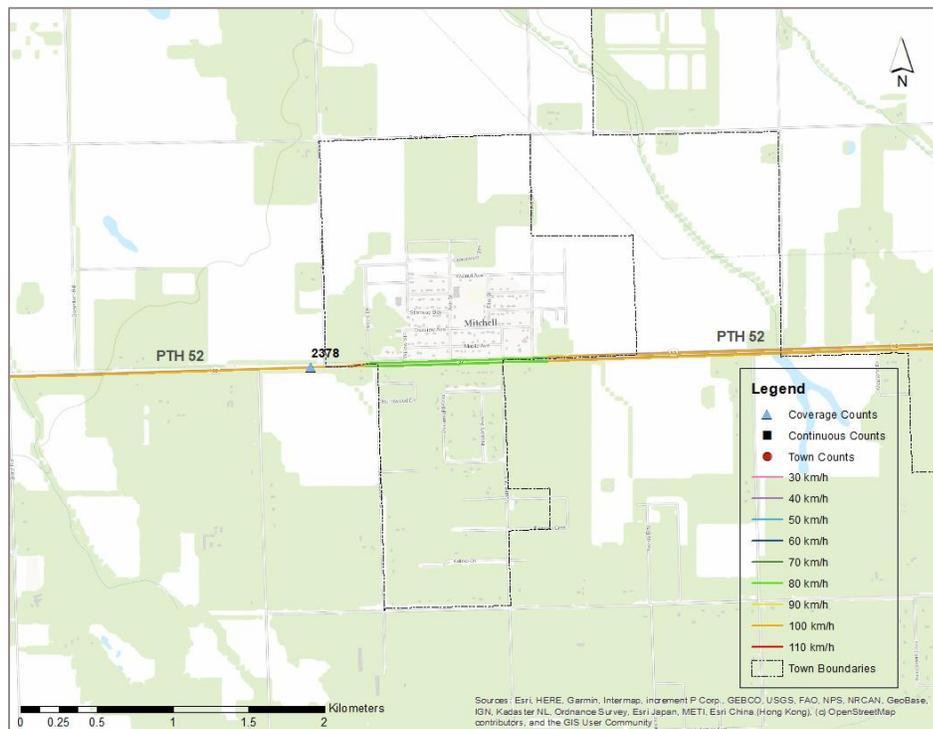
Figure 58: Town boundary of Mitchell and surrounding area
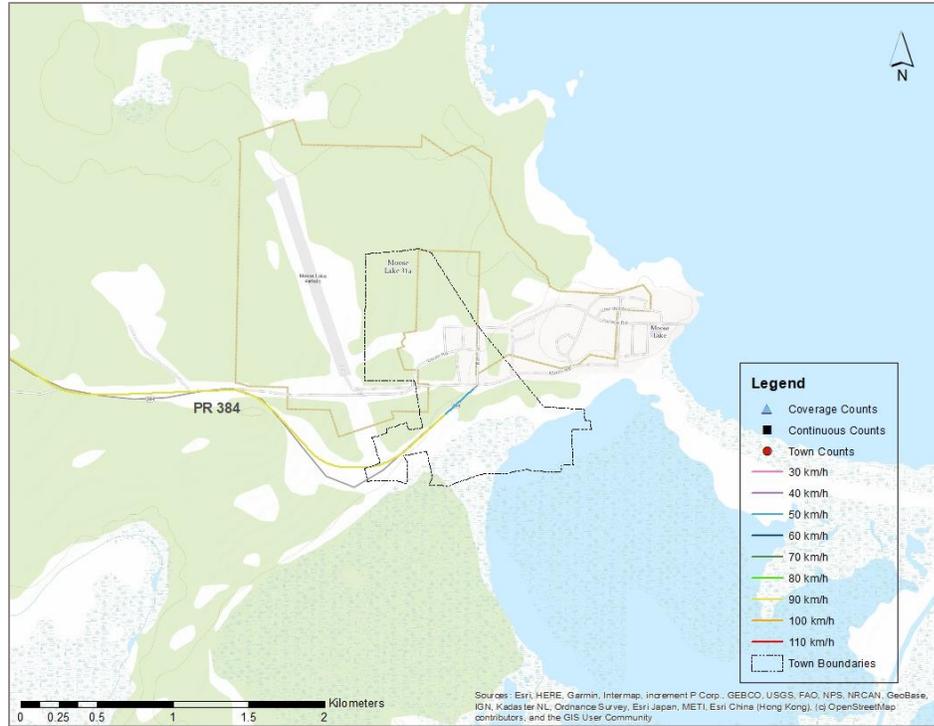
Figure 59: Town boundary of Moose Lake and surrounding area
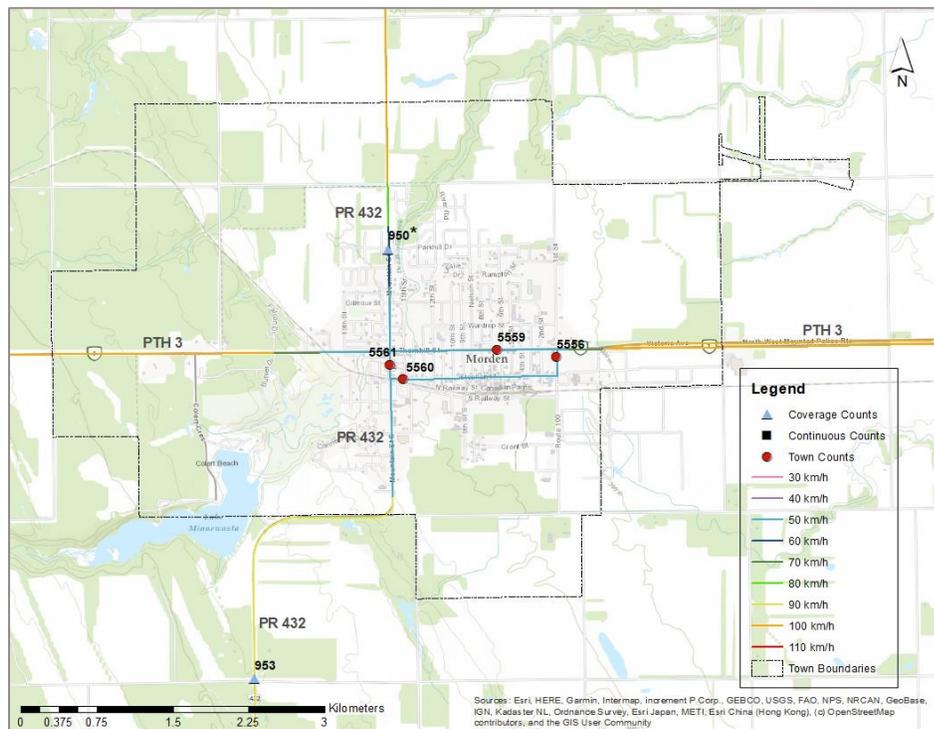
Figure 60: Town boundary of Morden and surrounding area

A-14
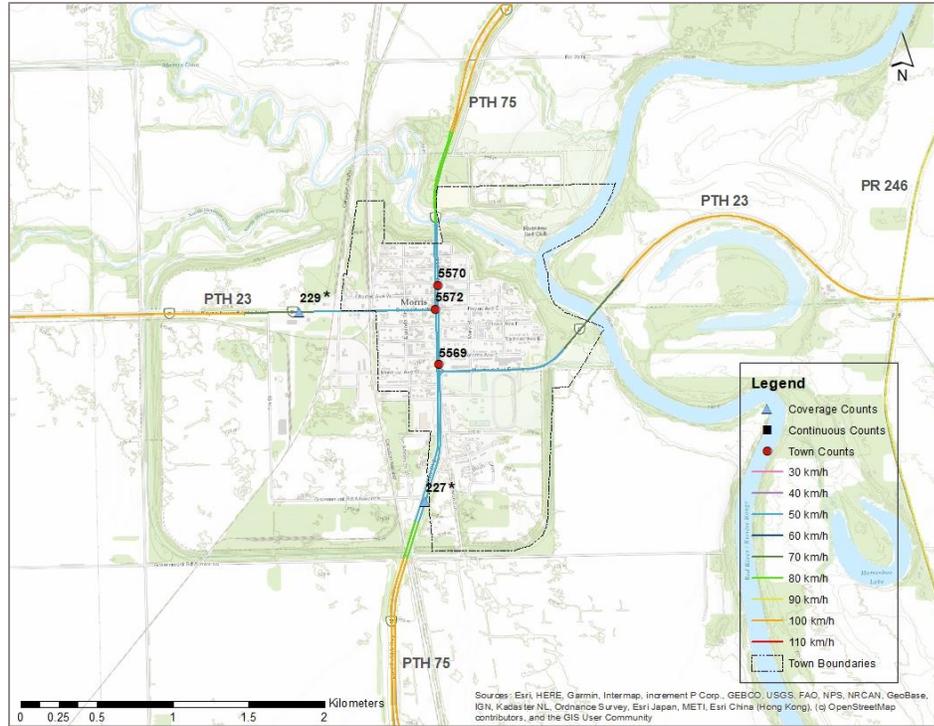
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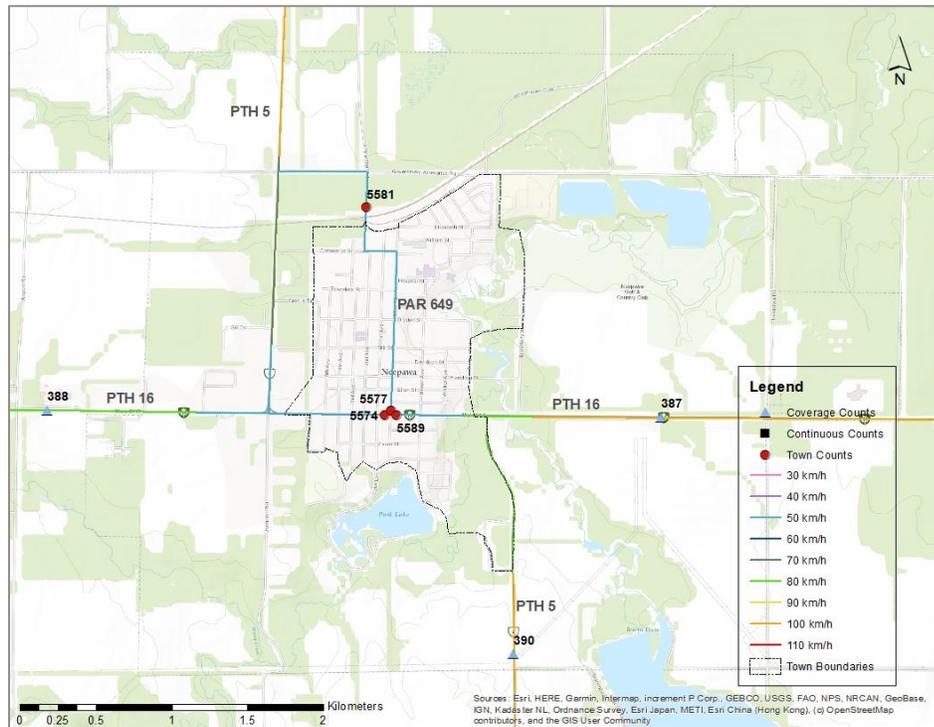
Figure 62: Town boundary of Neepawa and surrounding area
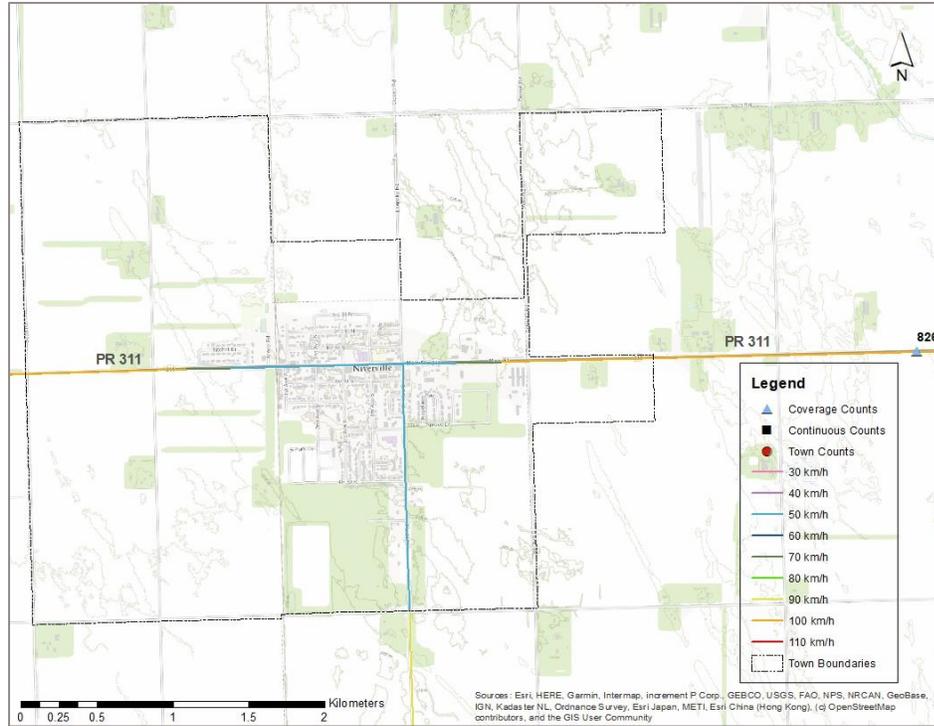
Figure 63: Town boundary of Niverville and surrounding area
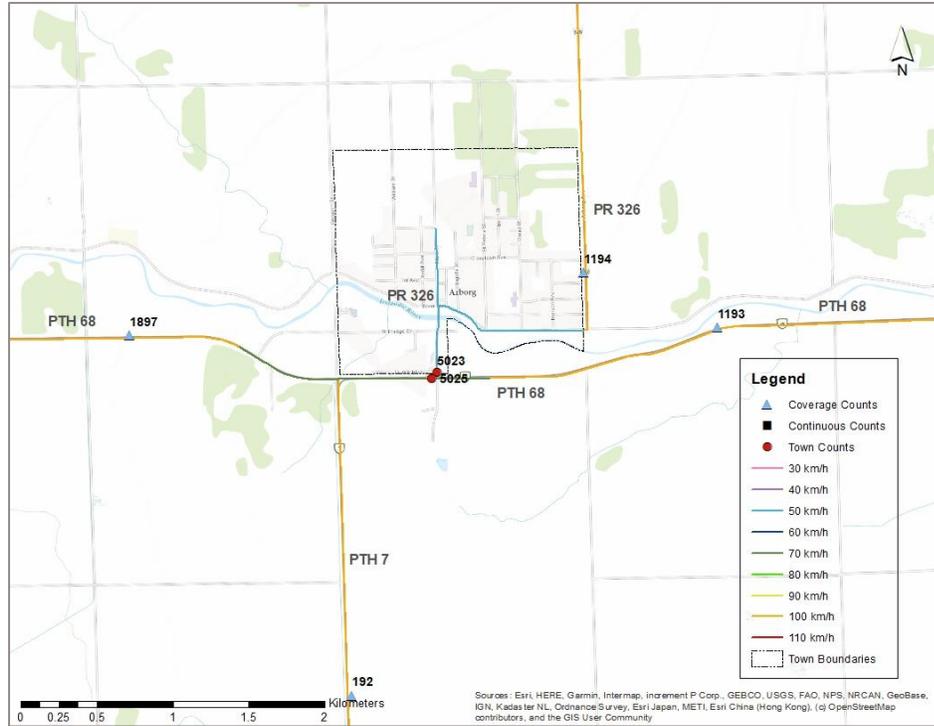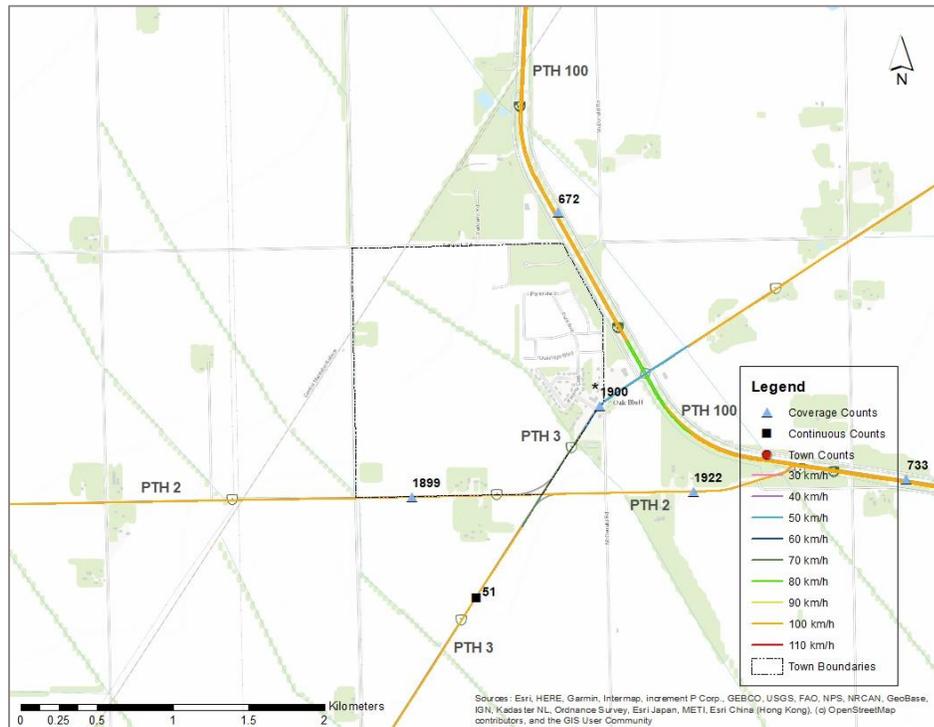

Figure 64: Town boundary of Oak Bluff and surrounding area
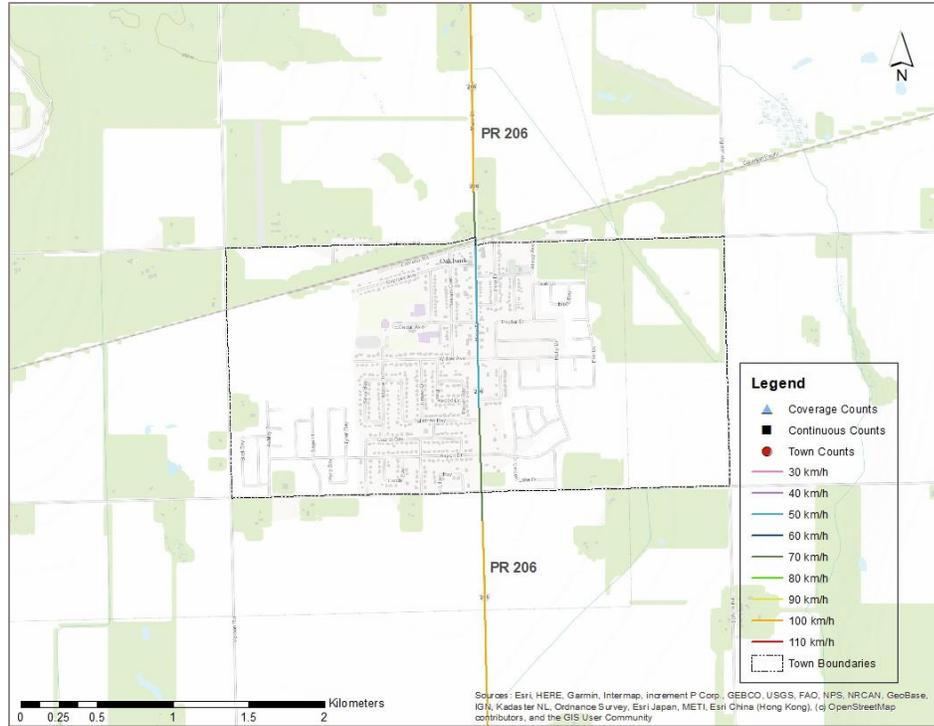
Figure 65: Town boundary of Oakbank and surrounding area
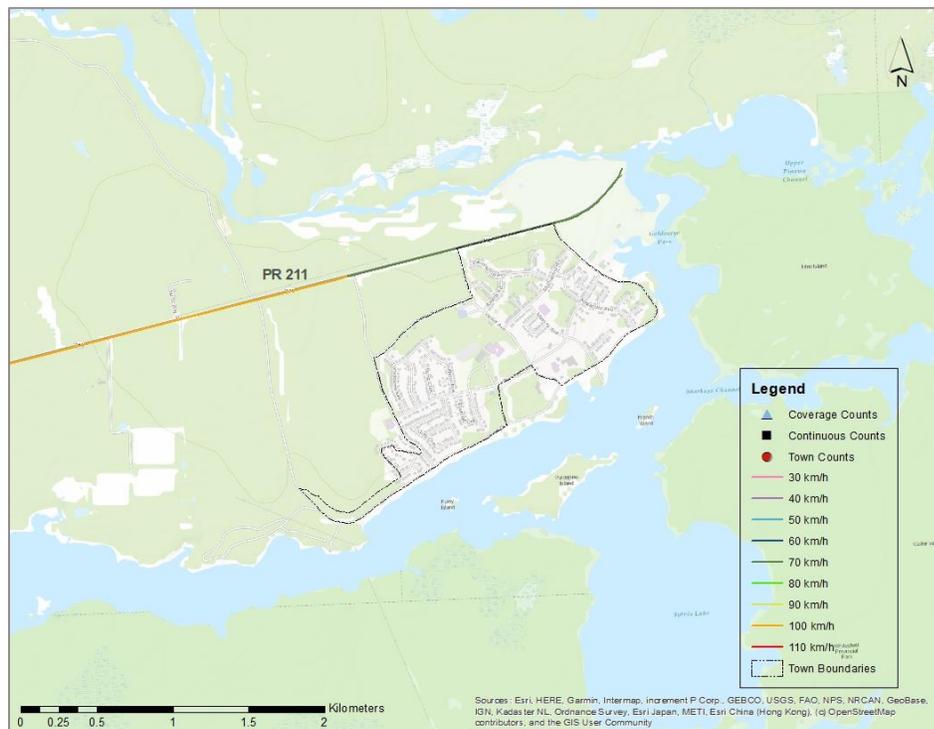
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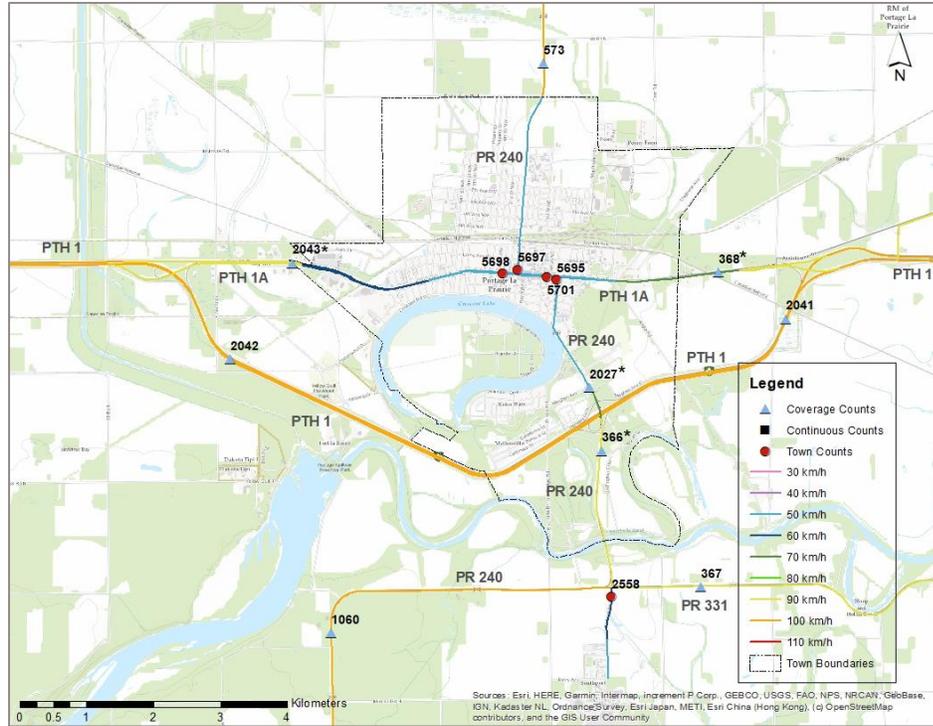
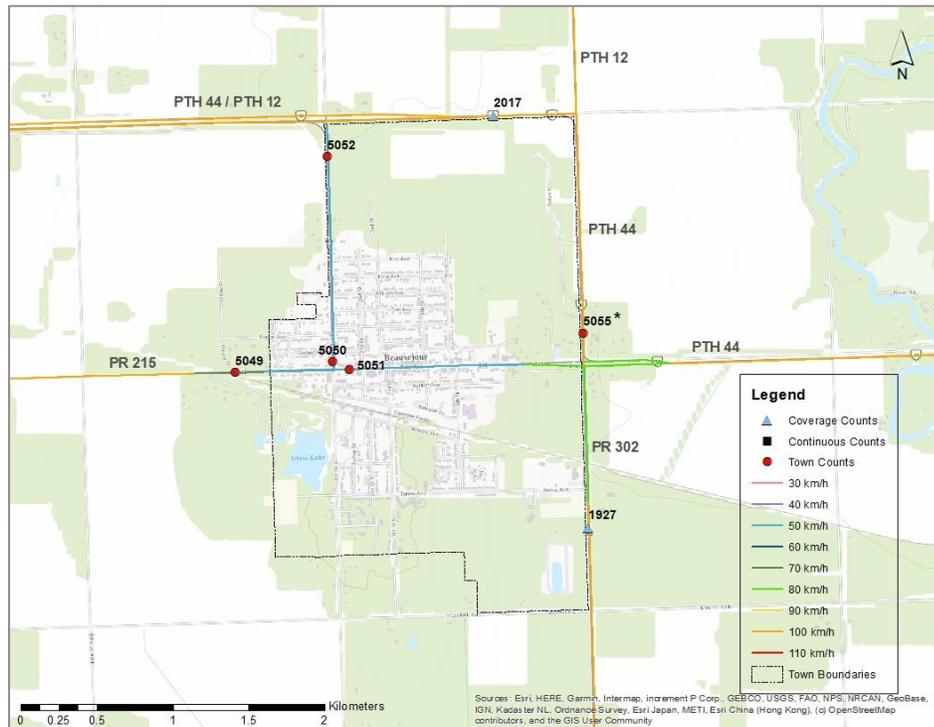**Figure 67: Town boundary of Portage la Prairie and surrounding area**
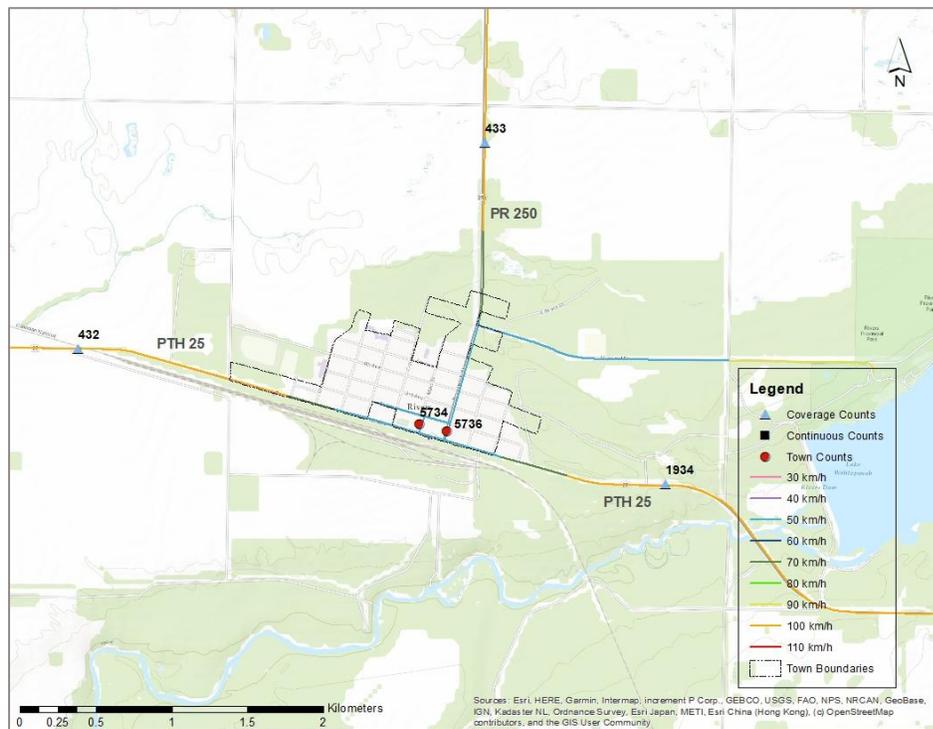
Figure 68: Town boundary of Rivers and surrounding area
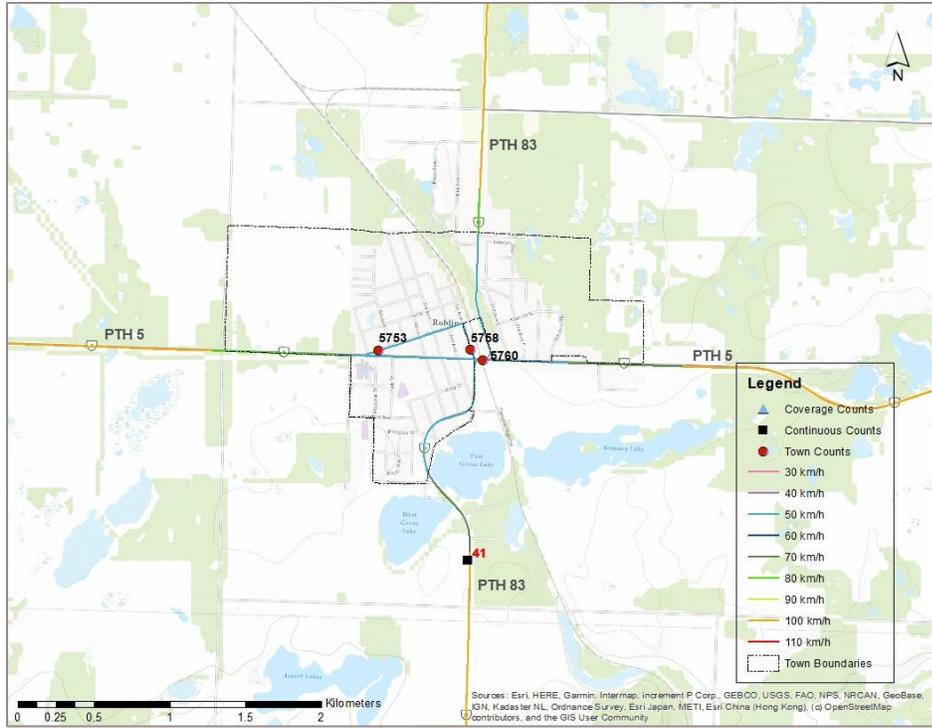
Figure 69: Town boundary of Roblin and surrounding area
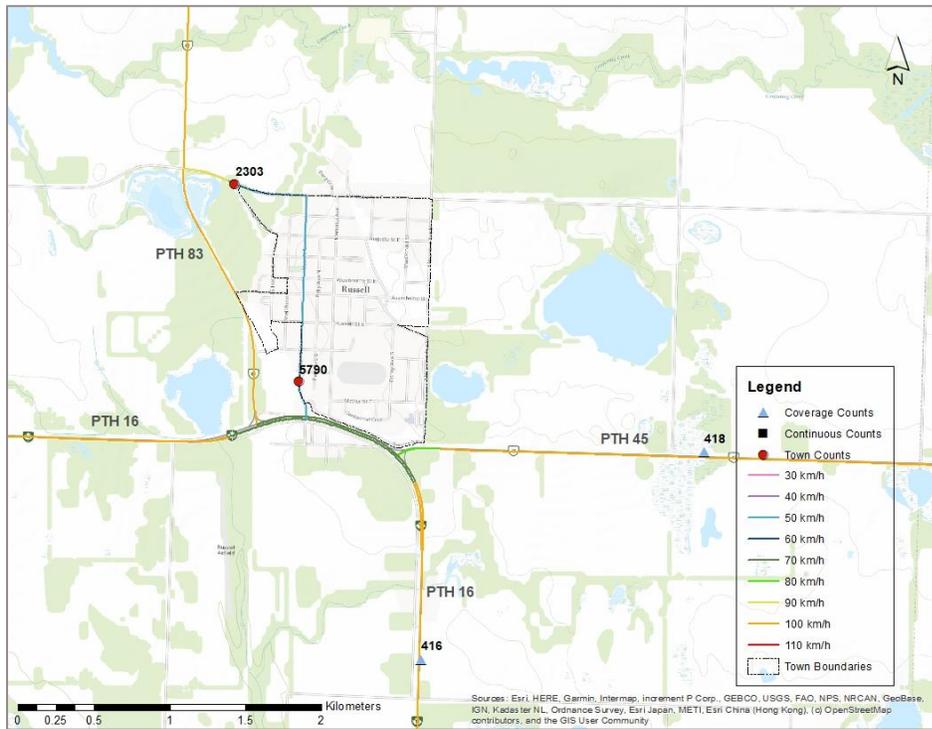
Figure 70: Town boundary of Russell and surrounding area

Figure 71: Town boundary of Selkirk and surrounding area

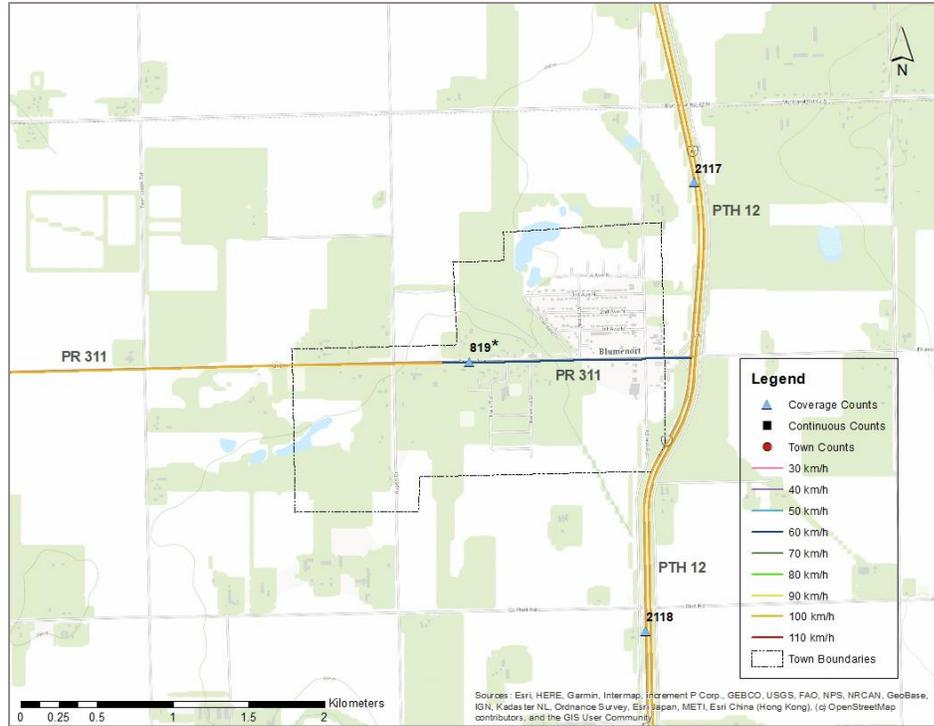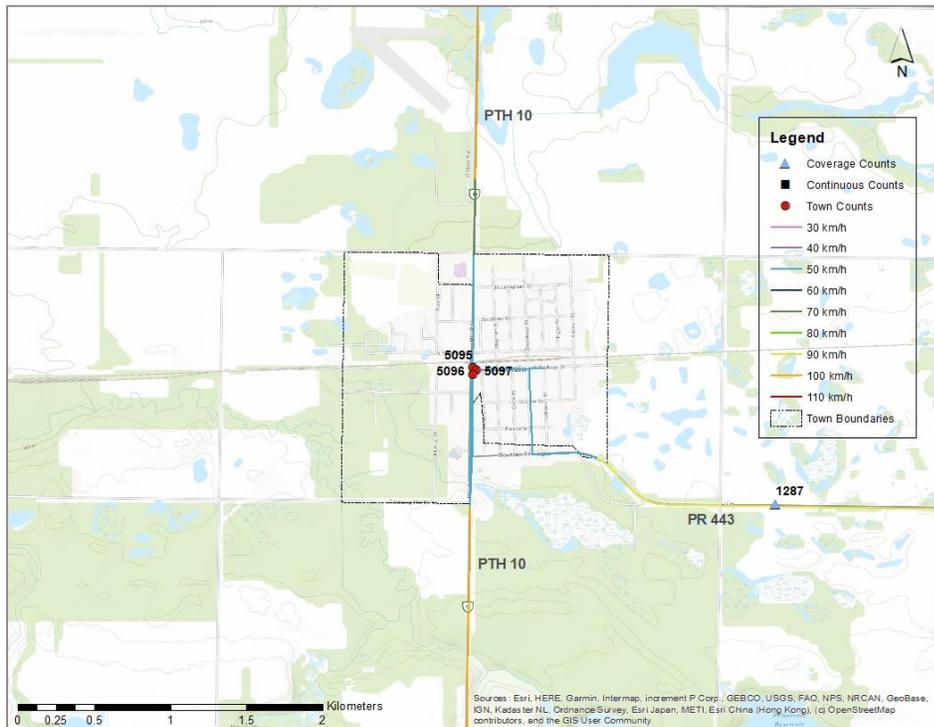**Figure 72: Town boundary of Shilo CFB-BFC and surrounding area**
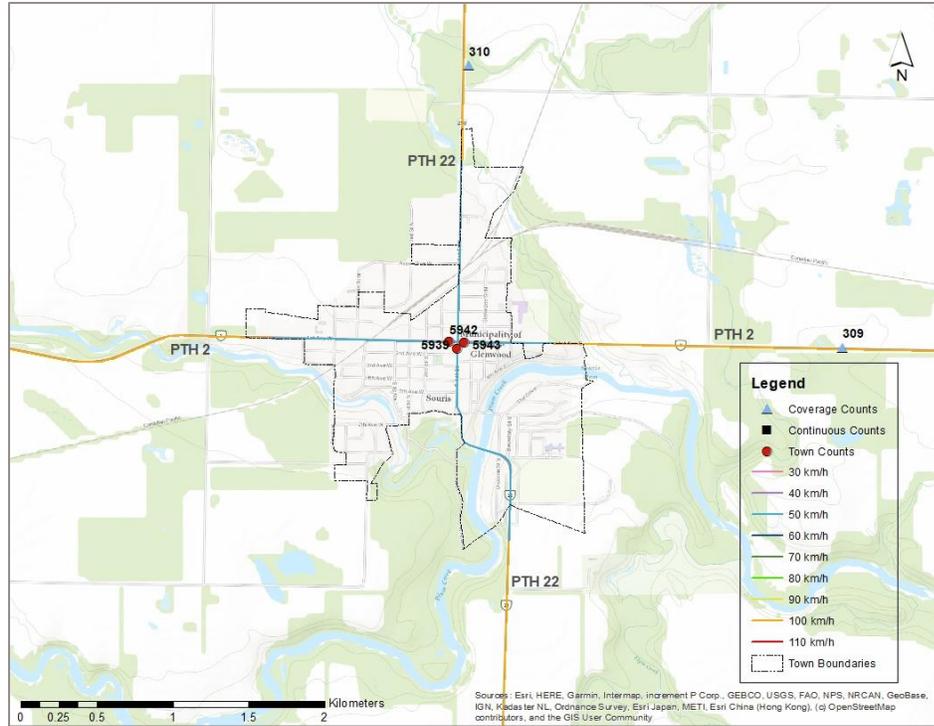
Figure 73: Town boundary of Souris and surrounding area
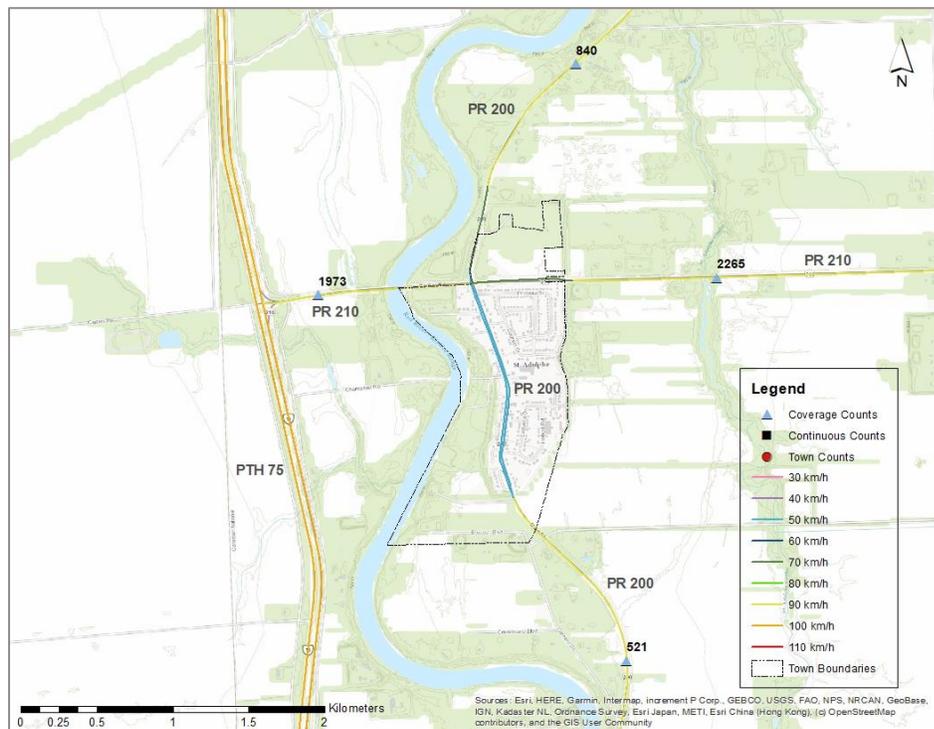
Figure 74: Town boundary of St. Adolphe and surrounding area
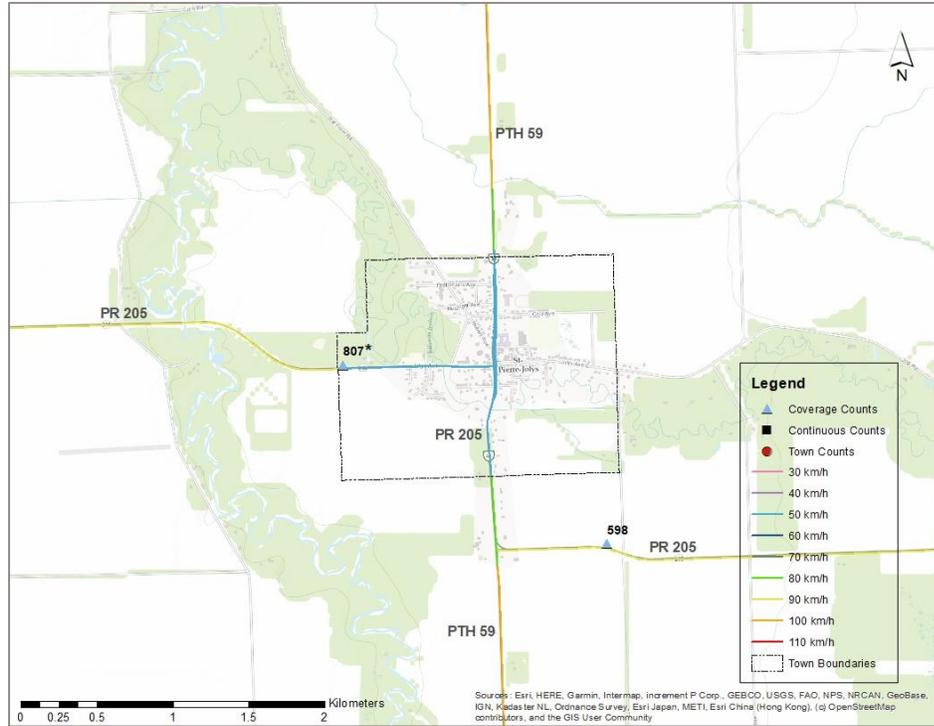
Figure 75: Town boundary of St. Pierre-Jolys and surrounding area
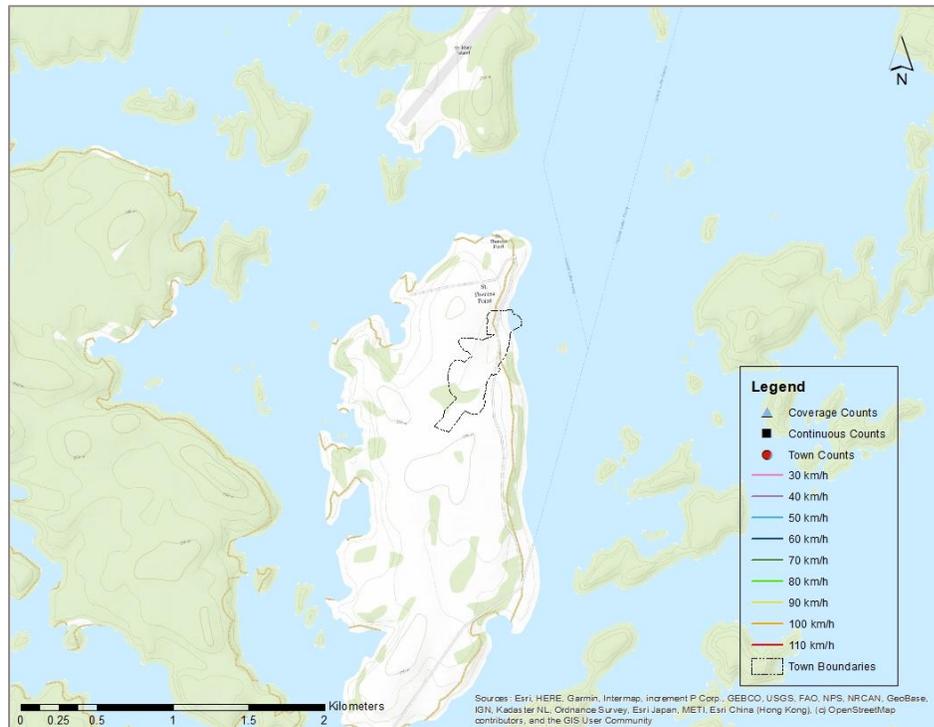
Figure 76: Town boundary of St. Theresa Point and surrounding area
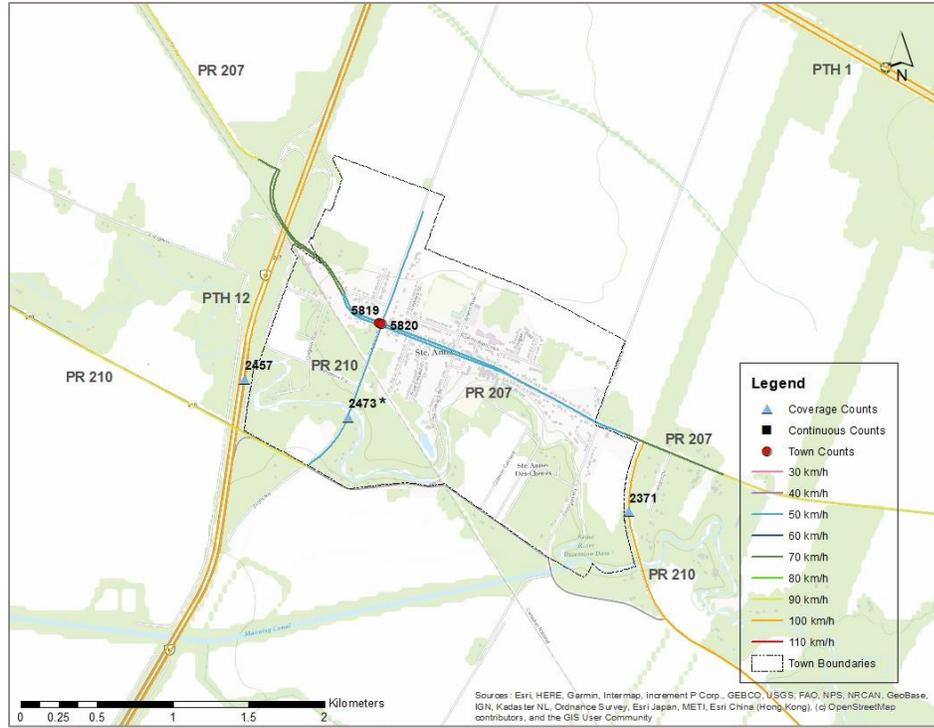
Figure 77: Town boundary of Ste. Anne and surrounding area
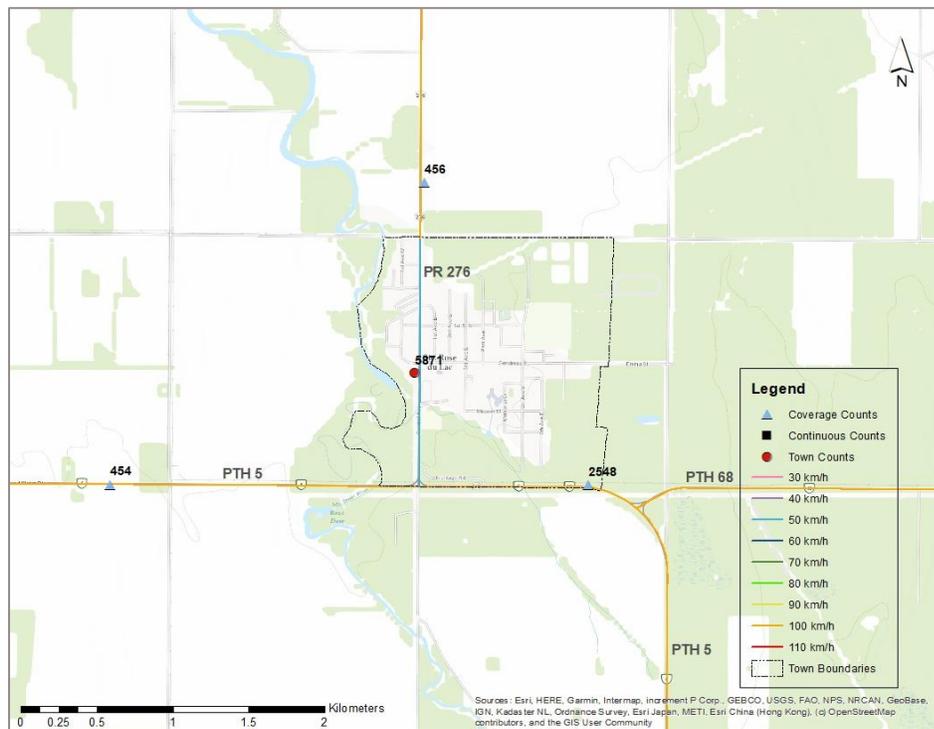
Figure 78: Town boundary of Ste. Rose du Lac and surrounding area
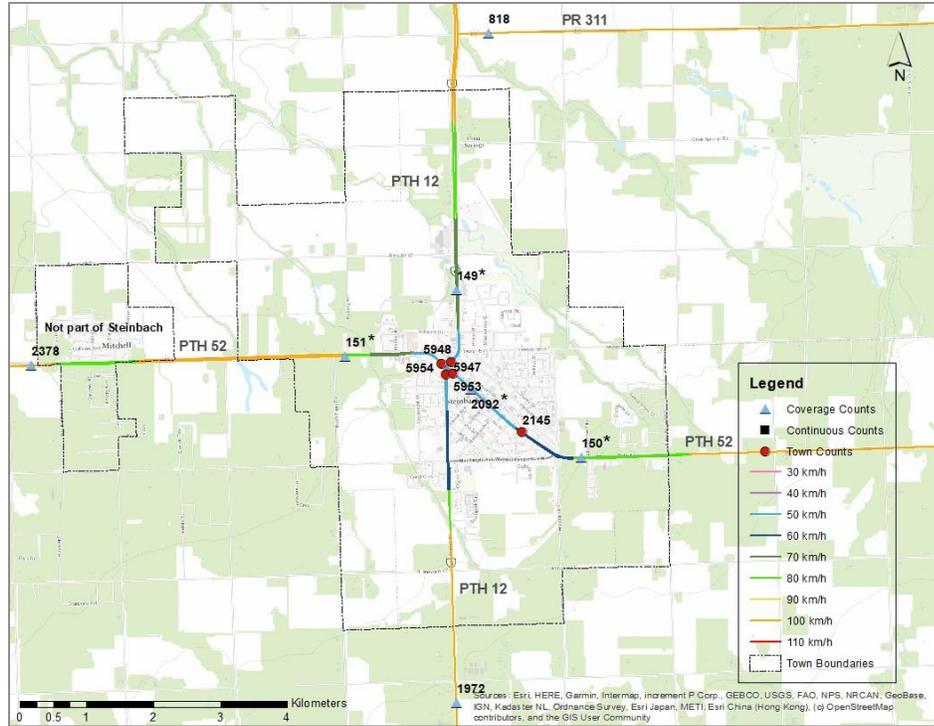
Figure 79: Town boundary of Steinbach and surrounding area
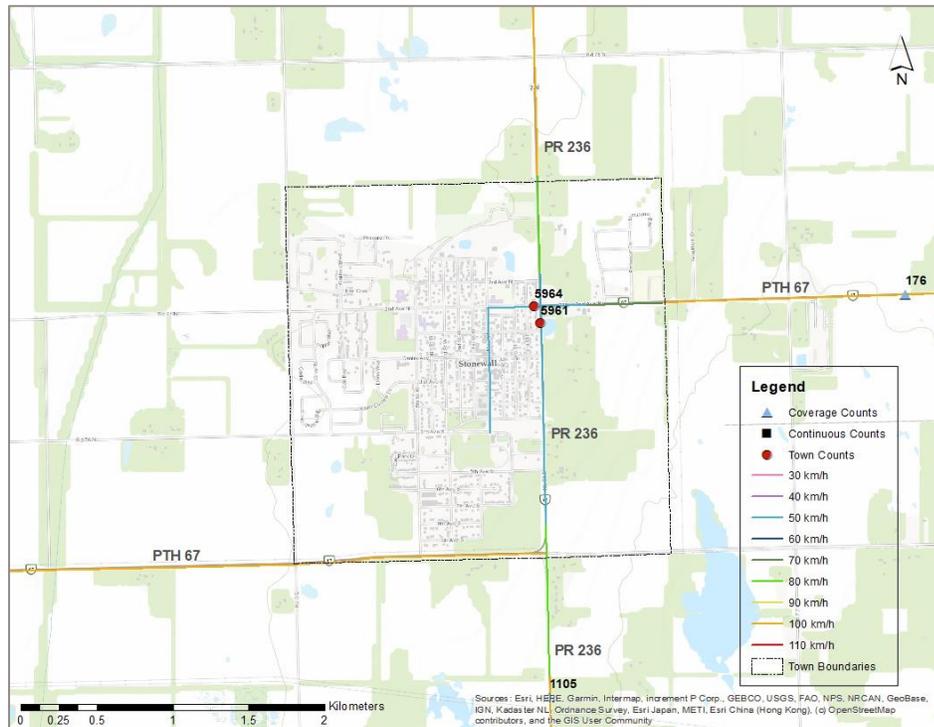
Figure 80: Town boundary of Stonewall and surrounding area
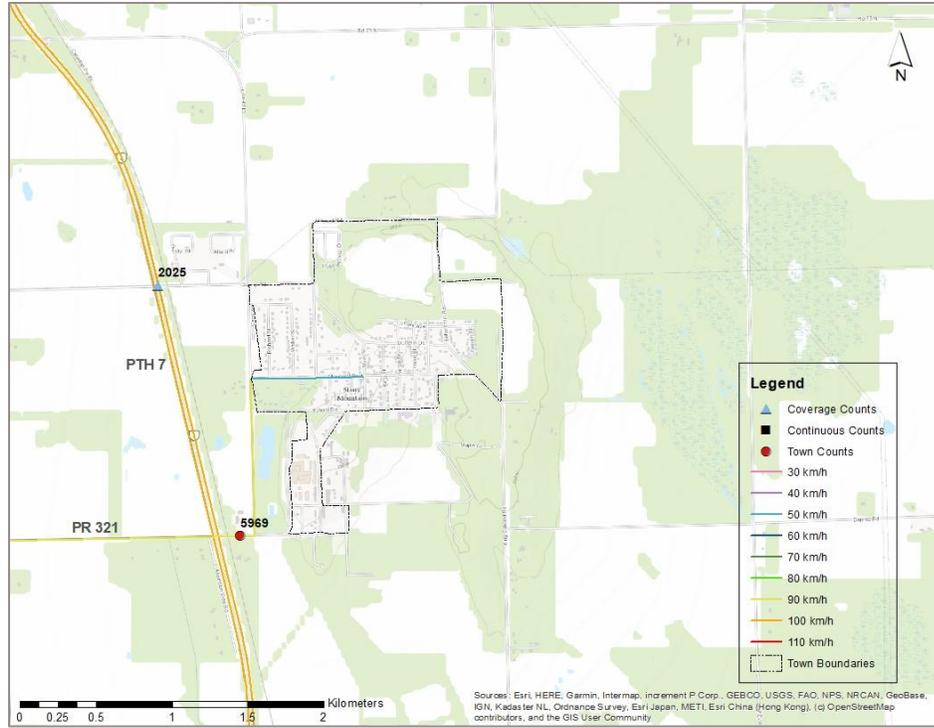
Figure 81: Town boundary of Stony Mountain and surrounding area
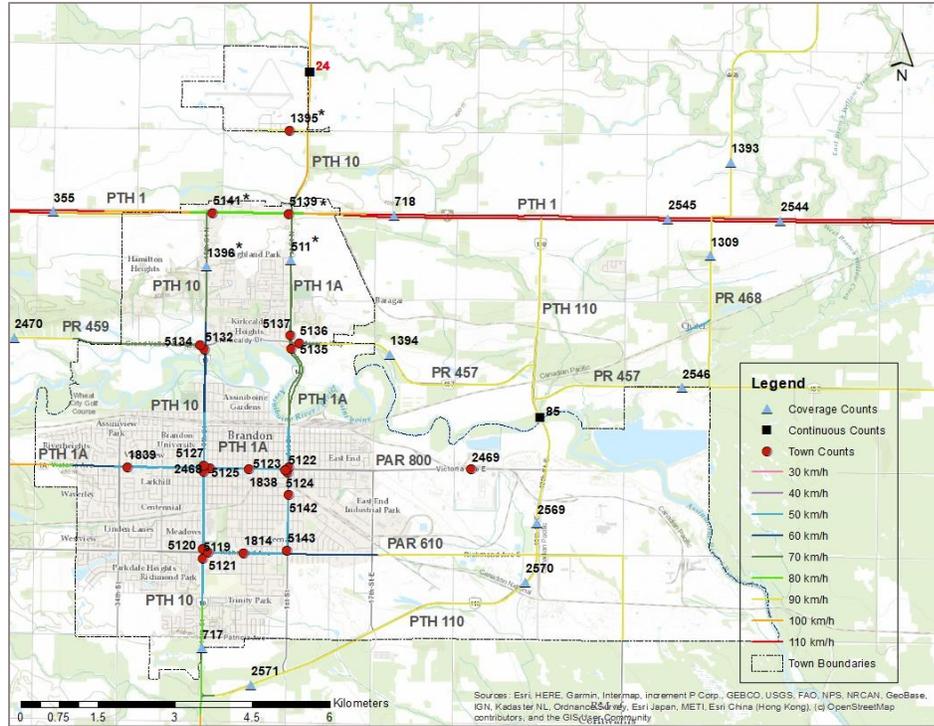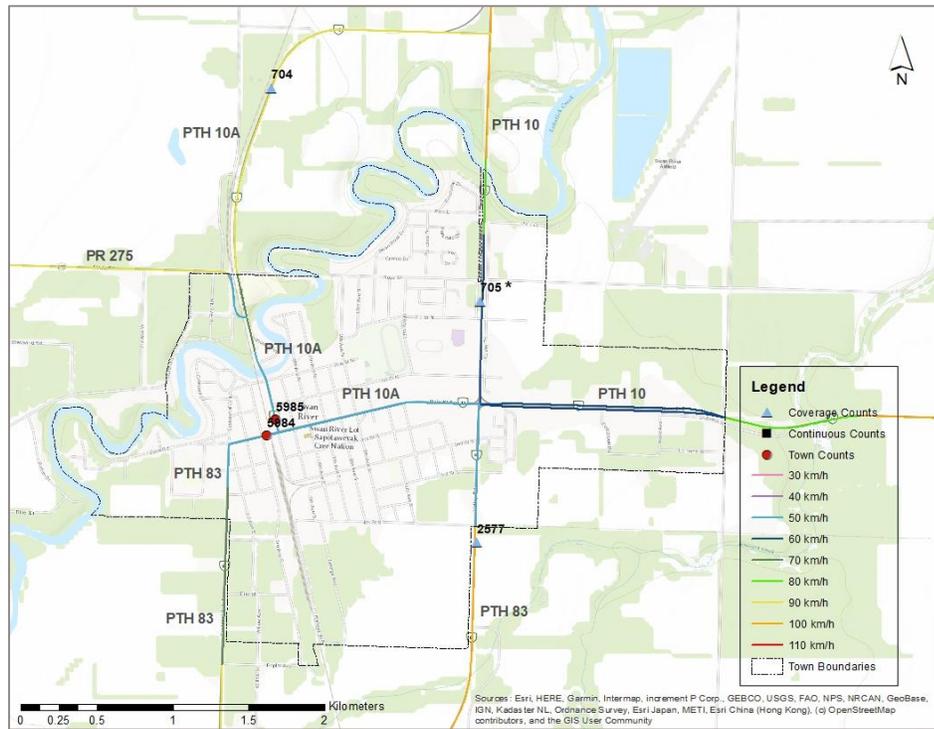

**Figure 82: Town boundary of Swan River and surrounding area**
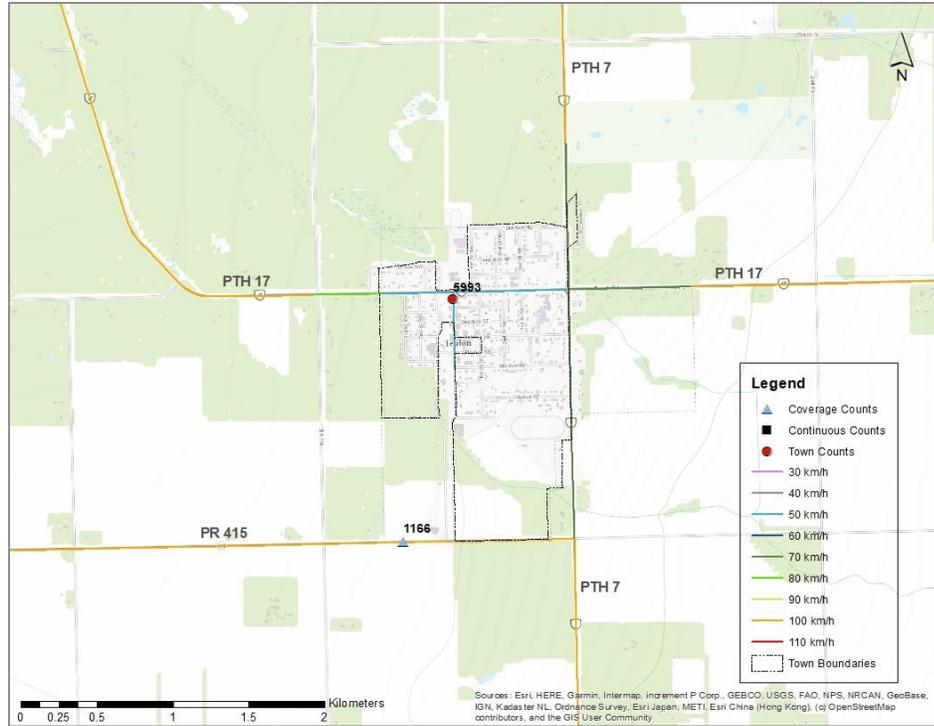
Figure 83: Town boundary of Teulon and surrounding area
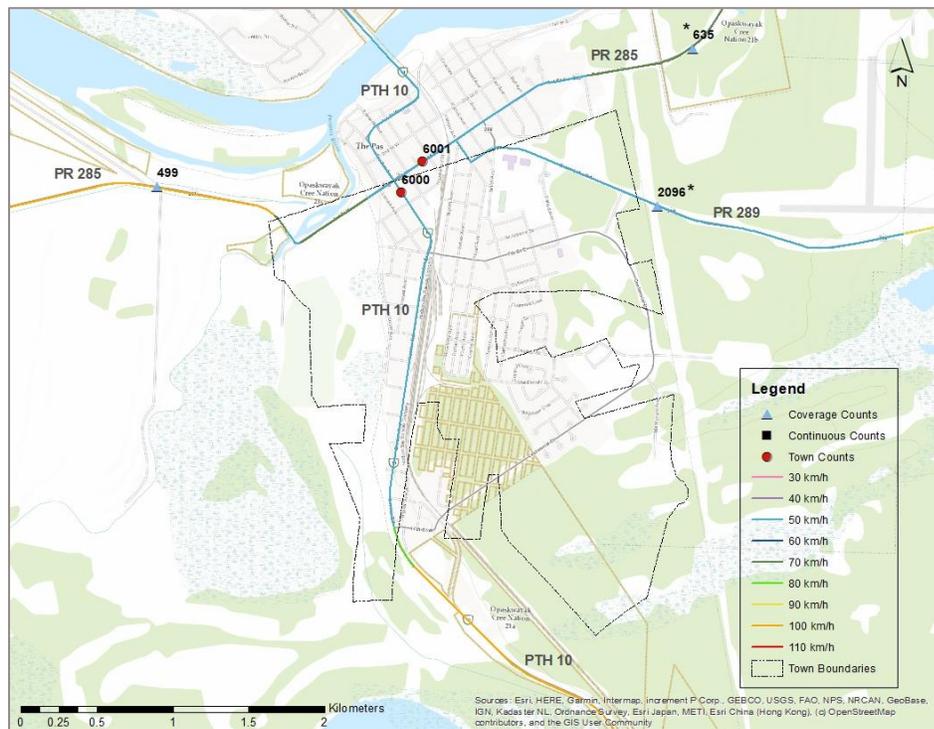
Figure 84: Town boundary of The Pas and surrounding area

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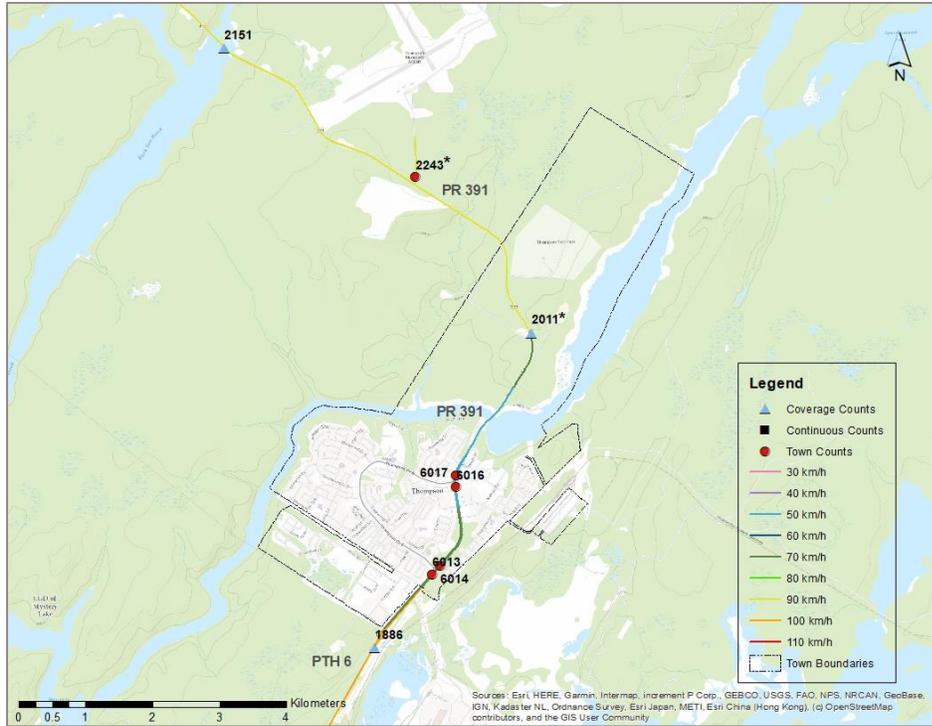
Figure 85: Town boundary of Thompson and surrounding area
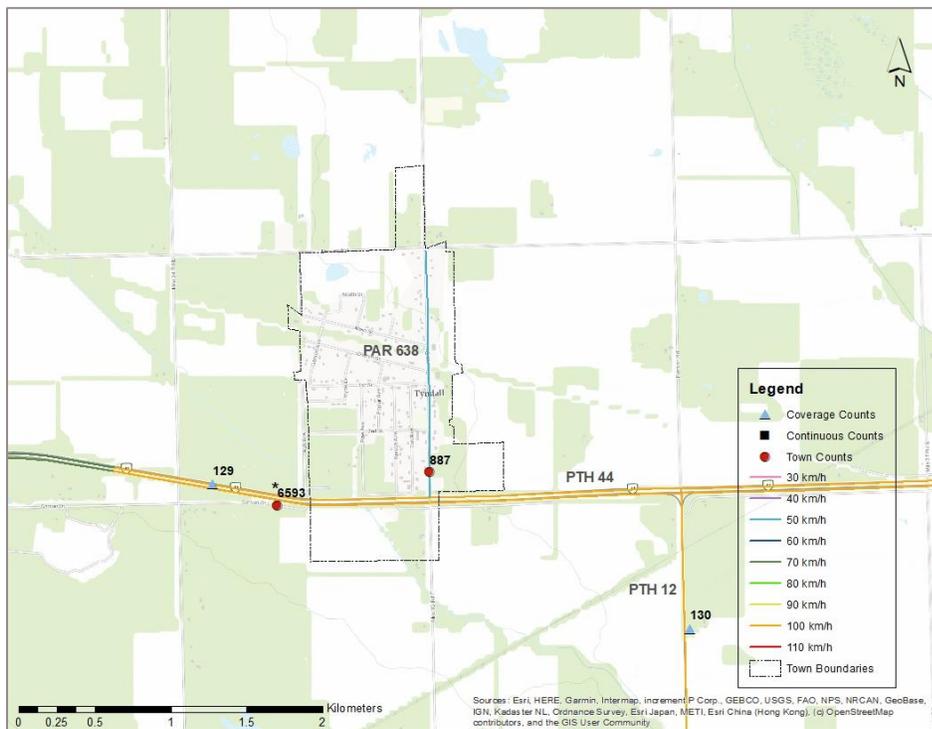
Figure 86: Town boundary of Tyndall and surrounding area
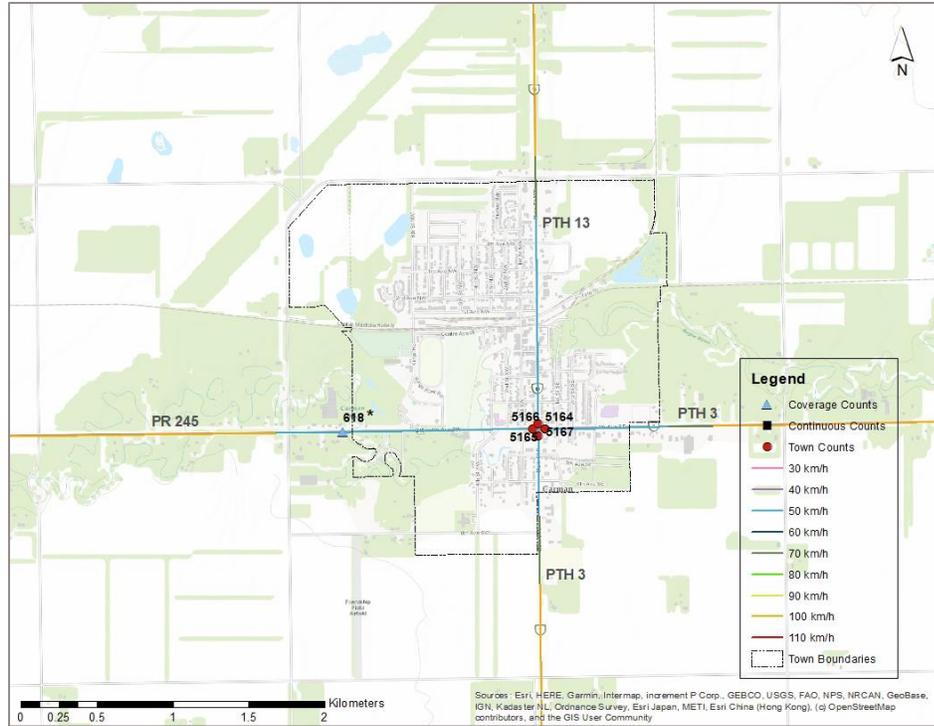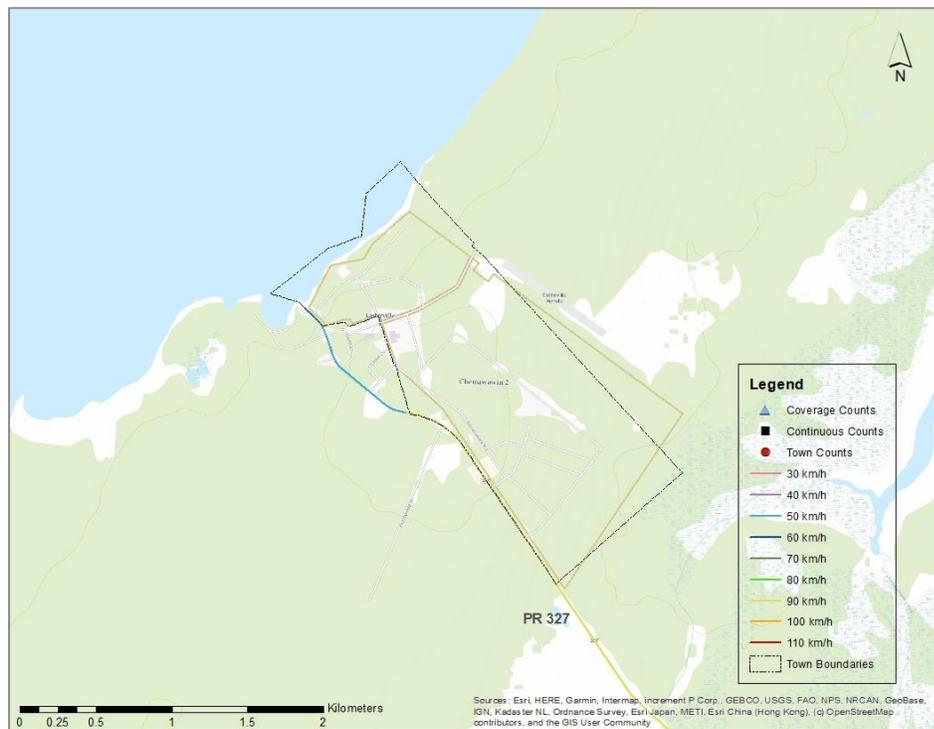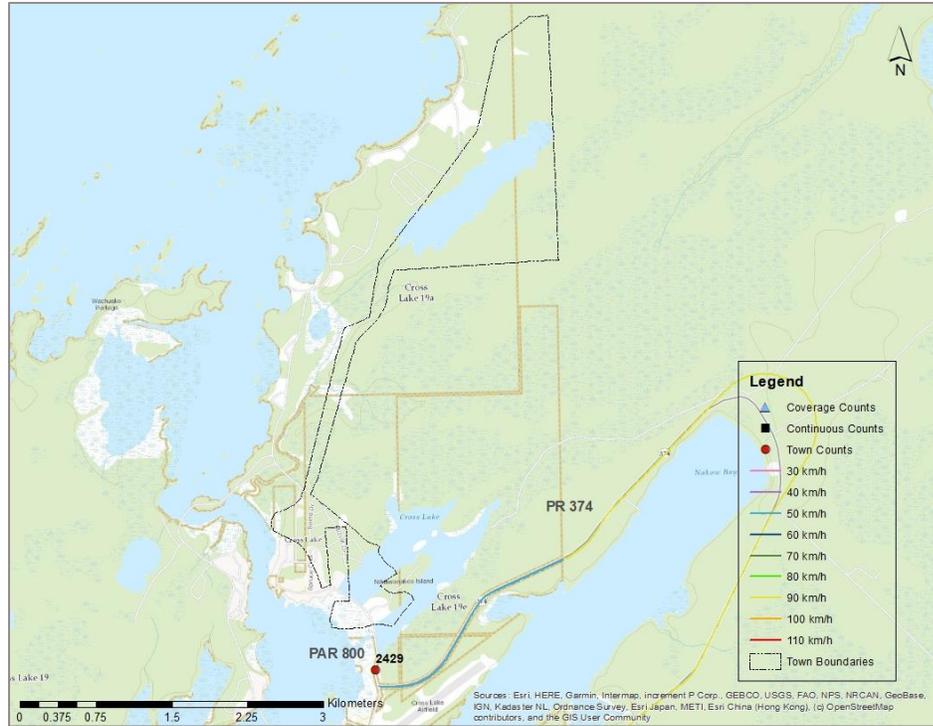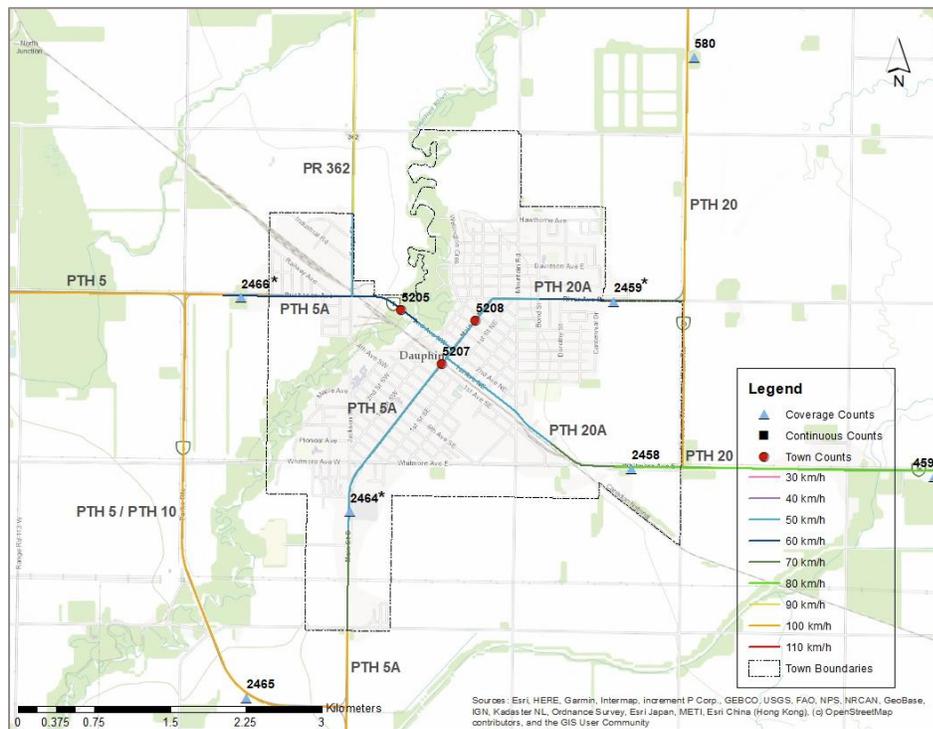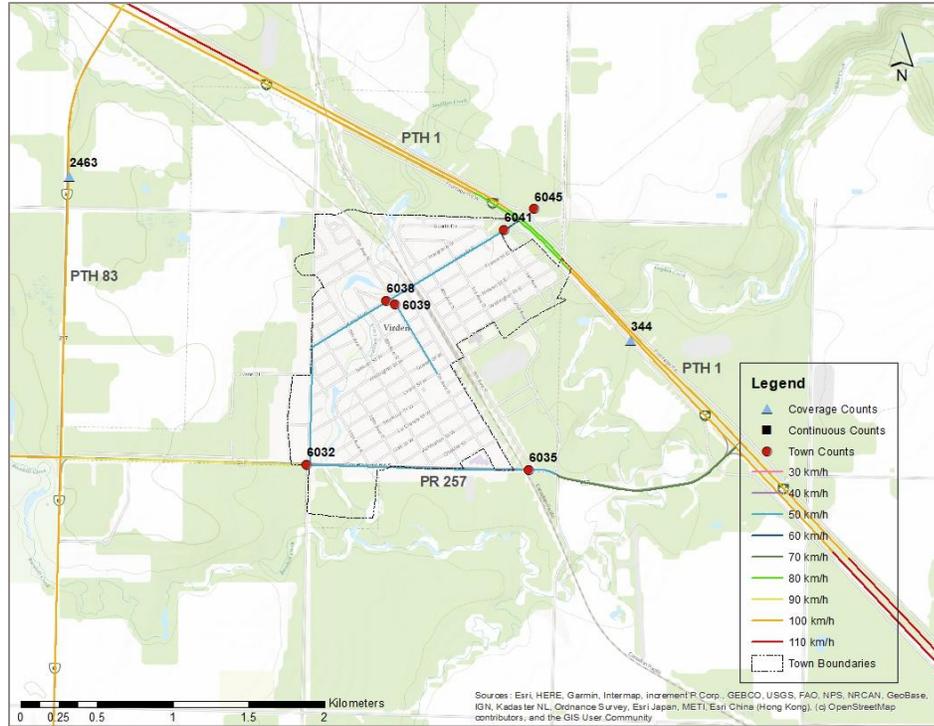
Figure 87: Town boundary of Virden and surrounding area
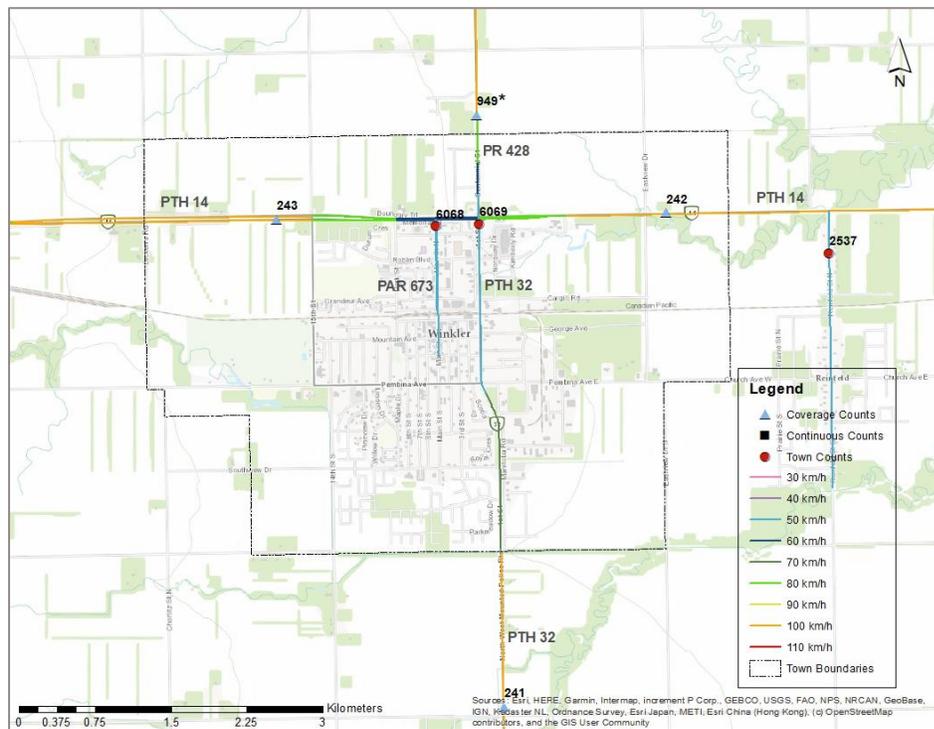
Figure 88: Town boundary of Winkler and surrounding area

APPENDIX B: MANITOBA TPG DESCRIPTIONS

The TPGs in Manitoba were originally established in 1993 using a cluster analysis of the seasonal and hourly traffic volume patterns at continuous count stations (Clayton and Lucas, 1993). Over the years, various revisions and updates have occurred, most recently in 2006, when new continuous count stations were added to the grouping procedure, and the reassignment resulted in seven distinct TPGs (Regehr *et al.*, 2006).

The following seven subsections in this appendix provide detailed information about the traffic periodicities experienced in 2019 for each TPG.

TPG 1

Figure 89 shows the hourly, DOW and monthly temporal variations as at TPG 1 stations based on the PSC data collected in 2019. A total of 12 continuous count stations are categorized as TPG 1. In 2019, two of these stations had data errors and were not included in the development; therefore, 10 continuous count stations are used to develop the distributions at TPG 1.

Figure 89: Hourly, DOW, and monthly temporal traffic patterns at TPG 1

TPG 2

Figure 90 shows the hourly, DOW and monthly temporal variations as at TPG 2 stations based on the PSC data collected in 2019. A total of 24 continuous count stations are categorized as TPG 2. In 2019, six of these stations had data errors and were not included in the development; therefore, 18 continuous count stations are used to develop the distributions at TPG 2.

Figure 90: Hourly, DOW, and monthly temporal traffic patterns at TPG 2

TPG 3

Figure 91 shows the hourly, DOW and monthly temporal variations as at TPG 3 stations based on the PSC data collected in 2019. A total of three continuous count stations are categorized as TPG 3. In 2019, two of these stations had data errors and were not included in the development; therefore, one continuous count station is used to develop the distributions at TPG 3.

Figure 91: Hourly, DOW, and monthly temporal traffic patterns at TPG 3

TPG 4

Figure 92 shows the hourly, DOW and monthly temporal variations as at TPG 4 stations based on the PSC data collected in 2019. A total of 14 continuous count stations are categorized as TPG 4. In 2019, six of these stations had data errors and were not included in the development; therefore, eight continuous count stations are used to develop the distributions at TPG 4.

Figure 92: Hourly, DOW, and monthly temporal traffic patterns at TPG 4

TPG 5

Figure 93 shows the hourly, DOW and monthly temporal variations as at TPG 5 stations based on the PSC data collected in 2019. A total of three continuous count stations are categorized as TPG 5. In 2019, none of these stations had data errors; therefore, three continuous count stations are used to develop the distributions at TPG 5.

Figure 93: Hourly, DOW, and monthly temporal traffic patterns at TPG 5

TPG 6

Figure 94 shows the hourly, DOW and monthly temporal variations as at TPG 6 stations based on the PSC data collected in 2019. A total of five continuous count stations are categorized as TPG 6. In 2019, none of these stations had data errors; therefore, five continuous count stations are used to develop the distributions at TPG 6.

Figure 94: Hourly, DOW, and monthly temporal traffic patterns at TPG 6

TPG 7

Figure 95 shows the hourly, DOW and monthly temporal variations as at TPG 7 stations based on the PSC data collected in 2019. A total of five continuous count stations are categorized as TPG 7. In 2019, none of these stations had data errors; therefore, five continuous count stations are used to develop the distributions at TPG 7.

Figure 95: Hourly, DOW, and monthly temporal traffic patterns at TPG 7

APPENDIX C: LIST OF ADJUSTED COUNTS

This appendix provides a summary of the features of the 478 count stations evaluated using the decision algorithm. Table 39 displays the characteristics of each station including the highway on which they are located, the name of the geographic area (simplified as town name) they are located within, whether that area is one of the 55 towns identified in this research (yes, no), the initial type of count (coverage count or town count), and the result of the decision algorithm (town count or not town count).

Table 39: Features of the 478 count stations evaluated using the decision algorithm

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
129	44	Tyndall	Yes	Coverage Count	Not Town Count
130	12	Tyndall	Yes	Coverage Count	Not Town Count
149	12	Steinbach	Yes	Coverage Count	Town Count
150	52	Steinbach	Yes	Coverage Count	Town Count
151	52	Steinbach	Yes	Coverage Count	Town Count
172	800	Winnipeg	No	Town Count	Not Town Count
173	800	Winnipeg	No	Town Count	Not Town Count
176	67	Stonewall	Yes	Coverage Count	Not Town Count
192	7	Arborg	Yes	Coverage Count	Not Town Count
198	231	Gimli	Yes	Coverage Count	Not Town Count
200	9	Gimli	Yes	Coverage Count	Not Town Count
205	9	Selkirk	Yes	Coverage Count	Not Town Count
227	75	Morris	Yes	Coverage Count	Town Count
229	23	Morris	Yes	Coverage Count	Town Count
241	32	Winkler	Yes	Coverage Count	Not Town Count
242	14	Winkler	Yes	Coverage Count	Not Town Count
243	14	Winkler	Yes	Coverage Count	Not Town Count
309	2	Souris	Yes	Coverage Count	Not Town Count
310	22	Souris	Yes	Coverage Count	Not Town Count
322	3	Deloraine	Yes	Coverage Count	Not Town Count
328	3	Melita	Yes	Coverage Count	Not Town Count
330	83	Melita	Yes	Coverage Count	Not Town Count
344	1	Virden	Yes	Coverage Count	Not Town Count
355	1	Brandon	Yes	Coverage Count	Not Town Count
357	5	Carberry	Yes	Coverage Count	Not Town Count
366	240	Portage La Prairie	Yes	Coverage Count	Town Count
367	331	Portage La Prairie	Yes	Coverage Count	Not Town Count
368	1A	Portage La Prairie	Yes	Coverage Count	Town Count
387	16	Neepawa	Yes	Coverage Count	Not Town Count
388	16	Neepawa	Yes	Coverage Count	Not Town Count
390	5	Neepawa	Yes	Coverage Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
392	16A	Minnedosa	Yes	Coverage Count	Not Town Count
416	16	Russell	Yes	Coverage Count	Not Town Count
418	45	Russell	Yes	Coverage Count	Not Town Count
432	25	Rivers	Yes	Coverage Count	Not Town Count
433	250	Rivers	Yes	Coverage Count	Not Town Count
454	5	Ste. Rose	Yes	Coverage Count	Not Town Count
456	276	Ste. Rose	Yes	Coverage Count	Not Town Count
459	20	Dauphin	Yes	Coverage Count	Not Town Count
499	285	The Pas	Yes	Coverage Count	Not Town Count
501	10	Flin Flon	Yes	Coverage Count	Not Town Count
511	1A	Brandon	Yes	Coverage Count	Town Count
521	200	St. Adolphe	Yes	Coverage Count	Not Town Count
563	9	Selkirk	Yes	Coverage Count	Not Town Count
564	9A	Selkirk	Yes	Coverage Count	Town Count
565	9A	Selkirk	Yes	Coverage Count	Town Count
568	204	Selkirk	Yes	Coverage Count	Town Count
569	212	Selkirk	Yes	Coverage Count	Town Count
573	240	Portage La Prairie	Yes	Coverage Count	Not Town Count
580	20	Dauphin	Yes	Coverage Count	Not Town Count
589	800	Winnipeg	No	Town Count	Not Town Count
598	205	St. Pierre-Jolys	Yes	Coverage Count	Not Town Count
618	245	Carman	Yes	Coverage Count	Town Count
635	285	The Pas	Yes	Coverage Count	Town Count
644	800	Winnipeg	No	Town Count	Not Town Count
668	800	Winnipeg	No	Town Count	Not Town Count
669	800	Winnipeg	No	Town Count	Not Town Count
681	800	Winnipeg	No	Town Count	Not Town Count
685	800	Winnipeg	No	Town Count	Not Town Count
704	10A	Swan River	Yes	Coverage Count	Not Town Count
705	10	Swan River	Yes	Coverage Count	Town Count
717	10	Brandon	Yes	Coverage Count	Not Town Count
718	1	Brandon	Yes	Coverage Count	Not Town Count
724	18	Killarney	Yes	Coverage Count	Not Town Count
738	635	Middlebro	No	Town Count	Not Town Count
743	641	Wampum	No	Town Count	Not Town Count
744	639	Vassar	No	Town Count	Not Town Count
745	639	Vassar	No	Town Count	Not Town Count
797	216	Grunthal	Yes	Coverage Count	Not Town Count
807	205	St. Pierre-Jolys	Yes	Coverage Count	Town Count
818	311	Steinbach	Yes	Coverage Count	Not Town Count
819	311	Blumenort	Yes	Coverage Count	Town Count
826	311	Niverville	Yes	Coverage Count	Not Town Count
835	210	Landmark	Yes	Coverage Count	Town Count
836	210	Landmark	Yes	Coverage Count	Not Town Count
840	200	St. Adolphe	Yes	Coverage Count	Not Town Count
842	405	Ile des Chênes	Yes	Coverage Count	Not Town Count
844	207	Lorette	Yes	Coverage Count	Not Town Count
883	621	Molson	No	Town Count	Not Town Count
887	638	Tyndall	Yes	Town Count	Town Count
904	672	Libau	No	Town Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
943	201	Altona	Yes	Coverage Count	Not Town Count
949	428	Winkler	Yes	Coverage Count	Town Count
950	432	Morden	Yes	Coverage Count	Town Count
953	432	Morden	Yes	Coverage Count	Not Town Count
996	655	Homewood	No	Town Count	Not Town Count
1051	661	St. Eustache	No	Town Count	Not Town Count
1060	240	Portage La Prairie	Yes	Coverage Count	Not Town Count
1063	350	MacGregor	Yes	Coverage Count	Not Town Count
1064	350	MacGregor	Yes	Coverage Count	Not Town Count
1105	236	Stonewall	Yes	Coverage Count	Not Town Count
1116	624	High Bluff	No	Town Count	Not Town Count
1135	320	Selkirk	Yes	Coverage Count	Town Count
1145	647	Ponemah	No	Town Count	Not Town Count
1152	604	Arnes	No	Town Count	Not Town Count
1155	640	Hnausa	No	Town Count	Not Town Count
1166	415	Teulon	Yes	Coverage Count	Not Town Count
1193	68	Arborg	Yes	Coverage Count	Not Town Count
1194	326	Arborg	Yes	Coverage Count	Not Town Count
1222	645	Gypsumville	No	Town Count	Not Town Count
1260	618	Belmont	No	Town Count	Not Town Count
1261	618	Belmont	No	Town Count	Not Town Count
1279	675	Stockton	No	Town Count	Not Town Count
1287	443	Boissevain	Yes	Coverage Count	Not Town Count
1294	650	Nesbitt	No	Town Count	Not Town Count
1309	468	Brandon	Yes	Coverage Count	Not Town Count
1389	5	Carberry	Yes	Coverage Count	Not Town Count
1394	457	Brandon	Yes	Coverage Count	Not Town Count
1395	629	Brandon	Yes	Town Count	Not Town Count
1396	10	Brandon	Yes	Coverage Count	Town Count
1633	626	Methley Beach	No	Town Count	Not Town Count
1707	613	Garland	No	Town Count	Not Town Count
1756	445	Melita	Yes	Coverage Count	Not Town Count
1773	800	Manigotagan	No	Town Count	Not Town Count
1801	634	Ste. Genvieve	No	Town Count	Not Town Count
1814	610	Brandon	Yes	Town Count	Town Count
1831	201	Altona	Yes	Coverage Count	Town Count
1838	1A	Brandon	Yes	Town Count	Town Count
1839	1A	Brandon	Yes	Town Count	Town Count
1886	6	Thompson	Yes	Coverage Count	Not Town Count
1897	68	Arborg	Yes	Coverage Count	Not Town Count
1898		Ile des Chênes	Yes	Coverage Count	Not Town Count
1899	2	Oak Bluff	Yes	Coverage Count	Not Town Count
1900	3	Oak Bluff	Yes	Coverage Count	Town Count
1922	2	Oak Bluff	Yes	Coverage Count	Not Town Count
1927	302	Beausejour	Yes	Coverage Count	Not Town Count
1943	25	Rivers	Yes	Coverage Count	Not Town Count
1972	12	Steinbach	Yes	Coverage Count	Not Town Count
1973	210	St. Adolphe	Yes	Coverage Count	Not Town Count
2011	391	Thompson	Yes	Coverage Count	Town Count
2017	12	Beausejour	Yes	Coverage Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
2025	7	Stony Mountain	Yes	Coverage Count	Not Town Count
2027	240	Portage La Prairie	Yes	Coverage Count	Town Count
2035	206	Landmark	Yes	Coverage Count	Not Town Count
2041	1	Portage La Prairie	Yes	Coverage Count	Not Town Count
2042	1	Portage La Prairie	Yes	Coverage Count	Not Town Count
2043	1A	Portage La Prairie	Yes	Coverage Count	Town Count
2044	16	Minnedosa	Yes	Coverage Count	Not Town Count
2045	637	Wanless	No	Town Count	Not Town Count
2050	351	Carberry	Yes	Coverage Count	Not Town Count
2051	351	Carberry	Yes	Coverage Count	Town Count
2084	508	Selkirk	Yes	Coverage Count	Not Town Count
2092	52	Steinbach	Yes	Coverage Count	Town Count
2096	289	The Pas	Yes	Coverage Count	Town Count
2115	617	Lockport	No	Town Count	Not Town Count
2117	12	Blumenort	Yes	Coverage Count	Not Town Count
2118	12	Blumenort	Yes	Coverage Count	Not Town Count
2124	623	Nelson House	No	Town Count	Not Town Count
2145	52	Steinbach	Yes	Town Count	Town Count
2150	230	Selkirk	Yes	Coverage Count	Not Town Count
2151	391	Thompson	Yes	Coverage Count	Not Town Count
2182	502	Lac Du Bonnet	Yes	Coverage Count	Town Count
2189	262	Minnedosa	Yes	Coverage Count	Not Town Count
2190	355	Minnedosa	Yes	Coverage Count	Not Town Count
2198	N/A	Winnipeg	No	Town Count	Not Town Count
2219	630	St. Malo	No	Town Count	Not Town Count
2223	800	Kississing Lake	No	Town Count	Not Town Count
2224	800	Athapap	No	Town Count	Not Town Count
2225	800	Namew Lake	No	Town Count	Not Town Count
2227	628	The Pas (near)	Yes	Town Count	Not Town Count
2228	640	Wallace Lake	No	Town Count	Not Town Count
2229	642	Wanipigow Lake	No	Town Count	Not Town Count
2230	800	Ste. Elizabeth	No	Town Count	Not Town Count
2231	665	Rock Lake	No	Town Count	Not Town Count
2232	660	Pleasant Point	No	Town Count	Not Town Count
2235	637	Valley River	No	Town Count	Not Town Count
2236	638	Tummel	No	Town Count	Not Town Count
2239	605	Flin Flon (near)	Yes	Town Count	Not Town Count
2243	633	Thompson (near)	Yes	Town Count	Not Town Count
2244	619	Fairford	No	Town Count	Not Town Count
2246	645	Pine Dock	No	Town Count	Not Town Count
2248	800	Winnipeg	No	Town Count	Not Town Count
2265	210	St. Adolphe	Yes	Coverage Count	Not Town Count
2285	204	Selkirk	Yes	Coverage Count	Not Town Count
2296	800	Ruttan Lake	No	Town Count	Not Town Count
2299	800	Flin Flon (near)	Yes	Town Count	Not Town Count
2303	668	Russell	Yes	Town Count	Town Count
2317	3	Deloraine	Yes	Coverage Count	Not Town Count
2325	800	The Pas (near)	Yes	Town Count	Not Town Count
2326	800	The Pas (near)	Yes	Town Count	Not Town Count
2327	800	The Pas (near)	Yes	Town Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
2328	800	The Pas (near)	Yes	Town Count	Not Town Count
2358	800	The Pas (near)	Yes	Town Count	Not Town Count
2360	617	Winnipeg	No	Town Count	Not Town Count
2361	607	Winnipeg	No	Town Count	Not Town Count
2371	210	Ste. Anne	Yes	Coverage Count	Not Town Count
2378	52	Mitchell	Yes	Coverage Count	Not Town Count
2415	612	Elie	No	Town Count	Not Town Count
2419	604	Angusville	No	Town Count	Not Town Count
2425	10	Flin Flon	Yes	Coverage Count	Not Town Count
2426	800	Herb Lake Landing	No	Town Count	Not Town Count
2429	800	Cross Lake 19A	Yes	Town Count	Town Count
2452	800	Mallard	No	Town Count	Not Town Count
2455	800	Powerview-Pine Falls (near)	No	Town Count	Not Town Count
2457	12	Ste. Anne	Yes	Coverage Count	Not Town Count
2458	20A	Dauphin	Yes	Coverage Count	Not Town Count
2459	20A	Dauphin	Yes	Coverage Count	Town Count
2463	83	Virden	Yes	Coverage Count	Not Town Count
2464	5A	Dauphin	Yes	Coverage Count	Town Count
2465	5	Dauphin	Yes	Coverage Count	Not Town Count
2466	5A	Dauphin	Yes	Coverage Count	Town Count
2468	800	Brandon	Yes	Town Count	Town Count
2469	800	Brandon	Yes	Town Count	Town Count
2470	459	Brandon	Yes	Coverage Count	Not Town Count
2473	210	Ste. Anne	Yes	Coverage Count	Town Count
2474	632	Split Lake	No	Town Count	Not Town Count
2475	616	Gimli	Yes	Town Count	Not Town Count
2490	405	Ile des Chênes	Yes	Coverage Count	Not Town Count
2500	9	Selkirk	Yes	Coverage Count	Not Town Count
2511	10A	Flin Flon	Yes	Coverage Count	Town Count
2537	800	Winkler (Reinfeld)	Yes	Town Count	Town Count
2546	457	Brandon	Yes	Coverage Count	Not Town Count
2548	5	Ste. Rose	Yes	Coverage Count	Not Town Count
2553	247	La salle	Yes	Coverage Count	Not Town Count
2554	247	La salle	Yes	Coverage Count	Town Count
2556	330	La salle	Yes	Coverage Count	Not Town Count
2558	800	Portage La Prairie (Southport)	Yes	Town Count	Town Count
2562	800	Winkler (Schanzenfeld)	Yes	Town Count	Not Town Count
2569	110	Brandon	Yes	Coverage Count	Not Town Count
2570	110	Brandon	Yes	Coverage Count	Not Town Count
2571	110	Brandon	Yes	Coverage Count	Not Town Count
2577	83	Swan River	Yes	Coverage Count	Not Town Count
5001	39	Altona	Yes	Coverage Count	Not Town Count
5002	30	Altona	Yes	Coverage Count	Not Town Count
5003	201	Altona	Yes	Town Count	Town Count
5005	201	Altona	Yes	Town Count	Town Count
5013	50	Amaranth	No	Town Count	Not Town Count
5015	50	Amaranth	No	Town Count	Not Town Count
5023	326	Arborg	Yes	Town Count	Town Count
5025	68	Arborg	Yes	Town Count	Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
5029	6	Ashern	No	Town Count	Not Town Count
5030	325	Ashern	No	Town Count	Not Town Count
5036	6	Ashern	No	Town Count	Not Town Count
5041	605	Austin	No	Town Count	Not Town Count
5042	605	Austin	No	Town Count	Not Town Count
5049	215	Beausejour	Yes	Town Count	Town Count
5050	601	Beausejour	Yes	Town Count	Town Count
5051	215	Beausejour	Yes	Town Count	Town Count
5052	601	Beausejour	Yes	Town Count	Town Count
5055	44	Beausejour	Yes	Town Count	Not Town Count
5089	42	Birtle	No	Town Count	Not Town Count
5095	10	Boissevain	Yes	Town Count	Town Count
5096	10	Boissevain	Yes	Town Count	Town Count
5097	443	Boissevain	Yes	Town Count	Town Count
5107	266	Bowsman	No	Town Count	Not Town Count
5119	10	Brandon	Yes	Town Count	Town Count
5120	10	Brandon	Yes	Town Count	Town Count
5121	610	Brandon	Yes	Town Count	Town Count
5122	610	Brandon	Yes	Town Count	Town Count
5123	1A	Brandon	Yes	Town Count	Town Count
5124	1A	Brandon	Yes	Town Count	Town Count
5125	10	Brandon	Yes	Town Count	Town Count
5127	10	Brandon	Yes	Town Count	Town Count
5132	10	Brandon	Yes	Town Count	Town Count
5134	459	Brandon	Yes	Town Count	Town Count
5135	1A	Brandon	Yes	Town Count	Town Count
5136	457	Brandon	Yes	Town Count	Town Count
5137	1A	Brandon	Yes	Town Count	Town Count
5139	1	Brandon	Yes	Town Count	Not Town Count
5141	1	Brandon	Yes	Town Count	Not Town Count
5142	610	Brandon	Yes	Town Count	Town Count
5143	610	Brandon	Yes	Town Count	Town Count
5153	612	Carberry	Yes	Town Count	Town Count
5157	351	Carberry	Yes	Town Count	Town Count
5164	3	Carman	Yes	Town Count	Town Count
5165	13	Carman	Yes	Town Count	Town Count
5166	245	Carman	Yes	Town Count	Town Count
5167	3	Carman	Yes	Town Count	Town Count
5175	616	Crystal City	No	Town Count	Not Town Count
5177	616	Crystal City	No	Town Count	Not Town Count
5196	610	Darlingford	No	Town Count	Not Town Count
5205	5A	Dauphin	Yes	Town Count	Town Count
5207	5A	Dauphin	Yes	Town Count	Town Count
5208	20A	Dauphin	Yes	Town Count	Town Count
5216	618	Deloraine	Yes	Town Count	Town Count
5218	618	Deloraine	Yes	Town Count	Town Count
5220	618	Deloraine	Yes	Town Count	Town Count
5222	618	Deloraine	Yes	Town Count	Town Count
5229	200	Dominion city	No	Town Count	Not Town Count
5234	604	Dominion city	No	Town Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
5240	248	Elie	No	Town Count	Not Town Count
5247	621	Elkhorn	No	Town Count	Not Town Count
5251	256	Elkhorn	No	Town Count	Not Town Count
5270	200	Emerson	No	Town Count	Not Town Count
5278	623	Erickson	No	Town Count	Not Town Count
5282	623	Erickson	No	Town Count	Not Town Count
5294	10A	Ethelbert	No	Town Count	Not Town Count
5313	10	Flin Flon	Yes	Coverage Count	Not Town Count
5320	10A	Flin Flon	Yes	Town Count	Town Count
5322	291	Flin Flon	Yes	Town Count	Town Count
5323	10A	Flin Flon	Yes	Town Count	Town Count
5334	5	Gilbert Plains	No	Town Count	Not Town Count
5337	274	Gilbert Plains	No	Town Count	Not Town Count
5341	9	Gimli	Yes	Town Count	Town Count
5342	9	Gimli	Yes	Town Count	Town Count
5343	616	Gimli	Yes	Town Count	Town Count
5352	615	Gladstone	No	Town Count	Not Town Count
5364	627	Glenboro	No	Town Count	Not Town Count
5373	462	Glenella	No	Town Count	Not Town Count
5377	615	Grand Rapids	No	Town Count	Not Town Count
5384	366	Grandview	No	Town Count	Not Town Count
5385	617	Grandview	No	Town Count	Not Town Count
5395	30	Gretna	No	Town Count	Not Town Count
5396	620	Gretna	No	Town Count	Not Town Count
5401	205	Grunthal	Yes	Town Count	Town Count
5404	205	Grunthal	Yes	Town Count	Town Count
5417	634	Hartney	No	Town Count	Not Town Count
5423	634	Hartney	No	Town Count	Not Town Count
5427	635	Holland	No	Town Count	Not Town Count
5429	635	Holland	No	Town Count	Not Town Count
5434	621	Kelwood	No	Town Count	Not Town Count
5441	638	Killarney	Yes	Town Count	Town Count
5443	18	Killarney	Yes	Town Count	Town Count
5446	638	Killarney	Yes	Town Count	Town Count
5447	638	Killarney	Yes	Town Count	Town Count
5448	638	Killarney	Yes	Town Count	Town Count
5450	3	Killarney	Yes	Coverage Count	Not Town Count
5451	502	Lac Du Bonnet	Yes	Town Count	Town Count
5455	502	Lac Du Bonnet	Yes	Town Count	Town Count
5456	11	Lac Du Bonnet	Yes	Coverage Count	Not Town Count
5474	618	Lorette	Yes	Town Count	Town Count
5475	207	Lorette	Yes	Town Count	Town Count
5477	419	Lundar	No	Town Count	Not Town Count
5479	631	Lundar	No	Town Count	Not Town Count
5490	633	Macgregor	Yes	Town Count	Town Count
5499	635	Manitou	No	Town Count	Not Town Count
5506	50	McCreary	No	Town Count	Not Town Count
5509	625	McCreary	No	Town Count	Not Town Count
5518	644	Melita	Yes	Town Count	Town Count
5523	644	Melita	Yes	Town Count	Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
5528	637	Miami	No	Town Count	Not Town Count
5530	637	Miami	No	Town Count	Not Town Count
5539	628	Minitonas	No	Town Count	Not Town Count
5548	16A	Minnedosa	Yes	Town Count	Town Count
5551	262	Minnedosa	Yes	Town Count	Town Count
5556	638	Morden	Yes	Town Count	Town Count
5559	3	Morden	Yes	Town Count	Town Count
5560	638	Morden	Yes	Town Count	Town Count
5561	432	Morden	Yes	Town Count	Town Count
5569	75	Morris	Yes	Town Count	Town Count
5570	75	Morris	Yes	Town Count	Town Count
5572	23	Morris	Yes	Town Count	Town Count
5574	5	Neepawa	Yes	Town Count	Town Count
5577	649	Neepawa	Yes	Town Count	Town Count
5581	649	Neepawa	Yes	Town Count	Town Count
5589	5	Neepawa	Yes	Town Count	Town Count
5599	245	Notre Dame de Lourdes	No	Town Count	Not Town Count
5606	655	Oakburn	No	Town Count	Not Town Count
5626	643	Oakville	No	Town Count	Not Town Count
5632	632	Ochre River	No	Town Count	Not Town Count
5653	658	Pilot Mound	No	Town Count	Not Town Count
5683	306	Plum Coulee	No	Town Count	Not Town Count
5687	646	Plum Coulee	No	Town Count	Not Town Count
5695	240	Portage La Prairie	Yes	Town Count	Town Count
5697	240	Portage La Prairie	Yes	Town Count	Town Count
5698	1A	Portage La Prairie	Yes	Town Count	Town Count
5701	1A	Portage La Prairie	Yes	Town Count	Town Count
5710	24	Rapid City	No	Town Count	Not Town Count
5719	662	Reston	No	Town Count	Not Town Count
5720	662	Reston	No	Town Count	Not Town Count
5734	663	Rivers	Yes	Town Count	Town Count
5736	250	Rivers	Yes	Town Count	Town Count
5741	651	Riverton	No	Town Count	Not Town Count
5753	634	Roblin	Yes	Town Count	Town Count
5758	634	Roblin	Yes	Town Count	Town Count
5760	5	Roblin	Yes	Town Count	Town Count
5767	652	Roland	No	Town Count	Not Town Count
5774	652	Roland	No	Town Count	Not Town Count
5780	666	Rossburn	No	Town Count	Not Town Count
5790	668	Russell	Yes	Town Count	Town Count
5799	669	Sandy Lake	No	Town Count	Not Town Count
5819	632	Ste. Anne	Yes	Town Count	Town Count
5820	210	Ste. Anne	Yes	Town Count	Town Count
5853	629	St. Malo	No	Town Count	Not Town Count
5854	59	St. Malo	No	Town Count	Not Town Count
5871	276	Ste. Rose	Yes	Town Count	Town Count
5881	508	Selkirk (East Selkirk)	Yes	Town Count	Town Count
5882	212	Selkirk (East Selkirk)	Yes	Town Count	Town Count
5883	204	Selkirk	Yes	Coverage Count	Not Town Count
5886	9	Selkirk	Yes	Town Count	Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
5887	320	Selkirk	Yes	Town Count	Town Count
5889	204	Selkirk	Yes	Town Count	Town Count
5890	9A	Selkirk	Yes	Town Count	Town Count
5897	670	Shoal Lake	No	Town Count	Not Town Count
5939	22	Souris	Yes	Town Count	Town Count
5942	2	Souris	Yes	Town Count	Town Count
5943	2	Souris	Yes	Town Count	Town Count
5947	12	Steinbach	Yes	Town Count	Town Count
5948	12	Steinbach	Yes	Town Count	Town Count
5953	52	Steinbach	Yes	Town Count	Town Count
5954	52	Steinbach	Yes	Town Count	Town Count
5961	67	Stonewall	Yes	Town Count	Town Count
5964	664	Stonewall	Yes	Town Count	Town Count
5969	665	Stony Mountain	Yes	Town Count	Town Count
5973	354	Strathclair	No	Town Count	Not Town Count
5979	676	Strathclair	No	Town Count	Not Town Count
5984	83	Swan River	Yes	Town Count	Town Count
5985	10A	Swan River	Yes	Town Count	Town Count
5993	668	Teulon	Yes	Town Count	Town Count
6000	10	The Pas	Yes	Town Count	Town Count
6001	285	The Pas	Yes	Town Count	Town Count
6013	391	Thompson	Yes	Town Count	Town Count
6014	391	Thompson	Yes	Town Count	Town Count
6016	391	Thompson	Yes	Town Count	Town Count
6017	391	Thompson	Yes	Town Count	Town Count
6021	670	Treherne	No	Town Count	Not Town Count
6027	670	Treherne	No	Town Count	Not Town Count
6032	257	Virden	Yes	Town Count	Town Count
6035	257	Virden	Yes	Town Count	Town Count
6038	678	Virden	Yes	Town Count	Town Count
6039	678	Virden	Yes	Town Count	Town Count
6041	678	Virden	Yes	Town Count	Town Count
6045	259	Virden	Yes	Town Count	Town Count
6050	636	Wabowden	No	Town Count	Not Town Count
6052	671	Warren	No	Town Count	Not Town Count
6054	671	Warren	No	Town Count	Not Town Count
6061	681	Wawanesa	No	Town Count	Not Town Count
6068	673	Winkler	Yes	Town Count	Town Count
6069	32	Winkler	Yes	Town Count	Town Count
6078	672	Winnipeg Beach	No	Town Count	Not Town Count
6081	672	Winnipeg Beach	No	Town Count	Not Town Count
6087	640	Winnipegosis	No	Town Count	Not Town Count
6108	601	Alexander	No	Town Count	Not Town Count
6320	614	Cartwright	No	Town Count	Not Town Count
6338	9	Clanderboye	No	Town Count	Not Town Count
6421	206	Dugald	No	Town Count	Not Town Count
6422	15	Dugald	No	Town Count	Not Town Count
6428	619	Dunrea	No	Town Count	Not Town Count
6479	613	Elm Creek	No	Town Count	Not Town Count
6482	613	Elm Creek	No	Town Count	Not Town Count

Station	Highway	Town Name	Is Town one of 55 Identified?	Initial Count Type	Decision Algorithm Outcome
6501	68	Eriksdale	No	Town Count	Not Town Count
6503	417	Eriksdale	No	Town Count	Not Town Count
6518	800	Falcon Lake	No	Town Count	Not Town Count
6553	625	Foxwarren	No	Town Count	Not Town Count
6593	608	Tyndall	Yes	Town Count	Not Town Count
6600	608	Garson	No	Town Count	Not Town Count
6601	608	Garson	No	Town Count	Not Town Count
6609	615	Gladstone	No	Town Count	Not Town Count
6666	621	Grosse Isle	No	Town Count	Not Town Count
6671	321	Grosse Isle	No	Town Count	Not Town Count
6673	621	Grosse Isle	No	Town Count	Not Town Count
6679	622	Gunton	No	Town Count	Not Town Count
6708	623	Haywood	No	Town Count	Not Town Count
6712	623	Haywood	No	Town Count	Not Town Count
6756	627	Hochfeld	No	Town Count	Not Town Count
6786	405	Ile des Chênes	Yes	Town Count	Town Count
6790	612	Ile des Chênes	Yes	Town Count	Town Count
6801	620	Inglis	No	Town Count	Not Town Count
6832	637	Kenton	No	Town Count	Not Town Count
6885	317	Lac Du Bonnet	Yes	Coverage Count	Town Count
7005	350	MacGregor	Yes	Coverage Count	Town Count
7010	633	MacGregor	Yes	Town Count	Town Count
7057	641	Mariapolis	No	Town Count	Not Town Count
7083	643	Mcauley	No	Town Count	Not Town Count
7124	645	Miniota	No	Town Count	Not Town Count
7126	645	Miniota	No	Town Count	Not Town Count
7143	627	Moosehorn	No	Town Count	Not Town Count
7168	647	Napinka	No	Town Count	Not Town Count
7170	647	Napinka	No	Town Count	Not Town Count
7244	653	Oak Lake	No	Town Count	Not Town Count
7249	653	Oak Lake	No	Town Count	Not Town Count
7262	654	Oak river	No	Town Count	Not Town Count
7269	623	Otterburne	No	Town Count	Not Town Count
7280	624	Petersfield	No	Town Count	Not Town Count
7286	657	Pierson	No	Town Count	Not Town Count
7305	659	Pipestone	No	Town Count	Not Town Count
7358	302	Richer	No	Town Count	Not Town Count
7494	656	Sanford	No	Town Count	Not Town Count
7516	671	Sidney	No	Town Count	Not Town Count
7614	667	Swan Lake	No	Town Count	Not Town Count
7686	680	Waskada	No	Town Count	Not Town Count
7714	643	Whitemouth	No	Town Count	Not Town Count
7719	643	Whitemouth	No	Town Count	Not Town Count
7729	674	Woodlands	No	Town Count	Not Town Count
7732	674	Woodlands	No	Town Count	Not Town Count
7733	800	Alexander	No	Town Count	Not Town Count
7734	800	Altona	Yes	Town Count	Town Count
7735	800	Newhorst	No	Town Count	Not Town Count

APPENDIX D: EUCLIDEAN DISTANCES AND RANKS

This appendix presents the calculated Euclidean distances (denoted as "ED" in the table) between each completed survey and the seven TPGs and the Euclidean distances' associated rank relative to the other six TPGs.

Separated by station number, Table 40 provides the Euclidean distances and associated rank for each hourly and DOW survey as well as the weighted ranks for each of the hourly and DOW survey combinations. The weighted rank that was used in the decision-making process is shown as the final row for each station (in bold). In that row, the TPG selected is indicated using an asterisk beside the rank of the selected TPG.

Note that when multiple DOW and hourly surveys were available, multiple weighted ranks were developed by pairing the hourly and DOW surveys completed at the same time. When multiple DOW surveys were available but there was only a single hourly survey, weighted ranks were developed for each scenario by pairing the hourly survey with each of the available DOW surveys.

Table 40: Summary of the Euclidean distances, ranks, and weighted ranks for the hourly and DOW surveys conducted at each station

Station 5049								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
5049-1 (DOW)	ED	0.208	0.147	0.399	0.185	0.232	0.436	0.180
	Rank	4	1	6	3	5	7	2
5049-3 (DOW)	ED	0.218	0.187	0.438	0.206	0.274	0.470	0.183
	Rank	4	2	6	3	5	7	1
5049-avg (DOW)	ED	0.184	0.129	0.405	0.164	0.230	0.441	0.146
	Rank	4	1	6	3	5	7	2
5049-3 (Hourly)	ED	0.064	0.055	0.056	0.057	0.054	0.054	0.072
	Rank	6	3	4	5	1	2	7
Weighted Rank DOW: 5049-1 Hourly: 5049-3		5	2	5	4	3	4.5	4.5
Weighted Rank DOW: 5049-3		5	2.5	5	4	3	4.5	4

Hourly: 5049-3							

Weighted Rank DOW: 5049-avg Hourly: 5049-3	**5**	**2**	**5**	**4***	**3**	**4.5**	**4.5**

Station 5051							
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**

Survey		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5051-1 (DOW)	ED	0.150	0.117	0.430	0.138	0.253	0.467	0.151
	Rank	3	1	6	2	5	7	4
5051-3 (DOW)	ED	0.102	0.082	0.438	0.078	0.253	0.467	0.112
	Rank	3	2	6	1	5	7	4
5051-avg (DOW)	ED	0.105	0.068	0.428	0.084	0.242	0.461	0.110
	Rank	3	1	6	2	5	7	4
5051-3 (Hourly)	ED	0.061	0.026	0.032	0.029	0.030	0.014	0.042
	Rank	7	2	5	3	4	1	6
Weighted Rank DOW: 5051-1 Hourly: 5051-3		5	1.5	5.5	2.5	4.5	4	5
Weighted Rank DOW: 5051-3 Hourly: 5051-3		5	2	5.5	2	4.5	4	5
Weighted Rank DOW: 5051-avg Hourly: 5051-3		**5**	**1.5**	**5.5**	**2.5***	**4.5**	**4**	**5**

Station 5055							

Survey		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5055-1 (DOW)	ED	0.432	0.309	0.208	0.378	0.201	0.261	0.301
	Rank	7	5	2	6	1	3	4
5055-3 (DOW)	ED	0.271	0.154	0.285	0.219	0.140	0.326	0.129
	Rank	5	3	6	4	2	7	1
5055-avg (DOW)	ED	0.341	0.215	0.221	0.286	0.129	0.271	0.201
	Rank	7	3	4	6	1	5	2
5055-1 (Hourly)	ED	0.067	0.056	0.055	0.059	0.055	0.055	0.073
	Rank	6	4	2	5	1	3	7
5055-3 (Hourly)	ED	0.076	0.068	0.070	0.070	0.068	0.068	0.086
	Rank	6	3	5	4	1	2	7
5055-avg (Hourly)	ED	0.071	0.062	0.062	0.064	0.060	0.061	0.079
	Rank	6	3	4	5	1	2	7
Weighted Rank DOW: 5055-1 Hourly: 5055-1		6.5	4.5	2	5.5	1	3	5.5
Weighted Rank DOW: 5055-3 Hourly: 5055-3		5.5	3	5.5	4	1.5	4.5	4
Weighted Rank DOW: 5055-avg Hourly: 5055-avg		**6.5**	**3**	**4**	**5.5**	**1***	**3.5**	**4.5**

Station 5942								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
5942-2 (DOW)	ED	0.177	0.415	0.987	0.235	0.725	0.998	0.497
	Rank	1	3	6	2	5	7	4
5942-2 (Hourly)	ED	0.051	0.021	0.031	0.020	0.026	0.018	0.035
	Rank	7	3	5	2	4	1	6
Weighted Rank DOW: 5942-2 Hourly: 5942-2		**4**	**3**	**5.5**	**2***	**4.5**	**4**	**5**
Station 5220								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
5220-2 (DOW)	ED	0.257	0.325	0.801	0.259	0.721	0.941	0.320
	Rank	1	4	6	2	5	7	3
5220-2 (Hourly)	ED	5E-02	3E-02	4E-02	3E-02	3E-02	2E-02	4E-02
	Rank	7	4	5	2	3	1	6
Weighted Rank DOW: 5220-2 Hourly: 5220-2		**4**	**4**	**5.5**	**2***	**4**	**4**	**4.5**
Station 5222								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
5222-2 (DOW)	ED	0.283	0.363	0.844	0.289	0.766	0.985	0.350
	Rank	1	4	6	2	5	7	3
5222-2 (Hourly)	ED	0.0425	0.0285	0.0399	0.0240	0.0297	0.0306	0.0342
	Rank	7	2	6	1	3	4	5
Weighted Rank DOW: 5222-2 Hourly: 5222-2		**4**	**3**	**6**	**1.5***	**4**	**5.5**	**4**
Station 5518								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
5518-2 (DOW)	ED	0.375	0.601	1.137	0.420	1.030	1.217	0.580
	Rank	1	4	6	2	5	7	3
5518-2 (Hourly)	ED	0.078	0.047	0.055	0.045	0.050	0.037	0.054
	Rank	7	3	6	2	4	1	5
Weighted Rank DOW: 5518-2 Hourly: 5518-2		**4**	**3.5**	**6**	**2***	**4.5**	**4**	**4**
Station 2469								
Survey		**TPG 1**	**TPG 2**	**TPG 3**	**TPG 4**	**TPG 5**	**TPG 6**	**TPG 7**
2469-2 (DOW)	ED	0.386	0.491	0.866	0.446	0.683	0.901	0.531
	Rank	1	3	6	2	5	7	4
2469-2 (Hourly)	ED	0.040	0.055	0.055	0.055	0.049	0.060	0.061
	Rank	1	5	4	3	2	6	7

Weighted Rank DOW: 2469-2 Hourly: 2469-2		**1**	**4**	**5**	**2.5***	**3.5**	**6.5**	**5.5**

Station 5123								
Survey		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5123-2 (DOW)	ED	0.184	0.288	0.662	0.244	0.474	0.693	0.328
	Rank	1	3	6	2	5	7	4
5123-2 (Hourly)	ED	0.049	0.026	0.032	0.026	0.034	0.037	0.019
	Rank	7	3	4	2	5	6	1
Weighted Rank DOW: 5123-2 Hourly: 5123-2		**4**	**3**	**5**	**2***	**5**	**6.5**	**2.5**

Station 5135								
Survey		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5135-2 (DOW)	ED	0.173	0.273	0.645	0.231	0.458	0.676	0.314
	Rank	1	3	6	2	5	7	4
5135-2 (Hourly)	ED	0.036	0.017	0.026	0.015	0.023	0.028	0.019
	Rank	7	2	5	1	4	6	3
Weighted Rank DOW: 5135-2 Hourly: 5135-2		**4**	**2.5**	**5.5**	**1.5***	**4.5**	**6.5**	**3.5**

Station 5139								
Survey		TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	TPG 7
5139-2 (DOW)	ED	0.209	0.129	0.364	0.177	0.193	0.399	0.158
	Rank	5	1	6	3	4	7	2
5139-2 (Hourly)	ED	0.054	0.028	0.024	0.037	0.041	0.042	0.035
	Rank	7	2	1	4	5	6	3
Weighted Rank DOW: 5139-2 Hourly: 5139-2		**6**	**1.5***	**3.5**	**3.5**	**4.5**	**6.5**	**2.5**