ESTIMATING TRAFFIC VOLUMES FOR LOW-CLASS ROADS USING TRAVEL DEMAND MODELING

By

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Abstract

The majority of the world's road network is made up of low-class/low-volume roads. Most of these roads are omitted from asset management and preventative maintenance programs. In order to benefit from these programs, traffic statistics such as traffic volume are needed but are often not available for large portions of the low-class/low-volume road network.

This thesis describes a study using a travel demand model (TDM) to estimate traffic volumes on low-class roads in New Brunswick, Canada. The model was implemented in York County and the Census Consolidated Subdivision of Beresford. The results from the county case showed that estimates for arterial roads had the lowest average error (9%), followed by collectors (45%), and local roads (160%). Reducing the study area size resulted in increased estimation accuracy. The overall average error in the census consolidated subdivision estimates was 17%. In particular, estimation errors for local roads were limited to less than 40%. While the estimation errors for the local roads are still relatively high, the forecasted traffic volumes provide a solid foundation for identifying high-volume road segments and prioritizing funding. In both cases, the TDM produced a large amount of data for roads that previously had none. Available data were increased by 45% in York County and 144% in the Beresford area. Study results clearly show TDM is a practical, useful, cost-effective way for estimating traffic parameters on low-class roads and its implementation would lead to an extended asset management program and improved level of service on these roads.

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Chapter 1 – Introduction

Many Departments of Transportation (DOTs) use asset management programs to help plan, build, and maintain transportation infrastructure at a statewide level. There are several benefits to implementing an asset management program, such as lower long-term costs and improved service to users. Decisions made in asset management need to be based on quality information. In areas such as pavement management, maintenance and repair are usually performed on a periodic basis set by factors such as road class and traffic volume. Often, traffic count data are not available for significant portions of the network because it would be prohibitive to cover all roads, particularly lower class and rural roads. In cases where traffic volumes are needed but unavailable, travel demand models (TDMs) can be used to estimate such information. This study implements a travel demand model for a few regions in New Brunswick in order to examine the feasibility of using travel demand modeling to estimate traffic volumes on low-class roads.

1.1 – Problem Definition

The New Brunswick Department of Transportation (NBDOT) collects traffic volume information across the provincial highway network. There are permanent and temporary traffic count sites located along provincial highways. Traffic statistics are used for a variety of reasons, such as transportation planning, design, traffic operations, and business development.

NBDOT is currently developing an asset management model that will enable the department to optimally manage provincial assets in the most cost effective life cycle approach. Traffic volumes will most likely be introduced into the model over the coming years and play an important role in the recommended surface treatment strategy.

Traditionally, the traffic counting program has focused on the higher functional class highway system. Therefore, there are limited traffic volume statistics available for low-class highways. Low-class highways account for the majority (65% or more) of system kilometres. Although it is not practical to establish regular traffic count sites along the lower class roads it is important to establish traffic estimates or traffic volume ranges for these highway segments especially in the context of the asset management initiative.

An alternative to the establishment of count locations on low-class roads is to estimate traffic volumes via a travel demand model. Development information and socioeconomic data could be used in conjunction with established trip generation techniques to estimate travel demand among different zones in a region. The travel demand is assigned to different routes, which in turn is used to estimate traffic volume for highway segments.

1.2 – Research Goals

The main goal of this research is to explore the concept of using a TDM to estimate traffic volumes on low-class roads in New Brunswick. The following three objectives need to be completed to achieve this goal:

- Apply TDM methodologies using data that can be easily obtained for all areas in New Brunswick so that it can be applied anywhere in the province.
- Quantify the errors associated with the TDM by comparing the estimates from the model to observed traffic count data.
- Provide recommendations for estimating traffic volumes on low-class roads at a statewide level.

1.3 – Scope

This study examines the feasibility of using travel demand modeling to estimate low-class road traffic volumes. Two regions in New Brunswick were chosen to test and implement a TDM. Literature for this topic indicated that previous studies were typically performed at the county-wide level. York County, shown in Figure 1.1, was arbitrarily chosen for this study. The county covers a large area on the western side of the province, has a population of approximately 86,000, and contains the provincial capital city of Fredericton.

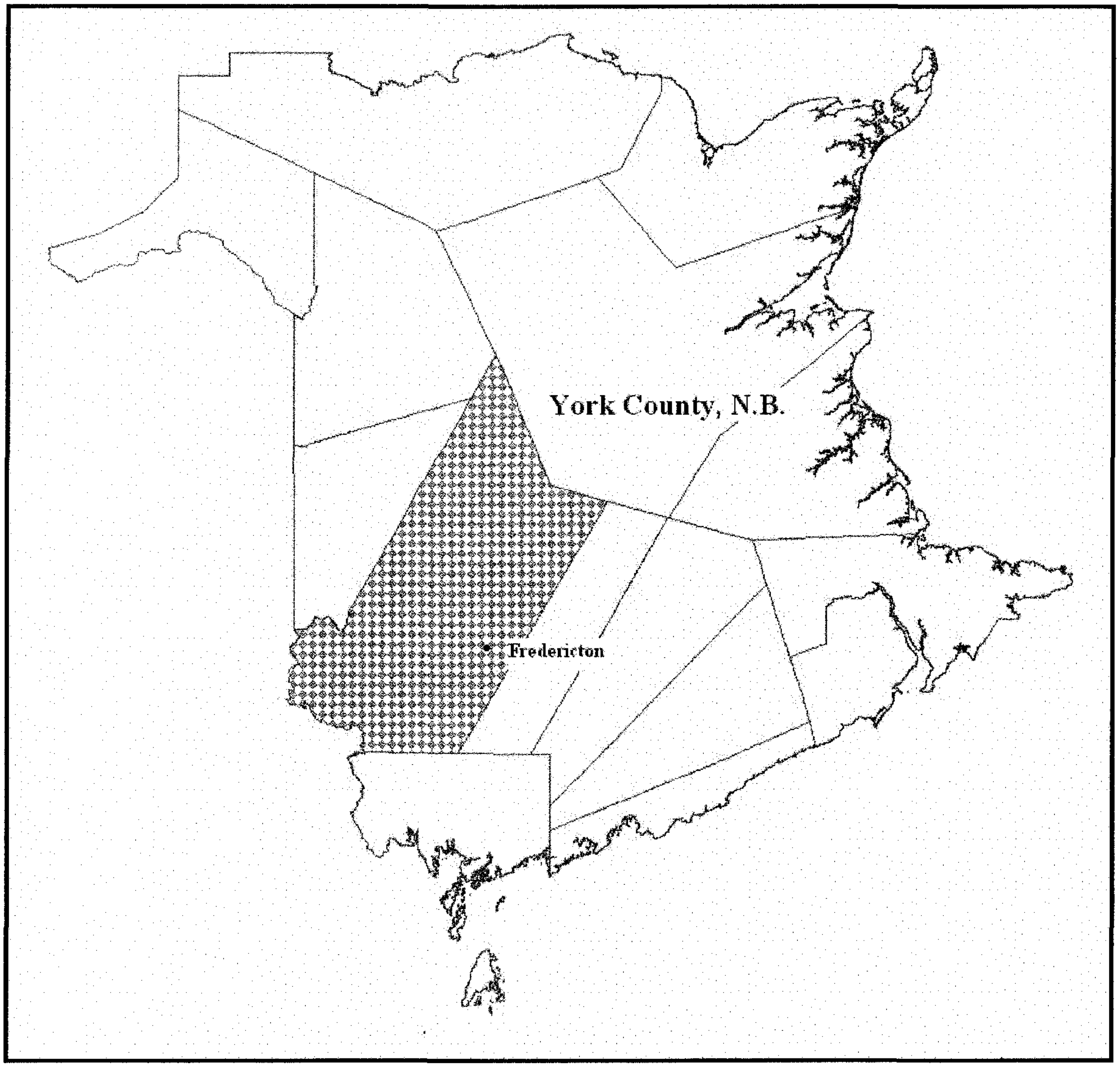

Figure 1.1: York County

In order to examine the TDM at a smaller scale and study the approaches with better accuracy, the scope was reduced to the Census Consolidated Subdivision (CCS) level. Beresford, shown in Figure 1.2, is located at the north of the province and has a population of approximately 10,000.

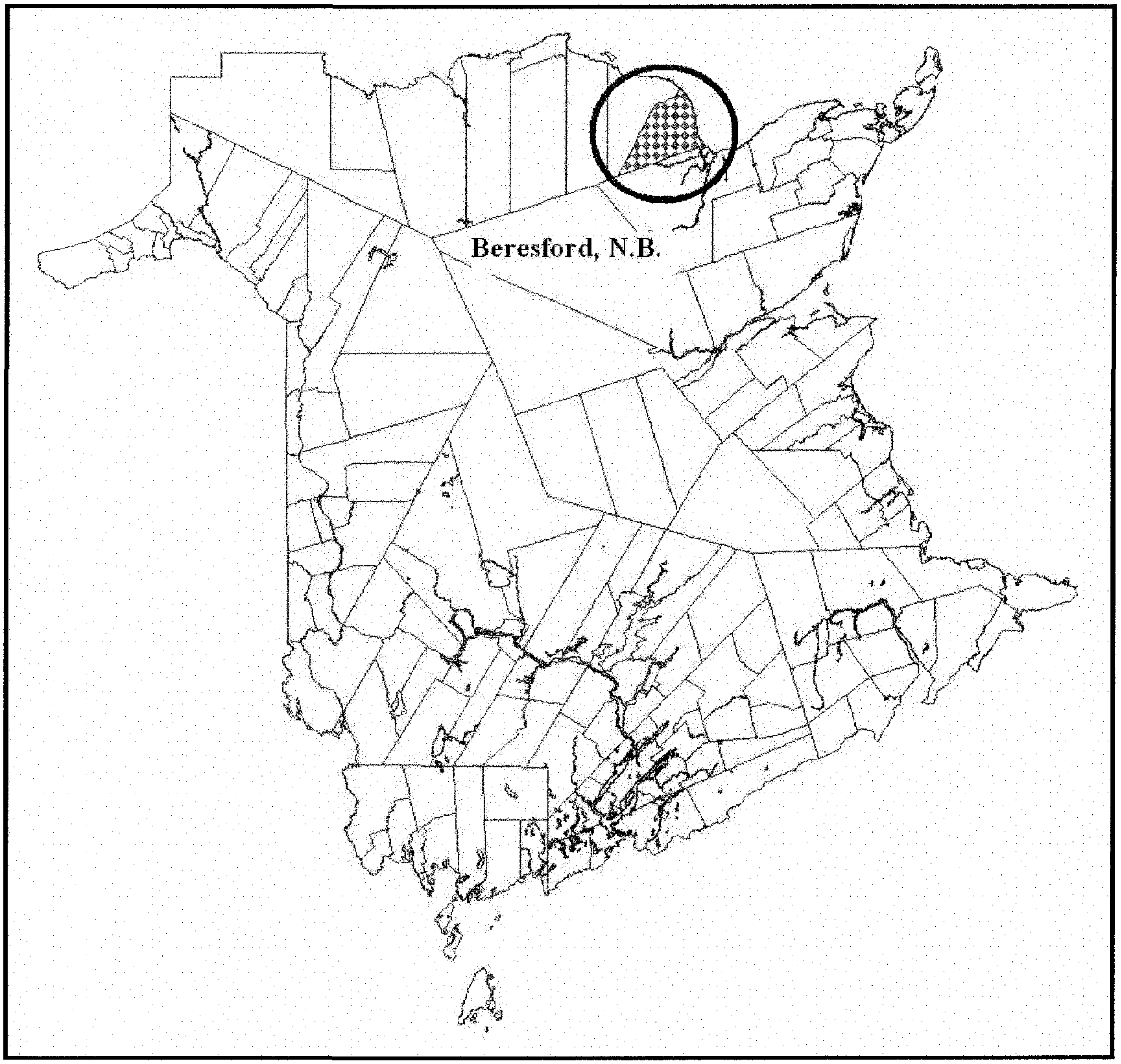

Figure 1.2: Beresford CCS

1.4 – Thesis Organization

The following sections form the remainder of the document. Chapter 2 is a review of relevant literature. The current state of the art and state of the practice of travel demand modeling and asset management are examined in the context of low-class roads. Chapter 3 details the methodology for each stage of the study. Chapter 4 presents the results and discussions for each stage and provides a quantitative analysis on the estimates obtained from the TDM. Chapter 5 contains the conclusions and recommendations arising from the study.

Chapter 2 – Literature Review

This chapter details the issues related to traffic volume estimation on low-class and low-volume roads. Various studies were profiled to identify the current state of the art and state of the practice in the areas of asset management and traffic estimation through travel demand modeling. Section 2.1 describes asset management and explains the role in terms of low-class/low-volume roads. Section 2.2 reviews the state of the practice in highway management and statewide travel demand modeling. Section 2.3 examines the state of the art of travel demand modeling in the context of low-class/low-volume roads. Section 2.4 summarizes the findings of the literature review.

2.1 – Asset Management for Low-Volume/Low-Class Roads

Many Departments of Transportation (DOTs) use asset management programs to help plan, build, and maintain infrastructure at a statewide level. Since the majority of highway system kilometres in a statewide network are classified as low-volume/low-class, asset management initiatives are proven to be very cost-effective for these types of roads. It is important to understand the concept of asset management in order to understand the role it can play in managing low-volume/low-class roads.

Both the Transportation Association of Canada (TAC) and the U.S. Federal Highway Administration (FHWA) provide their own respective definitions of asset management.

TAC defines asset management as:

"Asset Management is a comprehensive business strategy employing people, information and technology to effectively and efficiently allocate available funds amongst valued and competing asset needs." (TAC, 1999)

The FHWA defines asset management as:

"Asset Management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning." (FHWA, 1999)

Some of the benefits of asset management as outlined in the Michigan Asset Management Guide (Cambridge Systematics, 2006) include:

- Lower long term preservation costs
- Improved service to customers
- Improved cost effectiveness and use of available resources
- Improved communication with elected officials and the public
- Improved credibility and accountability for decision-making

According to the principles of asset management, decisions in resource allocation need to be based on quality information, such as traffic counts or estimated traffic volume, regarding inventory, condition, and funding. Funding for low-class roads is typically disproportionate to the number of kilometres in the system, making prioritization a necessity, and making traffic statistics and information even more important.

An emerging subset of asset management, the trend among highway agencies in Canada and the U.S., has been to adopt a pavement management system. Pavement management systems typically consist of the following four elements (Zimmerman and Peshkin, 2003):

- A database for storing pavement condition and inventory information
- Pavement deterioration models
- Rules to trigger the appropriate maintenance activities
- Methods to evaluate and improve the program

Highway agencies are all at various stages of system development. Constructing the inventory database represents the largest cost associated with implementing such a system. Due to the disproportional amount of traffic volume to kilometres of road and lack of actual traffic count data, it can be difficult to effectively include low-volume and low-class roads into any system (Seaver *et al.*, 2000).

Preventative maintenance has emerged as an effective tool in prioritizing resource allocation and maximizing the life of the infrastructure. Preventative maintenance is defined by the FHWA as follows:

"Preventative maintenance is the planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system [without increasing the structural capacity]" (FHWA, 2005).

Pavement deterioration models are often used to determine the forecasted pavement condition and required preventative maintenance. An important factor included in most pavement deterioration models is traffic volume. Low-volume/low-class roads make up a significant portion of the overall road network. Because the traffic volumes are not proportionate to the number of kilometres of road that must be maintained, funding for the maintenance and rehabilitation of these roads is often inadequate. Zimmerman and Peshkin (2003) concluded that including low-volume roads into the preventative maintenance and pavement management programs can significantly lower the annual cost and prolong the life of the overall network infrastructure. Traffic data are needed to effectively include and prioritize these roads.

2.2 – Traffic Data Collection Practices for Low-Volume/Low-Class Roads

Traffic count data are extremely useful in many applications, particularly in pavement management. Most jurisdictions assign traffic volumes to roads based on sample counts for the particular road class. Actual count data are often not available for large portions of the network. In the case of low-class/low-volume roads traffic count data are almost non-existent (Seaver *et al.*, 2000). This section reviews the current traffic data collection practices of selected agencies in Canada, the U.S., and Australia in the areas of highway and road maintenance, traffic counting, and volume estimation.

2.2.1 – Review of Canadian Practices

New Brunswick:

The NBDOT manages approximately 14,800 km of surfaced treated highway. Roads are classified by functional class with a breakdown shown in Table 2.1 (NBDOT, 2007a).

Table 2.1: New Brunswick Surface Treated Roads by Functional Class

Road Type	Kilometres	Percent of Total
Arterials	2100	14
Collectors	3000	20
Numbered Locals	3000	20
Named Locals	6700	45

Local highways represent the majority (65%) of the provincial road network. Traditionally, the traffic count program has focused on the higher functional class highway system. Therefore, there are limited traffic volume statistics available for lower class roads. Currently, all road classes except local named roads are included into their asset management program. Local named roads represent 45% of the provincial road network. An asset management model is being developed, as part of a recent initiative, to include all surface treated roads in the province, including local named roads. NBDOT is currently exploring methods in which to obtain data and information for local roads so that they can be effectively implemented into the program (NBDOT, 2007b). Refer to Appendix A – Communication with NBDOT for more information.

British Columbia:

For roadway maintenance purposes, the province of B.C. classifies its roads by volume. A separate classification system is used during the summer (8 types) and winter (6 types) months. Permanent traffic counters are installed on all numbered roads. Short-term counts are taken on low-class roads. Traffic on low-volume subdivision streets is estimated using local knowledge and the number of residences along / serviced by them.

The provincial road network consists of 83,400 lane km of road, of which, approximately 40,000 lane km are paved and 24,000 lane km are numbered highways. Non-numbered (low-class) roads make up 40% of the surface treated road network. Maintenance services on these roads are performed by contractors who must maintain the highways to the standard prescribed in the province's Road and Bridge Maintenance Contracts (R&B Contracts) for a highway of a particular classification.

All roads are included in the province's asset management program. Traffic volumes on these roads are essential as they are used to determine the road classification and subsequent treatment. The condition of high-volume roads is assessed on a recurring basis. The condition of a small number of low-volume roads are assessed on a recurring basis and are considered to be representative of the class (BC Ministry of Transportation, 2007). For more information, refer to Appendix A – Communication with B.C. Ministry of Transportation.

Alberta:

Alberta Infrastructure and Transportation has jurisdiction over 30,000 km of numbered highway. All of these highways are inventoried, have their traffic monitored using permanent traffic counters, and are subject to ongoing preventative maintenance programs. Maintenance schedules are determined by the volume of traffic that the road carries. Collecting or estimating traffic information on non-numbered highways or local roads are generally the responsibility of the local municipality (Alberta Infrastructure and Transportation, 2007). For more information, refer to Appendix A – Communication with Alberta Infrastructure and Transportation.

Saskatchewan:

Saskatchewan Highways and Transportation manages approximately 26,000 km of highway. Surface treated roads make up approximately 14,000 km of the network and are classified into three groups, shown in Table 2.2 with the associated number of kilometres.

Table 2.2: Percent of Surface Treated Roads in Saskatchewan

Road Type	Kilometres	Percent of Total
RR Class 1 (Asphalt Concrete)	5031	37
RR Class 2 (Asphalt Concrete)	4176	30
RR Class 2 (Aggregate Seal)	4587	33

RR Class 2 roads are considered low-class and represent 63% of the provincial surface treated road network. The same deterioration model is used for all roads in each class. Although traffic count data helps play a role in the deterioration model for each class, condition data are considered more important to system management. Condition data are periodically collected using an automated collection vehicle. Using current condition data, maintenance schedules are derived using the computer model and are structured to provide a range of treatments to account for variations in funding. Decision-makers use this information to identify network priorities and allocate resources accordingly (Safronetz *et al.*, 2007).

Quebec:

Pavement management in Quebec is controlled by a private firm that is based in the U.S. The province has jurisdiction over approximately 29,000 km of highway. Other than about 1,500 km of unpaved resource/remote access road, the province does not manage roads below the collector functional class level, which represents approximately 7,000 km (24%) of the network. All of the provincial roads are numbered and inventoried with regular traffic counts taken. A set factor of 5% of total investment is designated as funding for preventative maintenance, which is allocated within each region by a region manager. The province has solved the problem of managing its low-class road network by transferring most local and low-class roads to the municipalities during a major restructuring of the provincial transportation ministry in 1993 (Quebec Ministry of Transportation, 2007). For more information, refer to Appendix A – Communication with Quebec Ministry of Transportation.

There are currently no Canadian provinces that have implemented sophisticated province wide travel demand models. The models that have been created were typically project specific, i.e., predicting traffic volume on a new section of highway, or modeling freight movement between major cities. Detailed travel demand models typically only exist at the municipal level.

Low-class road traffic counting practices vary widely among the Canadian provinces. How effectively these roads are managed depends on two factors: the current state of the province's asset management program, and the amount of funding the province has available. British Columbia is fairly advanced in its asset management program and has included all of its roads. Traffic counts are taken to classify each road. Since traffic on low-volume roads tends to stay fairly predictable from year to year, the province only needs to take a small number of counts on these roads to monitor trends and can allocate more resources to high volume facilities. This way both high and low-class roads are managed effectively. In the case of Alberta, permanent traffic counting sites are installed on all provincial roads regardless of class. This is ideal as it provides decision makers ample data to work with; however this practice is not feasible for most highway agencies. New Brunswick is still in the process of implementing its asset management program. Local named roads, which represent 45% of the surface treated provincial road network, have no traffic count data available. It is not financially feasible for the province to include all of these roads into the traffic counting program. It is necessary to develop another method for obtaining such data.

2.2.2 – Review of U.S. Practices

In order to obtain an estimate of traffic statistics, e.g. Annual Average Daily Traffic (AADT), in the absence of a permanent traffic counting site, DOTs typically take a short term traffic count and then factor it to an annual daily average. In the United States, these sampled counts are usually assigned to all roads of the same class within a particular zone. States are required to report annually to the FHWA aggregate estimates of Vehicle Miles Traveled (VMT) on minor collector and local functional systems in rural, small urban, and urbanized areas to allocate federal funding. VMT is estimated by multiplying AADT by the length of the road segment. A survey of the various reporting practices of all U.S. states was performed by the FHWA (FHWA, 2003) in 2002. The document designates five states as having the most noteworthy practices. They are summarized here:

Georgia: Counts were stratified into four population groups: large urbanized areas, other urbanized areas, small urban areas, and rural areas; and four pavement types: urban paved/unpaved and rural paved/unpaved. Individual County VMT estimates were all found to be within 25% at a 90% confidence level. Statewide, estimates were found to be within 9% at a 90% confidence level.

Kansas: Traffic count data are collected on rural minor collectors over a six year cycle with approximately 500 24-hour counts taken per year. Ten percent samples of local rural and local urban roads are taken over a nine year cycle with 500 and 400 24-hour counts per year respectively. The state uses these data to allocate a portion of the motor fuel tax to each city and county on a proportional basis.

Kentucky: The state applies a factor to the AADT from minor collectors in each County to obtain an average AADT for local roads. The relationship between local and collector roads was determined by coverage counts taken on the minor collectors, and a one-time 4000 count random sample of local roads in the state.

New York: In order to obtain an accuracy of 10% at a 90% confidence level in its local road AADT estimates, approximately 2700 road segments need to be counted regularly. To meet this, the state has chosen to combine a 3-year collection period program with the local bridge counting program (9500 bridges over 10 years), railroad crossing counting program (2625 local roads over 5 years), and the county counter initiative.

Texas: Previously the state collected traffic counts from arbitrarily chosen static locations. These locations were not initially chosen to provide a statistical representation of the entire network, so an inherent bias was present in the data. The state is now implementing randomly selected traffic count locations for short term traffic counts. The approximate number of total counts per year for each type of district is as follows: 40 for rural areas (under 5000 people), 40 in small urban areas (between 5000-50000 people), 65 in small urbanized areas (50000-200000) and 175 in large urbanized areas (200000+). An average daily traffic value is established for each stratum.

Even though each state incorporates low-class roads into their traffic count program, the goal is to estimate the overall VMT for the state for the purposes of emissions calculations and funding distribution. Roads of the same class are grouped together and an average traffic value is taken. While the overall average estimate may be accurate, from an asset management perspective, this does not address the issue of identifying high volume links within the same class. Applying the same treatment to all roads in the same class (blanket approach) tends to be inefficient and TDM has not been used to estimate low-class road traffic. A method to distinguish between high and low-volume links within low-class roads is needed.

2.2.3 – Review of Australian Practices

Roads in Australia are managed by six state and two territory road transport and traffic authorities. These authorities are encompassed by Austroads, which is the Association of Australian and New Zealand Road Transport and Traffic Authorities whose purpose is to contribute to the achievement of improved Australian and New Zealand Road Transport outcomes. Each road agency in Australia manages their maintenance activities based on set targets, intervention levels, and response times. Level of service targets are established for each road class. While the terminology varies between states, roads are classified based on the following three parameters:

- Traffic Volumes, expressed in AADT
- Freight Levels, expressed in Equivalent Standard Axles, or tonnage
- Road Function

It is the responsibility of the state authority to collect the necessary data to establish these classifications. All roads are classified, which means all roads have had traffic counts taken. Once a road is classified, if it has a low-classification, it inherently has a low-volume. The volume classification allows decision makers to easily distinguish between high and low-volume roads. What is most interesting about the Australian practice is that in addition to statistical data collected by the agency, decision-makers rely heavily on community consultation and input. Factors such as importance to the community and community satisfaction are assigned to each road segment. Roads that the public deem of high importance and low satisfaction are considered to be high priority for improvement, regardless of classification (Austroads, 2006).

2.3 – State of the Art – Research Initiatives

This section reviews recent research in the area of traffic volume estimation, with an emphasis on low-class/low-volume roads. Some of the issues associated with travel demand modeling are also examined.

2.3.1 – Estimating Traffic Summary Statistics with Traffic Count Data Based Regression

Most AADT estimates in research are made using a short term traffic count and either a factor method or a more advanced method, such as neural networks (Sharma *et al.*, 2000). According to Zhao and Chung (2001), literature on estimating AADT for roads that do not have traffic counts is limited. In most cases they are low-class roads and thus not included in traffic counting programs. The few attempts that have been made have had varying degrees of success. They are outlined as follows.

A study in Purdue University, Indiana, developed a multiple regression method using data from 89 count stations to predict counts for 40 of the 92 counties in Indiana. The four predictors used were: county population, location type (urban/rural), access to other roads, and total arterial mileage. An R-squared of 0.75 was achieved (Mohamed *et al.*, 1998).

A regression model was developed for non-state roads in Broward County, Florida using the following predictors: function classification, number of lanes, area type, auto ownership, presence of non-state roads nearby, and service employment. The model has an adjusted R-squared of 0.5961 with a minimum/maximum prediction error of 1.31%/57% (Xia *et al.*, 1999).

Zhao and Chung's study (2001) also used the geographic area of Broward County, Florida. The following variables were used in regression analysis: function classification, number of lanes, direct access from a count station to expressway access points, accessibility to regional employment in Broward County, employment in a variable sized buffer around a count station, and population in a variable sized buffer in a count station. Four regression models were used with R-squared values ranging from 0.66-0.82. The model with the highest R-squared used all variables except the population buffer.

Eom *et al.* (2006) applied a spatial regression model to estimate AADT for roads in Wake County, North Carolina. The study used observed traffic counts from 200 of the County's 1200 monitoring stations to estimate traffic volumes. The estimates were compared to the remaining stations that were not used in the model. Traffic was assigned based on the observed values from the closest monitoring stations and several socioeconomic factors. This model worked fairly well in an urban setting where the density of counting stations was high; however it showed mediocre performance in more rural areas. An overall R-squared value of 0.6613 was obtained.

Seaver *et al.* (2000) was the only study that looked at estimating traffic volume specifically on rural local roads. Data used in the model development and analysis were obtained from the Georgia Department of Transportation for 80 of the 159 Counties. This included four of the five types of traffic count groups: non-Atlanta urbanized areas, small urban areas, paved roads in rural areas, and unpaved roads in rural areas. A multiple regression model was developed for each road type within or outside a metropolitan statistical area (MSA). The study was based on very detailed data; various combinations of 45 variables (typically 7 to 8 for each stratum) were used in the analysis. For example, for a particular stratum and road type the following variables were used: population density per square mile, unemployment rate, median travel time, percent of farms with 500+ acres, median time to leave for work, and the number of persons working outside the county.

Initial results were not very good for rural roads within or outside MSAs, indicating that additional subgroups may be needed within the road type. Regression clustering on rural paved roads outside MSAs yielded three strata. Models for each one had R-squared values of at least 0.90 and a predictive R-squared of at least 0.74. The regression models for the two strata within MSAs had an R-squared of 0.80-0.93 and a predictive R-squared of 0.57-0.61.

The study concluded that it is possible to mathematically model traffic volumes on low-volume roads. An appropriate model can be calibrated using existing count data and applied to each zone by stratifying the analysis zones. This allows for fairly accurate low-volume ADT estimates to be performed without the need for addition counts.

2.3.2 – Travel Demand Modeling for Estimating Low-Class Road Traffic

Literature on using a TDM to estimate low-class road traffic is scarce. Blume *et al.* (2005) examined cost-effective reporting of VMT on local roads. The study specified census data and trip generation as a viable method. The advantages and disadvantages of this method were listed as follows:

Advantages:

- Level of effort for implementation and updating is low
- Approach relies heavily on data sources perceived to be dependable and realistic
- Results are directly calculated for counties, census tracts, transportation analysis zones, and other regions
- Approach may verify mileage data already gathered by the DOT
- Supporting census data and local data are available to refine the approach

Disadvantages:

- Approach will not capture tourist travel unless additional ITE land use codes are used; codes for which data may not be as robust

- Average peak and off-peak speeds are not known
- Approach assumes all daily trips are home-based trips
- Approach cannot be used to estimate VMT on a single functional classification
- VMT on higher-order facilities (determined using a different methodology) must be subtracted out to produce an estimate specific to local roadways
- Census is not updated every year, so household numbers must be grown annually using other data sources
- Trips per household may or may not be a constant over time and across the state

Blume *et al.* (2005) implemented a model that used census data and sample counts. Two stratification variables were used in the study. The first took the sum of population and job density. This was to ensure that zones with largely unbalanced residents and jobs were treated the same as balanced zones, and assumed that jobs and residents have equivalent trip-generating characteristics. The second stratification variable used was roadway density. This was calculated as centerline miles of local roads and rural minor collectors per square mile in a zone.

Sample counts were taken for eight strata and an AADT based on median traffic volumes was estimated for each group. The estimated AADT was assigned to all the roads in the respective strata and VMT was calculated. The study identified the required number of sample counts to reach certain accuracy levels, ranging from 158 for 70-15 (15% error at the 70^{th} percentile), to 881 for 95-10. This study did not address the issue of estimating traffic volumes for individual road links.

Many U.S. jurisdictions have implemented statewide travel demand models. Horowitz and Farmer (1999) performed a critical review of the statewide travel forecasting methods used in practice by United States DOTs. The model used by Michigan is considered to be an indicator of the "state of the practice". It is a three step model that omits the mode choice portion of the traditional four step process, and retains the characteristics of an urban model. The model forecasts trips between 2392 Transportation Analysis Zones (TAZs); 2307 of which are within Michigan, and 85 which represent the other 47 contiguous states, Canada, and Mexico. Most of the modeling was done using the TransCAD software package and its built in modeling tools.

The data were disaggregated to the TAZ level using data from the Michigan Employment Security Commission, the Public Use Micro Sample data (PUMS), and the Census Transportation Planning Package (CTPP). Cross-classification tables were developed based on five different household sizes and three different income groups, for a total of 15 categories. Trip production rates for internal trips were calculated using equations from the NCHRP Report 187, "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters". These rates are distributed among five trip purposes based on proportions obtained from the National Personal Transportation Survey (NPTS).

The Institute of Transportation Engineers' Trip Generation was used to develop attraction equations for special generator sites. These consisted mainly of social/recreational trips. Trip distribution was estimated using the gravity model. Data from the NPTS were used in calibration, and traffic count data from the CTPP were used in validation. Horowitz and Farmer state that the Michigan model "epitomizes the state of the practice" as a mature statewide passenger model (Horowitz and Farmer, 1999).

Michigan's statewide TDM may be the most advanced but it still falls short in addressing the issue of low-class/low-volume roads. Roads classified as collector or above are generally included in the network, with local roads occasionally included for the purpose of connectivity. The vast majority of local roads are omitted (Michigan DOT, 1999). Refer to Appendix A – Communication with Michigan DOT for more information,

2.4 – Summary

Transportation Authorities use pavement management and preventative maintenance strategies to decrease the annual cost and increase the life of roadway infrastructure. Low-volume/low-class roads make up the majority of managed infrastructure and yet are seldom included in any detail into asset management programs. It has been shown that low-volume/low-class roads benefit from the application of pavement management and preventative maintenance programs.

Although traffic volume is an important factor in pavement deterioration modeling and preventative maintenance, traffic count data are not available for the majority of low-volume/low-class roads in a network. Research has shown that there is a high correlation between traffic volumes on low-class roads and socioeconomic information such as census data. Travel demand models show potential to provide accurate results in forecasting traffic volumes on these types of roads. Since low-volume/low-class roads are typically found in residential areas, through trips from tourist and other long range traffic do not contribute significantly to traffic volumes. Trip generation using census data has been identified as a cost-effective method to estimate traffic volumes for low-volume/low-class roads.

The calculation of VMT does not aid in the application of pavement management and preventative maintenance to low-class roads. There is a need to differentiate between individual roads within this class in order to prioritize the allocation of resources. A combination of travel demand modeling and stratification, by analysis zone and road type, can provide a means to identify higher priority roads.

Chapter 3 – Study Data and Methodology

This chapter discusses the methodology of using a travel demand model to obtain traffic volumes for low-class roads. Sections 1 and 2 detail the data and software used in this study. The third section presents the applied methodology used in this research including the various steps involved in the TDM. The forth section outlines how the model was evaluated.

3.1 – Introduction

The goal of this research is to develop a non-invasive financially feasible method to estimate traffic volumes on low-class roads that can be implemented at a statewide level. To do this, several initial steps needed to be taken. First, a region was chosen to perform the study. Second, the necessary geographic, road network files, and road data files were compiled. Third, data used in the models reviewed in Chapter 2 were compared to the data available for the selected region. Based on the available data and the results of previous studies, a strategy was chosen to generate trips and assign them to the low-class roads in the network.

The Province of New Brunswick was chosen as the study region. New Brunswick has a population of approximately 750,000 with a good distribution of both urban and rural areas. The provincial road network comprises approximately 14,800 km of surface treated road. A breakdown of kilometres of roads by class is shown in Table 2.1.

In choosing software, there were two main components to consider: GIS functionality and the ability to carry out travel demand modeling. At the time of this study, the New Brunswick DOT was in the process of converting all of its GIS data from CARIS files to ESRI (ArcGIS) format. ArcGIS is a very powerful GIS software package produced by ESRI Inc. One of the drawbacks of ArcGIS is that it does not have built-in travel demand modeling capabilities.

TransCAD Transportation GIS Software by Caliper Corporation is a package that incorporates Travel Demand Modeling (TDM) functionality with GIS architecture. TransCAD is currently used by several DOTs in the U.S. (most notably Michigan, which is considered a leader in this field) to forecast travel at all levels: statewide, regional, and local. TransCAD also has the ability to import and export files that are stored in ESRI format. Based on these reasons, and the familiarity of the researcher with the software, TransCAD was chosen as the platform to conduct this study.

3.2 – Study Data

3.2.1 – Road Network Files

Three different New Brunswick road network files were used at various points throughout this study:

3.2.1.1 - National Road Network (NRN)

The New Brunswick NRN file (Figure 3.1) was obtained from Geobase (www.geobase.ca) in the form of an ESRI shapefile (.shp). The file was imported into TransCAD and stored as a Standard Geographic Database file (.dbd). The following relevant information was provided for each road segment:

- TransCAD Road Segment ID
- Length
- Road Classification
- Route number (including any secondary/tertiary numbers)
- Number of Lanes
- Paved Status (Paved or Unpaved)
- Road Segment ID

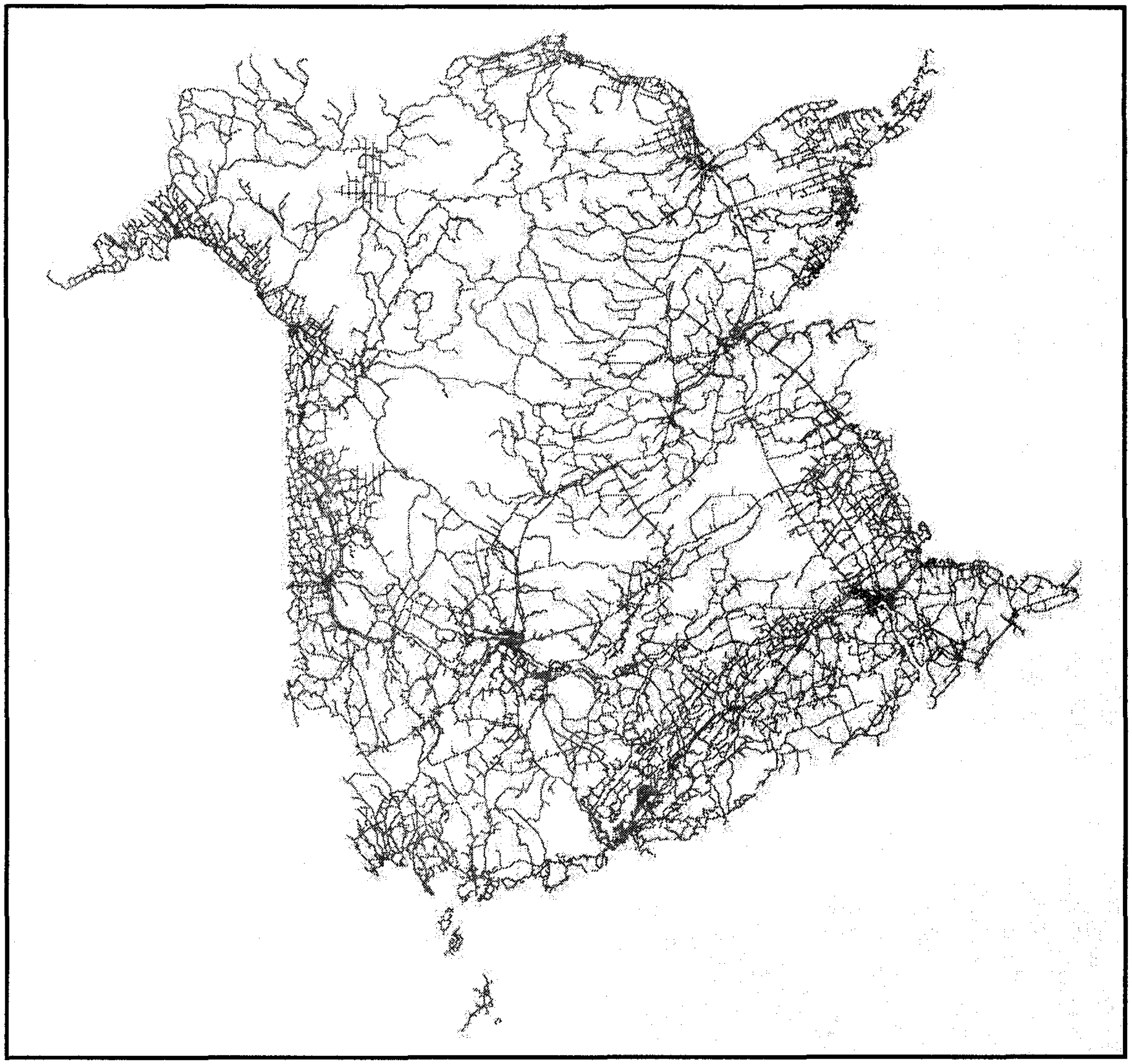

Figure 3.1: New Brunswick National Road Network

Roads were classified into four categories. The total kilometres and total road segments for each class are shown in Table 3.1.

Table 3.1: National Road Network by Classification

Class	Description	Kilometres	% of Total	Road Segments	% of Total
Freeway/Highway	Numbered highways	5600	28	12242	22
Collector	Non-numbered highways	10800	55	17124	30
Local/Street	Municipal Roads	3100	16	25943	46
Ramp	On/off ramps	260	1	1454	2

Municipal roads account for a small percentage (16%) of the road network but the largest number (46%) of road segments. Provincial numbered highways are classified as Freeway/Highway. All other provincial roads are classified as Collectors. There was some discrepancy between the NRN file and the NBDOT file regarding the total kilometres of each type of road, but this did not cause any problems in the analysis. Table 3.2 shows the summary statistics for the network. The network comprised 56,897 road segments, each with an individual segment ID and a total combined length of approximately 19700 km. The lengths of all road segments as well as the number of lanes are available.

Table 3.2: National Road Network Summary Statistics

Field	Count	Sum	Minimum	Maximum
ID	56897	-	1	56897
Length	56897	19717.55	0	19.86
NBRLANES	56897	-	1	4
ROADSEGID	56897	-	15034807	15091703

3.2.1.2 – New Brunswick Provincial Road Network

A file containing only the roads managed by the province was obtained from NBDOT (Figure 3.2). This was provided in ESRI format and imported into TransCAD. The following relevant information was provided for each road segment:

- TransCAD Road Segment ID
- Length
- Road Classification

Roads were divided into the following classifications:

- TransCanada Highway (Routes 1-2)
- Arterial (Routes 3-95)
- Collector (100-190)
- Local Numbered (200+)
- Local Named (Non-numbered)
- Non-Surface Treated/Other (Non-numbered)

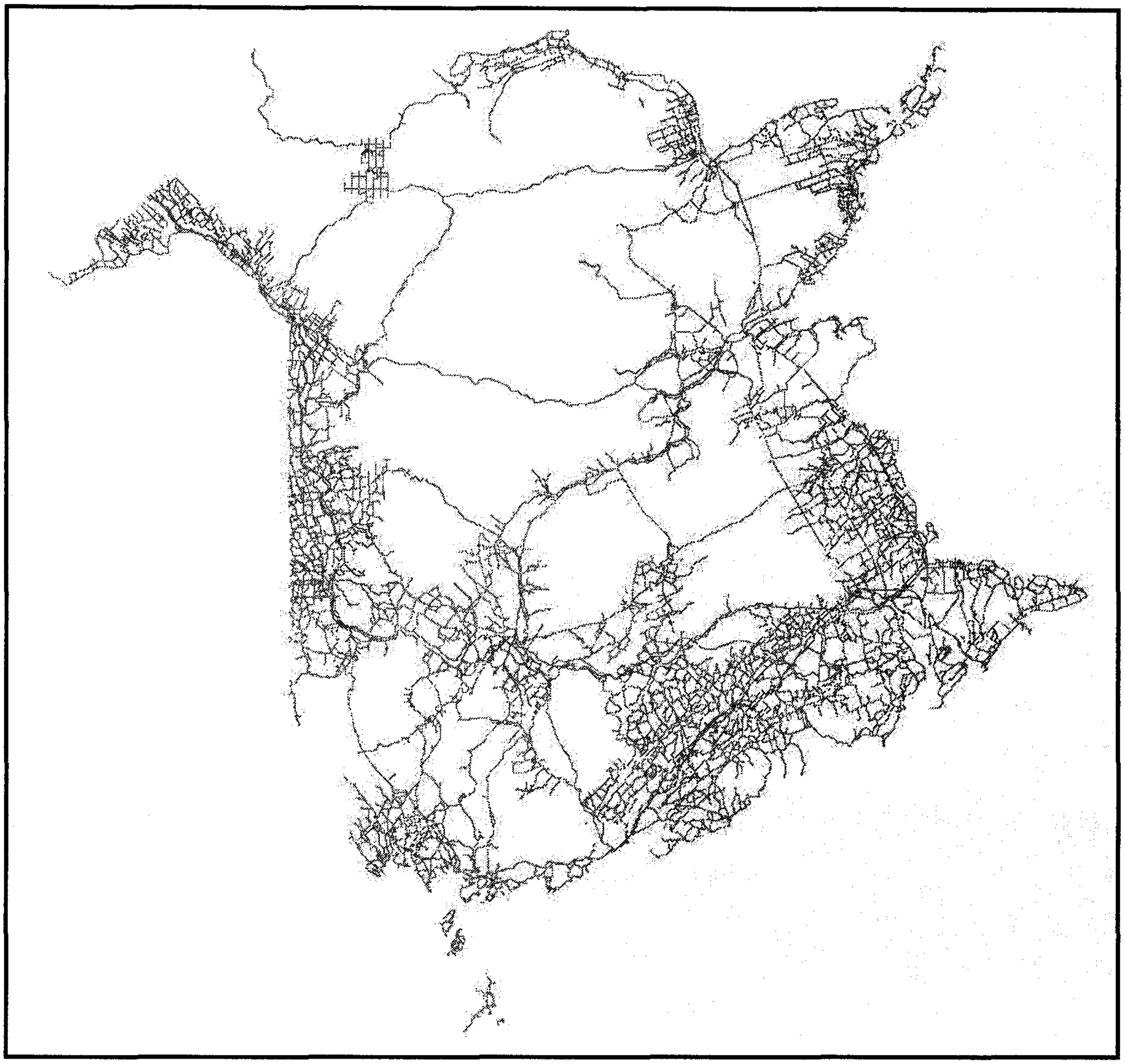

Figure 3.2: New Brunswick Provincial Road Network

Table 3.3: New Brunswick Provincial Road Network Summary Statistics

Field	Count	Sum	Minimum	Maximum
ID	23407	-	1	23417
Length	23407	14297.39	0	11.34386

Table 3.3 shows the summary statistics of the relevant data for the network. There is a total of approximately 14300 km of road represented by 23407 road segments, each with a corresponding ID. The total length of the road network managed by the province is

about 72% of the National Road Network. It can be seen that municipal and most rural local roads are excluded.

3.2.1.3 – Roads covered by the New Brunswick Traffic Counting Program

A file containing only the roads with available traffic counts was provided by NBDOT (Figure 3.3), again in ESRI format. The file was originally created using the CARIS design software and exported as a shapefile.

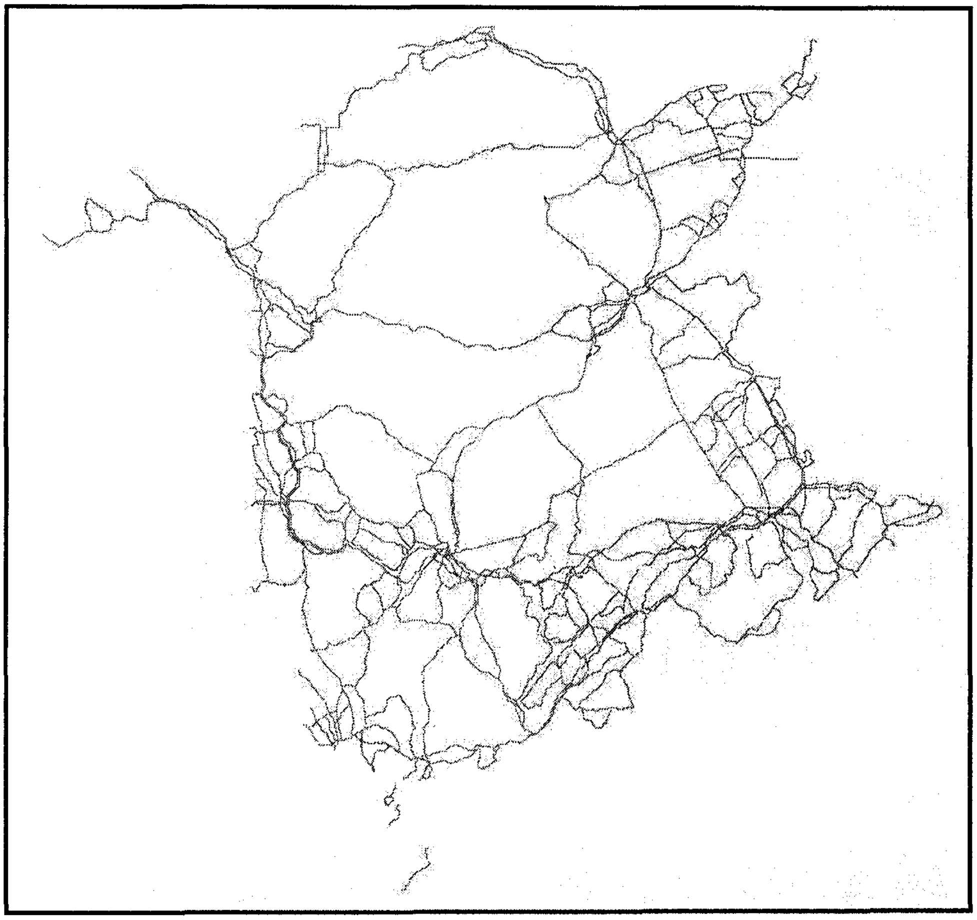

Figure 3.3: Road network covered by the New Brunswick Traffic Counting Program

Table 3.4 shows the summary statistics for the network. There is a total of approximately 5700 km of road represented by 657 road segments, each with a corresponding ID. This represents about 29% of the National Road Network and 40% of the provincial road network. It can be seen that most local roads are omitted from the provincial traffic monitoring program.

Table 3.4: Roads Covered by the New Brunswick Traffic Counting Program Summary Statistics

Field	Count	Sum	Minimum	Maximum
ID	657	-	1	657
Length	657	5668.929	0.000614	108.5348

Since CARIS is CAD based rather than GIS based, all of the traffic counts contained in the file were text labels with lead lines and were not connected electronically to the road segments. This meant that traffic counts had to be entered manually for each road segment in the analysis area. Some distortion of the text labels and lead lines occurred during the file conversion, which meant that a hardcopy map was needed to visually connect a road segment with the corresponding traffic count. This was provided by NBDOT and can be seen in Figure 3.4. Refer to Appendix B for a larger view of the map.

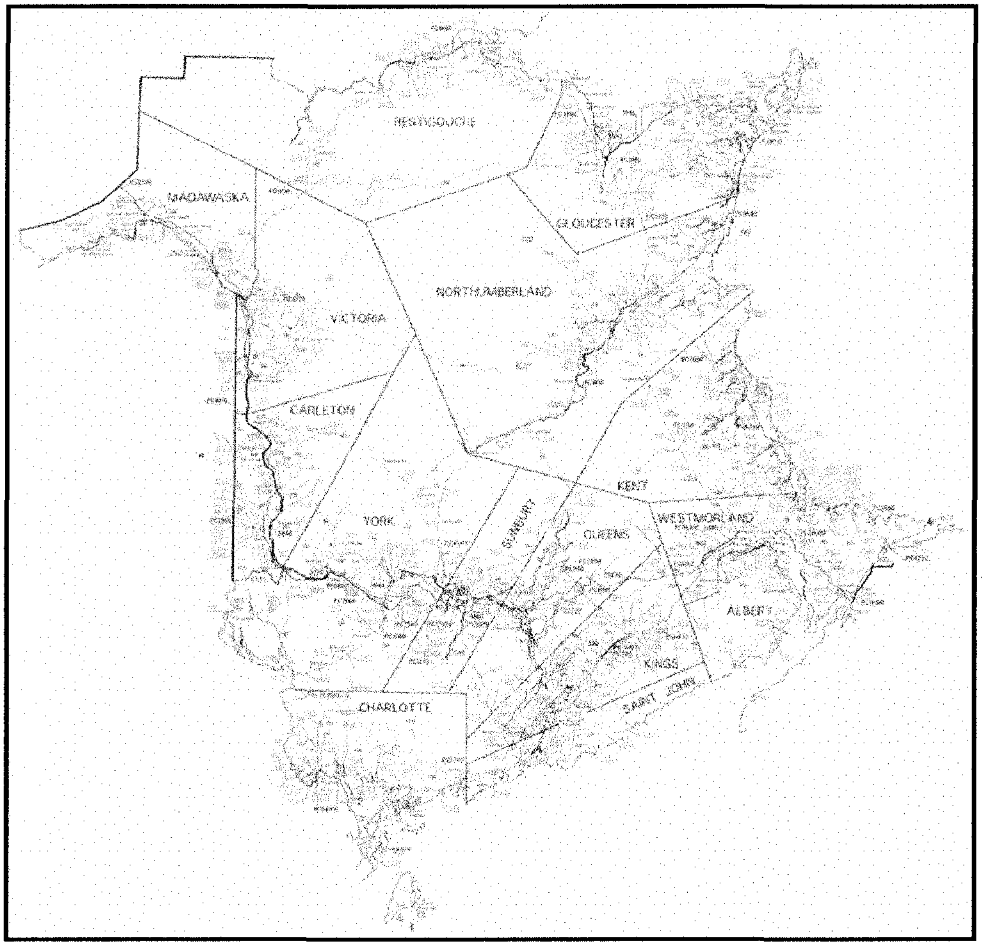

Figure 3.4: Hardcopy of Provincial Road Map with Traffic Counts

3.2.2 – Socioeconomic Data

The literature review in chapter 2 has indicated that several socioeconomic parameters, such as vehicles per household, can be included in the trip generation model to enhance accuracy. It is also noted that the choice of which parameters to include in the model is largely constrained by the availability of the data. In order to apply a model at a province-wide level, the available data must be homogenous for all TAZs across the province.

The socioeconomic data used in this model were taken from Statistics Canada's 2001 Census. Each dissemination area (DA) in New Brunswick was designated as a TAZ, resulting in a total of 1497 TAZs. It was noticed that the size of the DAs was linked to population density (i.e. there are more, smaller, DAs in dense population areas), therefore it is felt appropriate to use DAs as TAZs. The geographic file for the dissemination areas was provided by Statistics Canada and can be found in Figure 3.5. Both the census data and geographic file were obtained through the University of New Brunswick's Data Services website.

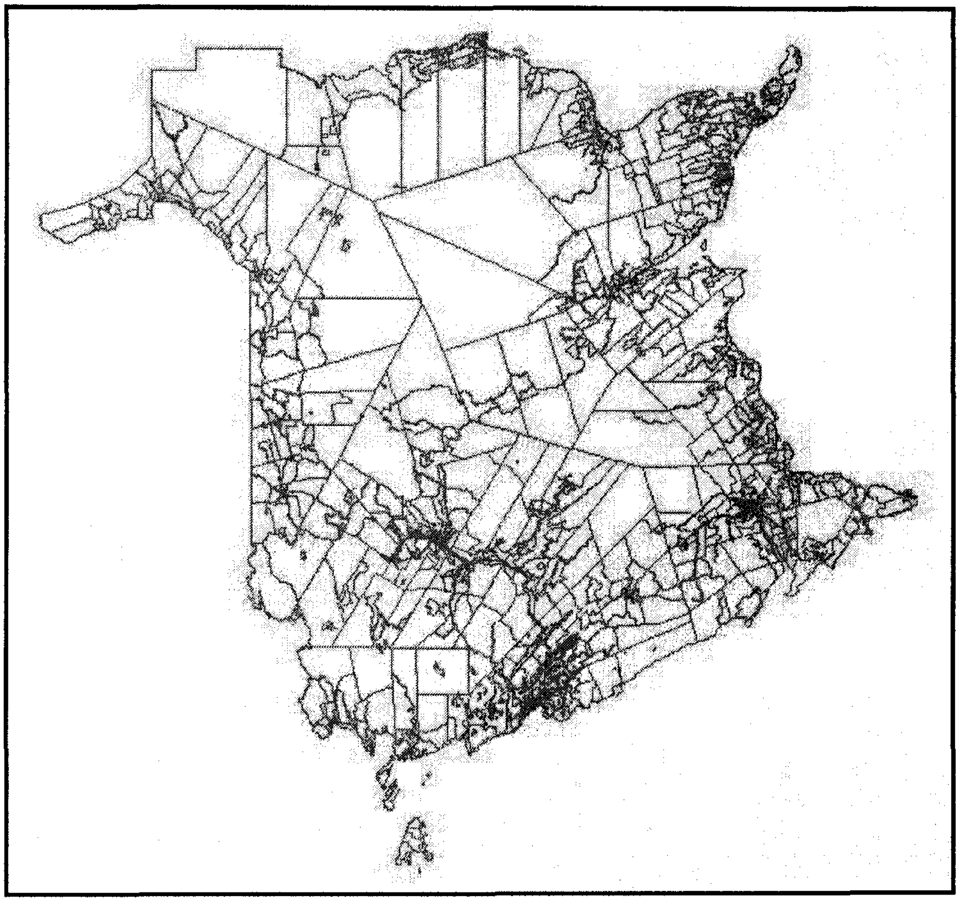

Figure 3.5: New Brunswick Dissemination Areas (DAs)

The census data were viewed using the Beyond 20/20 software package where the relevant New Brunswick data were extracted, and exported into Microsoft Excel format. Some editing of the data was performed in excel. This pre-formatting was necessary to ensure that the socioeconomic data would spatially reference to the correct dissemination area when it was imported into TransCAD. Table 3.5 shows a sample of the socioeconomic data linked to the dissemination areas.

Table 3.5: Socioeconomic Data used for TAZs

ID	Area	DA ID	Total Households	Income per Household (000s)	Non-Retail Employment	Retail Employment
1	5.32	13150131	410	41.65	335	120
2	108.41	13150134	255	49.6	280	125
3	5.86	13150130	110	37.04	105	40
4	3.37	13150129	225	38.97	190	40
6	1.06	13150128	475	43.24	480	145
7	8.53	13150155	100	34.04	90	60
8	2.78	13150154	120	42.9	165	0
9	0.67	13150127	305	45.45	300	65
10	0.87	13150126	175	43.98	135	40
11	2.57	13150125	170	53.4	190	70
12	3.05	13150124	375	41.55	405	125
13	29.61	13150135	375	44.28	420	120
14	1.21	13150123	430	50.5	355	120
15	1.92	13150138	100	39.67	95	25
16	5.5	13150119	405	49.47	350	185
17	7.09	13150139	335	53.63	400	140
18	0.14	13150122	135	35.2	100	45
19	3.19	13150136	110	49.68	110	35
20	0.67	13150121	435	54.19	545	145
21	2.13	13150137	350	46.1	365	145
22	0.65	13150120	300	71.1	390	130

3.3 – Applied Methodology

This section presents the methodology used in the construction and implementation of a travel demand model with a focus on low-class road traffic volume estimation. The model was implemented at both the County level and the Census Consolidated Subdivision level.

3.3.1 – Study Area Size

Literature reviewed in Chapter 2 indicates that estimating traffic volumes with TDM were rarely performed at the province-wide or statewide level, and mostly at the county-wide level. The TDM for this study was implemented at the county level to make appropriate comparisons. York County, New Brunswick was arbitrarily chosen as the analysis region. The region had a population of approximately 86,000, and area of 3572 square km, and comprised 138 DAs. In order to examine the TDM at a smaller scale and study the approaches with better accuracy, the scope was then reduced to the Census Consolidated Subdivision level. The CCS was arbitrarily selected to ensure that the study region encompassed an area for which available traffic counts could be linked to local traffic. The northern New Brunswick area of Beresford was selected for the study. The region had a population of approximately 10,000, an area of 194 square km, and comprised 22 DAs.

In order to isolate the study area, the geographic files were clipped using TransCAD's area clipping function. Each DA was designated as a TAZ. Zone centroids were used as traffic generating sites. These were connected to the road network using the closest connection. Inherently, as a result of the TAZ, some roads inside the TAZ would not be assigned traffic. Multiple centroid connections were used in order to compensate for this.

3.3.2 – Modeling Approach

The travel demand model was developed using TransCAD's built in four step model and omitting the mode choice step. The Quick Response Method (QRM) was used for trip generation, trip attraction, and trip balancing. The following section details this process.

TransCAD offers three methods of trip production: Cross-classification, Regression, and Discrete Choice. The QRM uses a cross-classification trip-rate table with paramters from NCHRP 187 (1978). This table includes trip-rates for three trip purposes: home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). Data required for this method included the total number of households (HH) in the zone and the average income per household for the zone. Since the trip rate table in NCHRP 187 is based on 1970 dollars, an inflation index was applied. Using the Consumer Price Index to calculate the inflation, a factor of 4.69 was applied to the 1978 numbers. Table 3.6 shows the cross-classification trip rate table used in this study. The total generated trips can be calculated using the following equation:

$$G_i = [\text{Total Households in Zone i}] \times [\text{Trip Rate based on Avg. Income for Zone i}] \quad [2.1]$$

Table 3.6: Trip Production Cross-Classification Table from NCHRP 187

Income Range 2001 $ (000's)	Average Daily person trips per HH	% Average Daily Person Trips by Purpose		
		HBW	HBNW	NHB
0-14	4.5	21	57	22
14-19	6.8	21	57	22
19-23	8.4	21	57	22
23-28	10.2	18	59	23
28-33	11.9	18	59	23
33-38	13.2	16	61	23
38-42	14.4	16	61	23
42-47	15.1	16	61	23
47-59	16.4	15	62	23
59-70	17.7	14	62	24
70-94	18.0	13	62	25
94-117	19.0	13	62	25
117+	19.2	13	62	25

The number of trips generated per household is a fundamental parameter and is inherently subject to high variation. Miller *et al.* (2006) acknowledged this and performed a study to investigate discrepancies between residential trip generation rates in the context of borrowing national average rates (NCHRP rates) for local application. The study concluded that there are no significant differences in mean rates attributable to the use of an average value instead of a site-specific value, so it was felt that these rates could be applied in this study.

The QRM uses an attraction model from NCHRP 187. This model is a regression equation that estimates the number of person trips attracted to a zone based on the number of dwelling units in a zone and the zone's work activity. Data required for this method included the total number of households in the zone, retail employment in the zone, and non-retail employment in the zone. Balancing productions and attractions was done by holding the productions constant (this was recommended in the TransCAD travel demand modeling guide). The equation for each type of attraction is shown below:

$$\text{HBW Trip Attractions} = F_1\ [1.7\,(X_1)] \qquad [2.2]$$

$$\text{HBNW Trip Attractions} = F_2\ [10.0(X_2) + 0.5(X_3) + 1.0(X_4)] \qquad [2.3]$$

$$\text{NHB Trip Attractions} = F_3\ [2.0(X_2) + 2.5(X_3) + 0.5(X_4)] \qquad [2.4]$$

X_1 = Analysis Area Total Employment

X_2 = Analysis Area Retail Employment

X_3 = Analysis Area Non - Retail Employment

X_4 = Analysis Area Dwelling Units

Where: F_1, F_2, and F_3 are areawide control factors.

$$F_1 = \frac{\text{Areawide Productions for HBW Trips}}{1.7(Z_1)}$$

$$F_2 = \frac{\text{Areawide Productions for HBNW Trips}}{[10.0(Z_2) + 0.5(Z_3) + 1.0(Z_4)]}$$

$$F_3 = \frac{\text{Areawide Productions for NHB Trips}}{[2.0(Z_2) + 2.5(Z_3) + 0.5(Z_4)]}$$

Z_1 = Areawide Total Employment

Z_2 = Areawide Retail Employment

Z_3 = Areawide Non - Retail Employment

Z_4 = Areawide Dwelling Units

The gravity model was used to distribute trips among the zones. In order to do this, an impedance matrix needed to be created. The distance between centroids was used to fill the matrix. The value in the cells on the diagonal (i.e. Zone 1 to Zone 1) was manually changed from 0 to 9999 to force trips to be distributed to other zones. The friction factor matrix was created using this impedance matrix. Person trips were converted to vehicle trips using the default recommended average occupancy value of 1.62 persons per vehicle (NCHRP 187, 1978). Next an impedance function was used to distribute trips among zones. This study used a Gamma function with the parameters shown in Table 3.7.

Table 3.7: Gravity Model Gamma Function Parameters

Trip Purpose	A	B	C
HBW	28507	0.02	0.123
HBO	139173	1.285	0.094
NHB	219113	1.332	0.010

*Source: (NCHRP 365, 1998)

The following data are necessary to apply the gravity model:

P_i : the number of trips produced by (or originating in) each zone i

A_j : the number of trips attracted to (or terminating in) each zone j

d_{ij} : the impedance between each ij pair of zones

$f(d_{ij})$: the friction factor between each ij pair of zones

The gamma function equation is defined as follows:

$$f(d_{ij}) = a \cdot d_{ij}^{-b} \cdot e^{-c(d_{ij})} : a > 0, c \geq 0 \qquad [2.5]$$

These are the parameters recommended in Travel Estimation Techniques for Urban Planning (NCHRP 365, 1998). Although some of the study area was considered rural, the overall traffic flow of the region was still expected to follow the urban model as most areas are within the influencing areas of urban centers, so it was felt that these parameters could be applied in this context. The result of this step was an O-D matrix for all zone-to-zone trips for each type of trip: HBW, HBNW, and NHB.

The final step was to assign each trip to the road network and generate traffic volumes. Several formatting steps were required before this could be achieved. These included cross-referencing the centroid nodes to the nodes they represent in the road network; indexing the O-D matrices with the road network node representation of the centroids nodes; and replacing links on the road network that had a length of zero with a non-zero value.

The STOCH method (Sheffi, 1985) was used to perform the traffic assignment for the QRM. This method distributes trips between O-D pairs using the shortest path, but also assigns a portion of the trips to other 'reasonable' routes based on probabilities calculated by a logit route choice model. This method was chosen over the all-or-nothing method in order to increase the range of roads on the network that would be assigned traffic volumes. Although typically used to model congestion, an equilibrium method was also implemented in an attempt to improve on the results obtained from the stochastic assignment. The observed NBDOT traffic volumes were manually entered as capacity constraints on the corresponding road segments in the network. Traffic assignment was performed for each trip type resulting in total traffic volumes on each link for each trip type; the sum of which represents the total estimated daily traffic volume on each link.

3.4 – Model Evaluation

The performance of the model was evaluated by comparing estimated traffic volumes to the available observed traffic volumes on the corresponding road segment. Since there are no observed traffic volumes on most local named roads, accuracy had to be judged using volume comparisons on local numbered roads. Accuracy was quantified using Absolute Percentage Error (APE), which is described in the following formula:

$$APE = \frac{|Observed - Estimated|}{Observed} \times 100 \qquad [2.6]$$

The following statistics, average error, the 50th percentile error (P50), the 75th percentile error (P75), and the 90th percentile error (P90) are used in this study. It was found that previous studies typically expressed accuracy in terms of P90. These statistics can take account of large errors resulting from outliers. A regression analysis was performed based on the pairs of observed traffic versus estimated traffic to obtain an R-squared value for each class. The R-square is defined as:

$$R^2 = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2} \qquad [2.7]$$

Where:

y_i = Observed Traffic Volume

$\hat{y}_i$ = Predicted Traffic Volume from Regression Model

$\bar{y}_i$ = Average of Observed Traffic Volume

The predicted traffic volume used in this calculation was the projected value from the linear regression model. The regression analysis involved fitting the estimated traffic from the TDM with the observed traffic counts to evaluate the correlation and statistical significance between the two. The regression models with high R-squared values were used for calibration purposes in the subsequent analyses.

The Sum of Squares Error (SSE) is calculated for each class using the following equation:

$$SSE = \sum (y_i - \hat{y}_i)^2 \qquad [2.8]$$

Where:

y_i = Observed Traffic Volume

$\hat{y}_i$ = Predicted Traffic Volume

The SSE was used to compare the model performance before and after the calibration using the developed regression analysis.

Chapter 4 – Data Analysis

This chapter presents the results obtained in both the county-wide implementation and the CCS implementation. The study was initially performed at the county-wide level to allow for comparisons to be made with other studies. The model was not implemented province-wide for two reasons. After the county-wide study was completed it was found that an increased resolution was needed which meant a smaller study area (e.g. the CCS level). There also existed a practical issue with running the model at a province-wide level. The origin-destination matrix for the county-wide implementation was 138×138 with a trip assignment processing time of approximately 20 minutes. The matrix for a province-wide implementation would be 1497×1497, and since processing time increases exponentially, it was determined that this was not a viable option. In Chapter 2, Michigan was identified as having a statewide TDM comprising 2393 TAZs. The overall model is composed of several smaller models including urban and county-wide, and does not include the local road network.

4.1 – Case Study 1: York County

The NBDOT manages a total of 1420 km of roads in York County, of which 643 km (45%) are considered to be included in the traffic counting program. The AADT on each of these roads is derived from 55 locations throughout the county using either short term counts or data from permanent count sites. Table 4.1 shows the breakdown of roads by functional class. All road classes down to and including local numbered roads are covered by the traffic counting program. Local named roads represent 345 km of the provincial road network in York County. This represents 24% of the total York County road network, and 35% of all paved roads. Except for one small segment, local named roads are not included in the traffic counting program.

Table 4.1: Roads by Functional Class in York County

Road Type	Road Covered by traffic Counting Program (km)	Total Road (km)	% Covered by Traffic Counting Program
Highway/Freeway	88	88	100
Arterial	117	117	100
Collector	210	210	100
Local Numbered	228	228	100
Local Named	2	345	0.5
Non-Surface Treated	0	432	0

Figures 4.1 and 4.2 show the road network in York County with and without centroid connectors. After some preliminary tests, the number of centroid connections was increased from one to three to increase the distribution of traffic on roads in the DA.

These segments were created so that the angular distances between segments would be fairly equal.

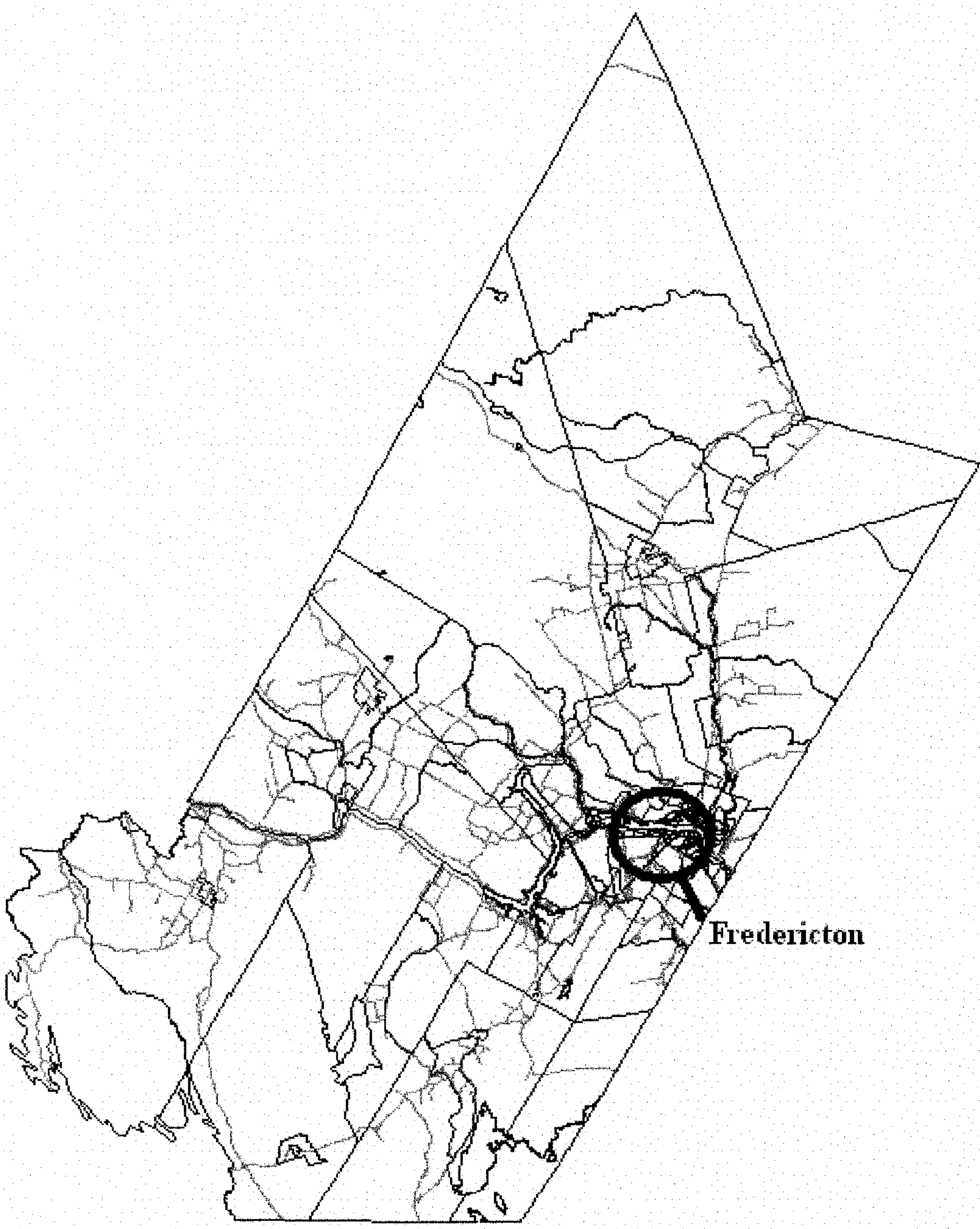

Figure 4.1: York County Dissemination Areas and Road Network

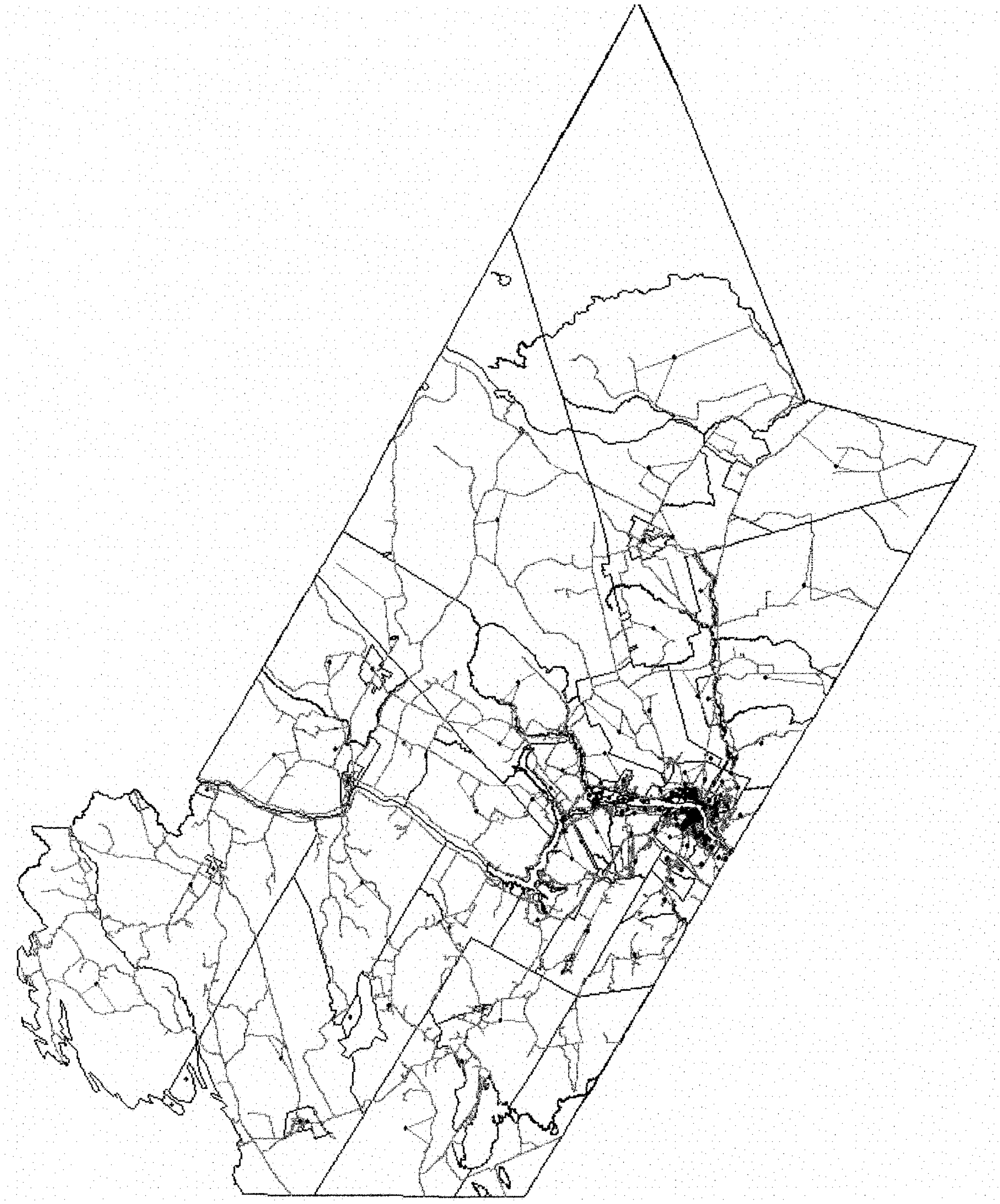

Figure 4.2: Centroid Connections to the Road Network

The road network in York County was represented in TransCAD as 2932 road segments. To put this in context, 920 of these road segments (31%) are on roads that are included in the traffic counting program (arterial, collector, and local numbered). The travel demand model implemented in the study produced traffic volumes for 1892 (65%) of the 2932 road segments.

Traffic volumes were estimated for 935 km (66%) of the 1420 km of provincial roads in the county. The NBDOT currently has 645 km (45%) of the road network covered by the traffic counting program. Traffic volumes were estimated for 290 km of road that previously did not have any traffic count data available. This represented an increase in available data of 45% compared to the current traffic count data. Traffic volumes were estimated for 183 km (52%) of local named provincial roads. Figure 4.3 shows the York County road network with labeled numbered highways. Arterial highways are highlighted in dark red. Collector highways are highlighted in purple. Local numbered highways are represented by a red dashed line. All other parts of the road network, including local named roads are shown in grey. A sample of estimated traffic volumes for individual road links is shown in Appendix C.

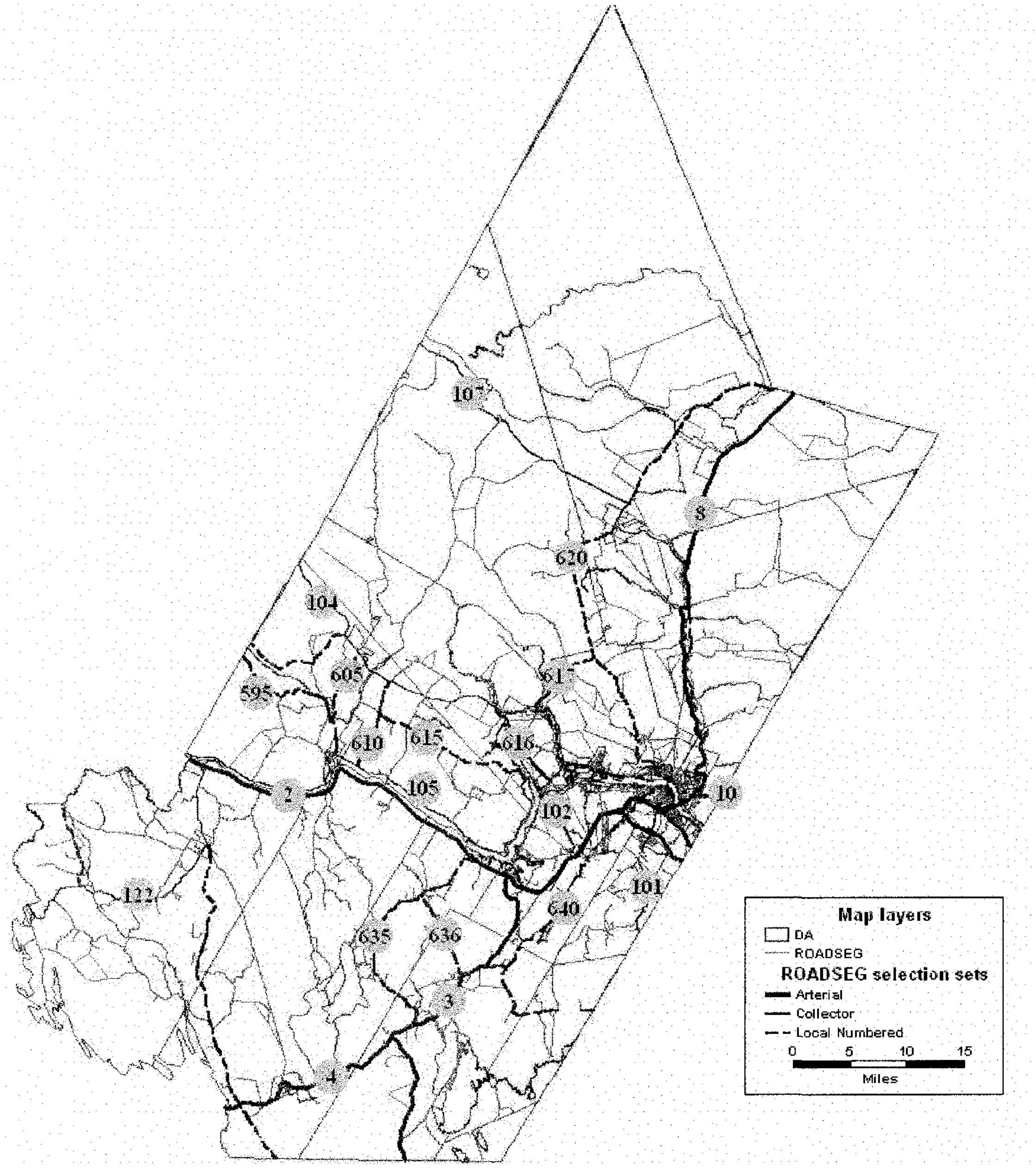

Figure 4.3: York County Road Network

4.1.1 – Study Results

The majority of the population of York County serves the City of Fredericton, which is also the provincial capital. The County has a population of approximately 86,000. The Trans Canada No. 2 four lane highway runs east-west through the center of the County, passing just south of Fredericton. Detailed views of the observed traffic count locations can be found in Appendix D.

There are four Arterial highways in the County. Traffic volumes from the hardcopy map provided by the NBDOT were used to compare the traffic volumes estimated by the TDM. Nine counts were used in the comparison of the Arterial road segments. One observed volume from Highway 4 was located at the endpoint of the highway, so no estimated traffic volume was assigned. There is a section of Highway 8 that runs parallel to Highway 628. The nature of the trip assignment method caused these roads to split the traffic volume evenly, resulting in a large overestimation of one count and a large underestimation in the other. Traffic counts on Highway 628 and the corresponding section of Highway 8 were both omitted from the comparison. Figure 4.4 shows the locations of the traffic counts on the arterial highway system and whether the value was over or underestimated.

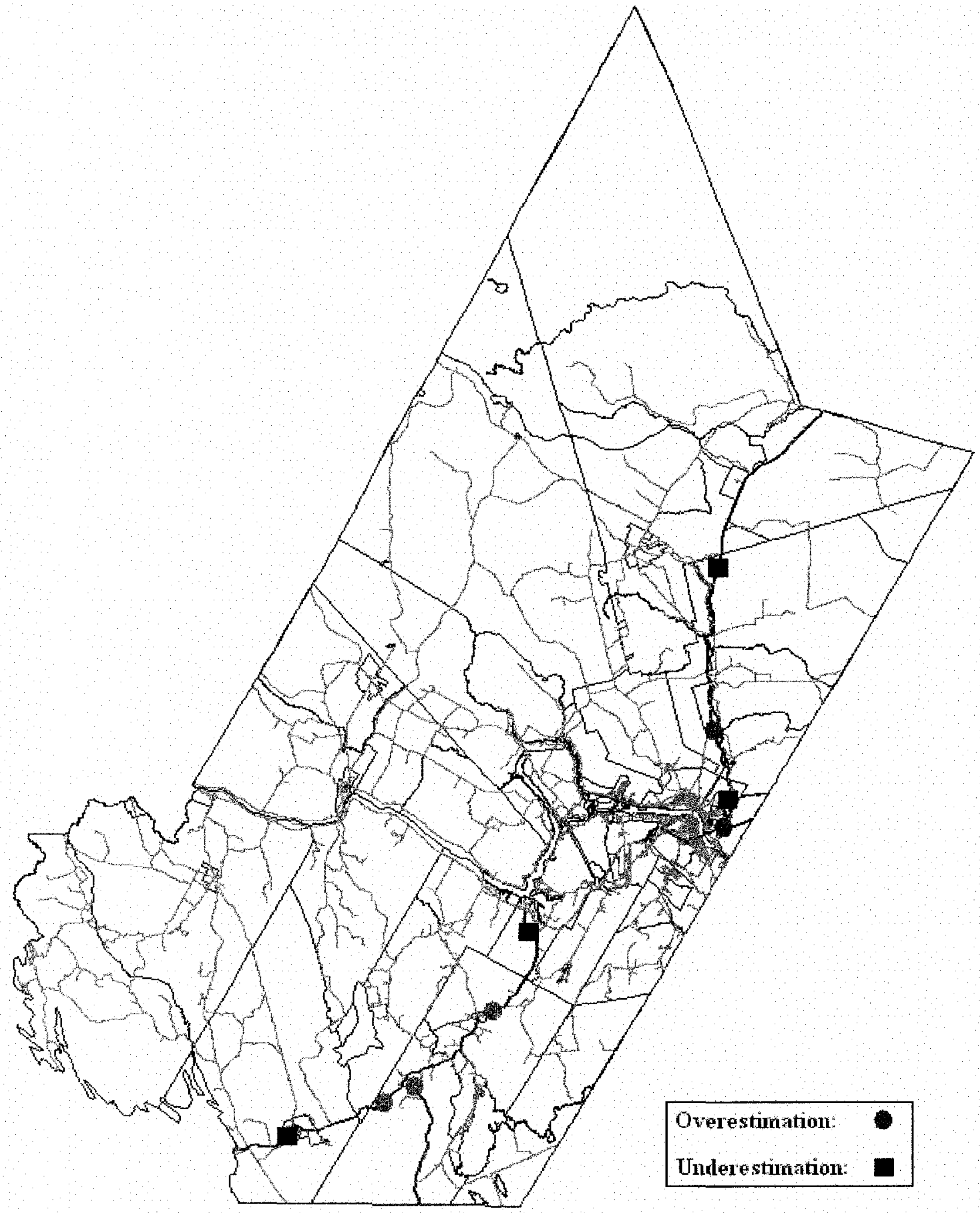

Figure 4.4: Traffic Count Locations on Arterial Highways in York County

Table 4.2 shows the individual link accuracy as well as the average error, the 50th percentile error (P50), the 75th percentile error (P75), and the 90th percentile error (P90) for the arterial estimates.

Table 4.2: Estimated Arterial Traffic Volumes and Percentage Error

Route	Observed	Estimated	Abs % Error	Over/Under
8	2420	2413	0.29%	U
8	4990	5344	7.09%	O
8	2380	2260	5.04%	U
3	2040	1880	7.84%	U
3	3130	3327	6.29%	O
3	2100	2284	8.76%	O
4	1010	1391	37.72%	O
4	770	699	9.22%	U
10	3700	3733	0.89%	O
		Average	9.24%	
		P50	7.09%	
		P75	8.76%	
		P90	14.92%	

The estimates for the arterial highways had a fairly low average error. Only one of the nine comparisons made had an error greater than 10%. Since these trunk roads are expected to carry the majority of the traffic throughout the zone, the low percentage error indicates that the trip productions and attractions are being modeled very well. There was no clear tendency toward over or underestimating volumes. A regression analysis between the observed and estimated traffic is shown in Figure 4.5. A trend line and a one-to-one diagonal line were also added. The one-to-one line represents a perfect correlation between estimated and observed results. The linear regression equation on the plot describes the relationship between estimated values from the TDM and the observed traffic counts. The high R-squared value of 0.9807 emphasizes there is a strong linear relationship between the two. Such a relationship is important and could be used to calibrate the model for more accurate estimates or to remove any obvious bias toward over/underestimation in the TDM estimates.

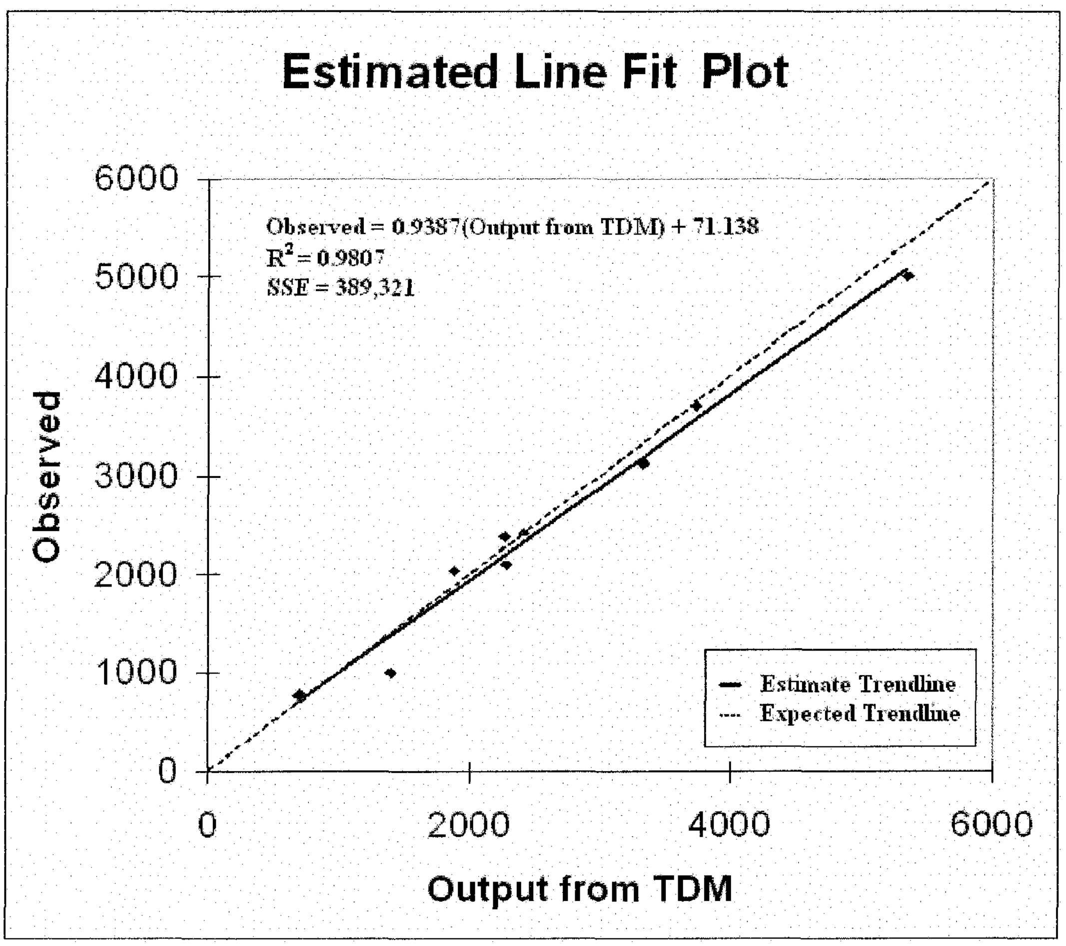

Figure 4.5: Observed Arterial Traffic Volumes versus TDM Estimates in York County

Figure 4.6 shows the observed traffic volumes versus the calibrated estimates from the regression model. The dot plot based on the observed traffic versus the calibrated estimates moved much closer to the one-to-one reference line indicating a better agreement between the two. The SSE between the observed traffic and uncalibrated estimates from the TDM was 389,321, as shown in Figure 4.5. It was reduced to 262,655 after calibration, as shown in Figure 4.6. The regression model shown in Figure 4.5 could be used in future research to calibrate estimates from the TDM for individual arterial road segments without traffic counts. The methodology is to use observed traffic counts and corresponding estimates from the TDM to develop a regression model for each functional class and apply them to the rest of the road segments in the class to remove any over/underestimation bias from the TDM.

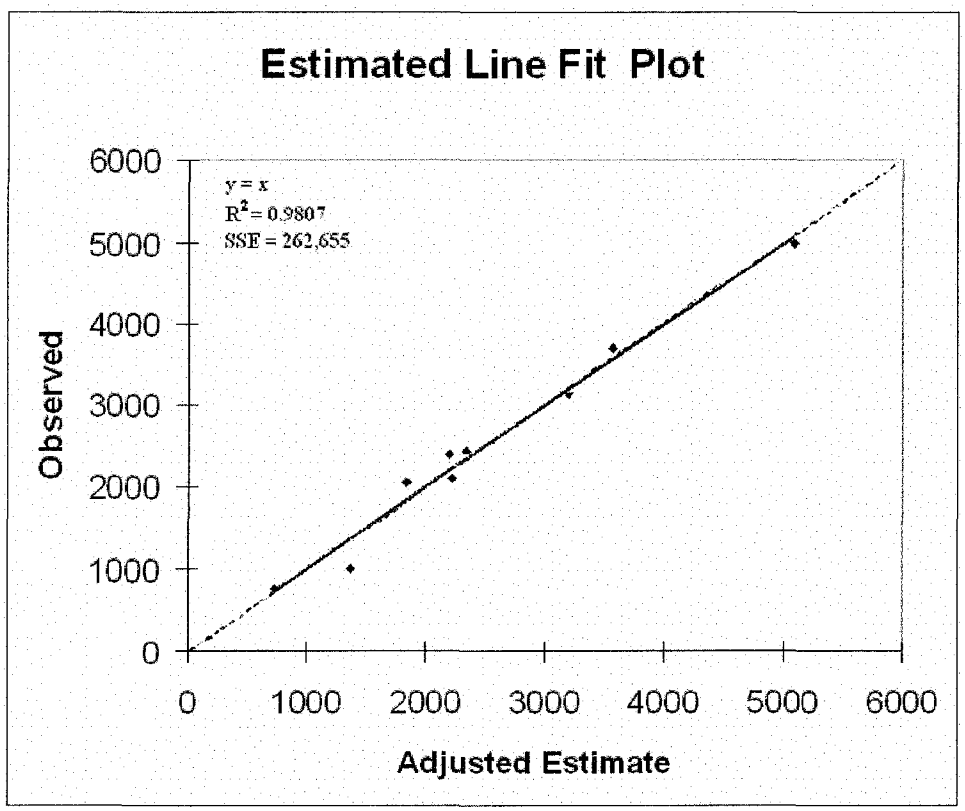

Figure 4.6: Observed Arterial Traffic Volumes versus Adjusted Estimates in York County

The calibration and validation work was carried out for the arterial estimates but there were only slight improvements obtained. The small sample size also limited the capability of carrying out such analyses. Therefore, the results were not presented here. The small errors shown in Table 4.2 also make these efforts unnecessary. Nevertheless, regression calibration models were developed and applied to lower functional class roads, such as collector and local, where the estimation errors were significant and the sample sizes were larger.

There are six Collector highways in the County. Sixteen observed traffic volumes were used to compare with the estimated collector values. Two Sections of Highway 105 and one section of Highway 104 were omitted as they were too close to the zone boundary to be assigned traffic. Figure 4.7 shows the locations of the traffic counts on the collector highway system and whether the value was over or underestimated.

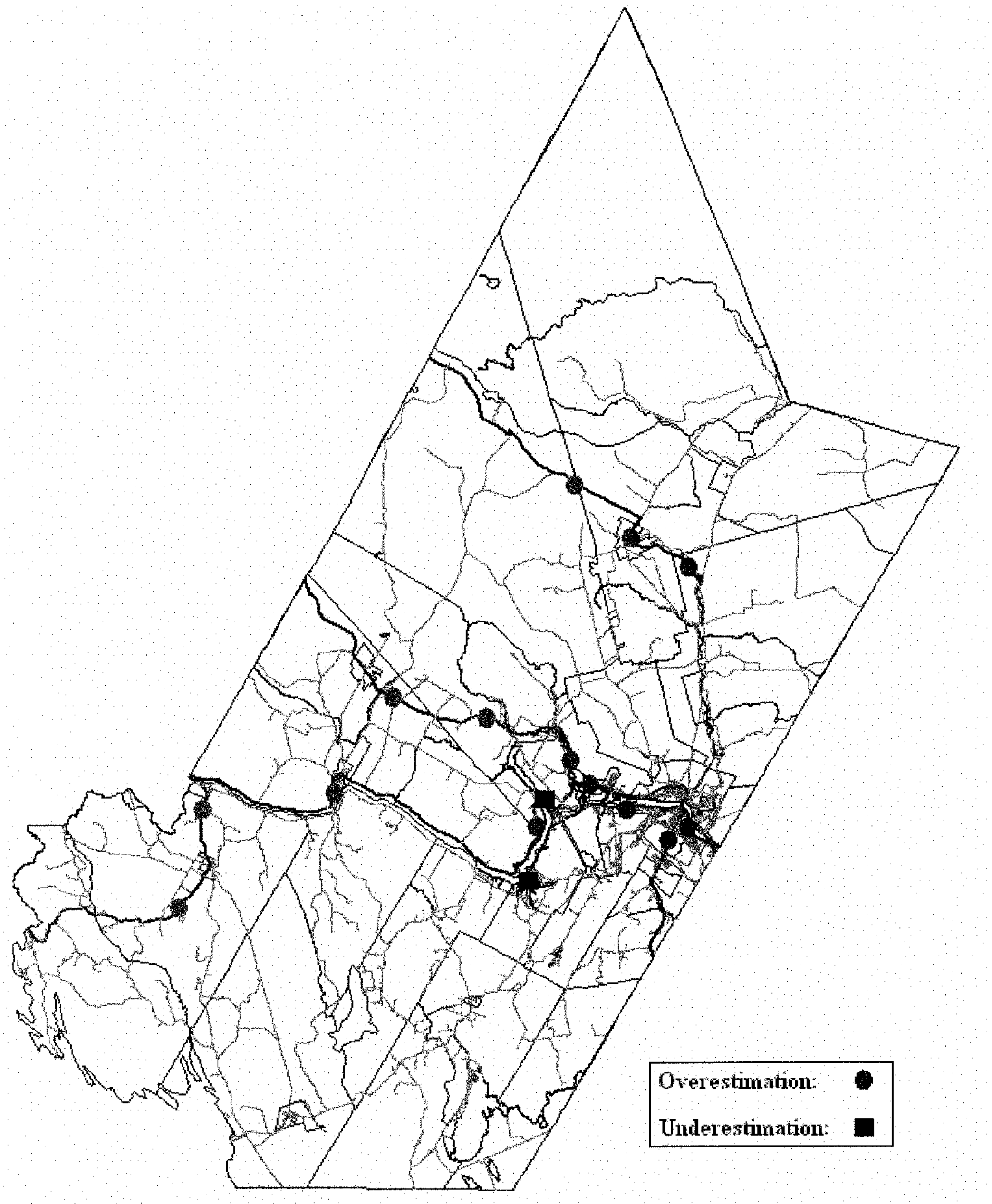

Figure 4.7: Traffic Count Locations on Collector Highways in York County

Table 4.3 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for the collector estimates.

Table 4.3: Estimated Collector Traffic Volumes and Percentage Error

Route	Observed	Estimated	Abs % Error	Over/Under
107	630	1254	99.05%	O
107	1350	1655	22.59%	O
107	950	1834	93.05%	O
104	1010	2552	152.67%	O
104	1390	2877	106.98%	O
104	2400	2448	2.00%	O
105	2330	3287	41.07%	O
105	2440	3081	26.27%	O
105	2430	1512	37.78%	U
105	4350	4804	10.44%	O
PC102	1540	2267	47.21%	O
PC102	12100	12945	6.98%	O
102	9700	9372	3.38%	U
101	15500	19656	26.81%	O
122	430	545	26.74%	O
122	700	786	12.29%	O
		Avg	44.71%	
		P50	26.78%	
		P75	58.67%	
		P90	103.01%	

Collector volumes were over estimated on all but two cases, which indicates that the traffic did not get assigned appropriately at this level. Low-volume roads tended to have the worst estimates, while high volume estimates had a relatively low error. The regression analysis is shown in Figure 4.8. The high R-squared value of 0.9665 indicates that there is a strong correlation between observed and estimated traffic.

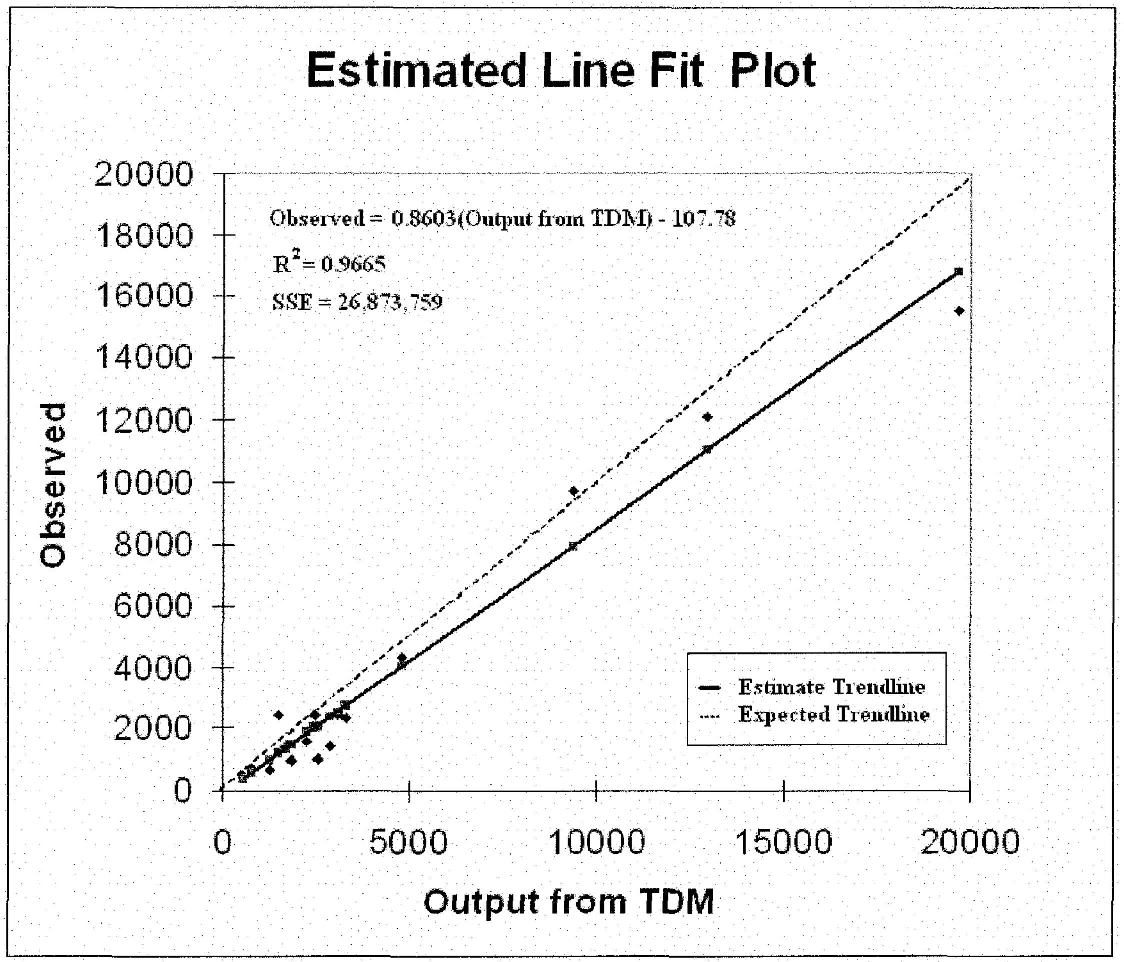

Figure 4.8: Observed Collector Traffic Volumes versus TDM Estimates in York County

The high R-squared value suggests that the regression model could be used to improve the overall accuracy of estimates for road segments with no traffic count data. Four traffic counts were removed so they could be used for model validation and the regression analysis was performed on the remaining twelve which produced the following equation:

$$Observed = 0.8254 \times Output\ from TDM + 63.567 \quad [4.1]$$

Table 4.4 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for the test group estimates from the TDM and regression model.

Table 4.4: Estimated Collector Traffic Volumes from the Regression Model

Route	Observed	Direct Estimates from TDM	Abs % Error	Calibrated Estimates from Regression	Abs % Error
104	1010	2552	152.67%	2170	114.85%
122	700	786	12.29	712	1.76%
PC102	12100	12945	6.98%	10748	11.17%
105	2330	3287	41.07%	2777	19.17%
		Average	53.25%		36.74%
		P50	26.68%		15.17%
		P75	68.97%		43.09%
		P90	119.19%		86.15%

The average error, P50, P75, and P90 errors were all reduced. For example, the average error was reduced from 53% to 36%, and the P90 was reduced to 86% from about 120%. This reinforces the indication that the calibration regression model can improve the accuracy of the TDM estimates for road segments with no traffic count data.

There are eleven Local Numbered highways in the County. These roads (numbered 595-640) are located in rural areas, typically running through or connecting small communities to higher class facilities. Ten observed traffic volumes were used to compare with the estimated local numbered values. Highway 628 was omitted for the reasons mentioned above. Figure 4.9 shows the locations of the traffic counts on the local numbered highway system and whether the value was over or underestimated.

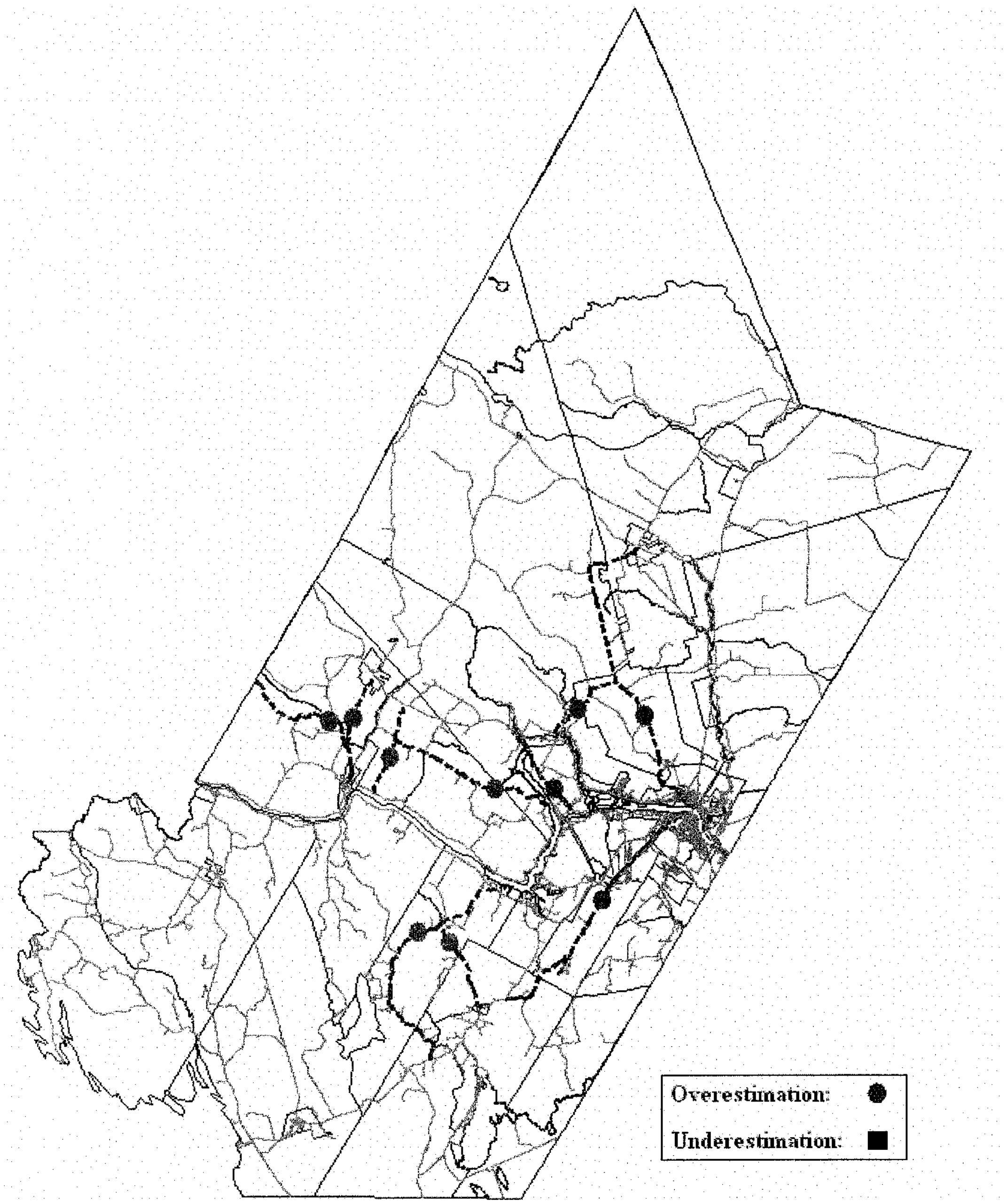

Figure 4.9: Traffic Count Locations on Local Numbered Highways in York County

Table 4.5 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for local numbered estimates.

Table 4.5: Estimated Local Numbered Traffic Volumes and Percentage Error

Route	Observed	Estimated	Abs % Error	Over/Under
595	650	763	17.38%	O
605	570	636	11.58%	O
610	370	1544	317.30%	O
615	260	2125	717.31%	O
616	1600	2056	28.50%	O
617	1100	1935	75.91%	O
620	1370	2895	111.31%	O
640	1800	5280	193.33%	O
635	440	1564	255.45%	O
636	430	488	13.49%	O
		Avg	174.16%	
		P50	93.61%	
		P75	239.92%	
		P90	357.30%	

Estimates for local numbered roads were all overestimated and had the highest average error of all the road classes (174%). The regression analysis is shown in Figure 4.10. The R-squared value for local numbered traffic estimations was 0.5414 which indicates that the correlation between observed and estimated values is moderately weak.

Therefore, a regression calibration model was not developed and used to calibrate the estimates from the TDM.

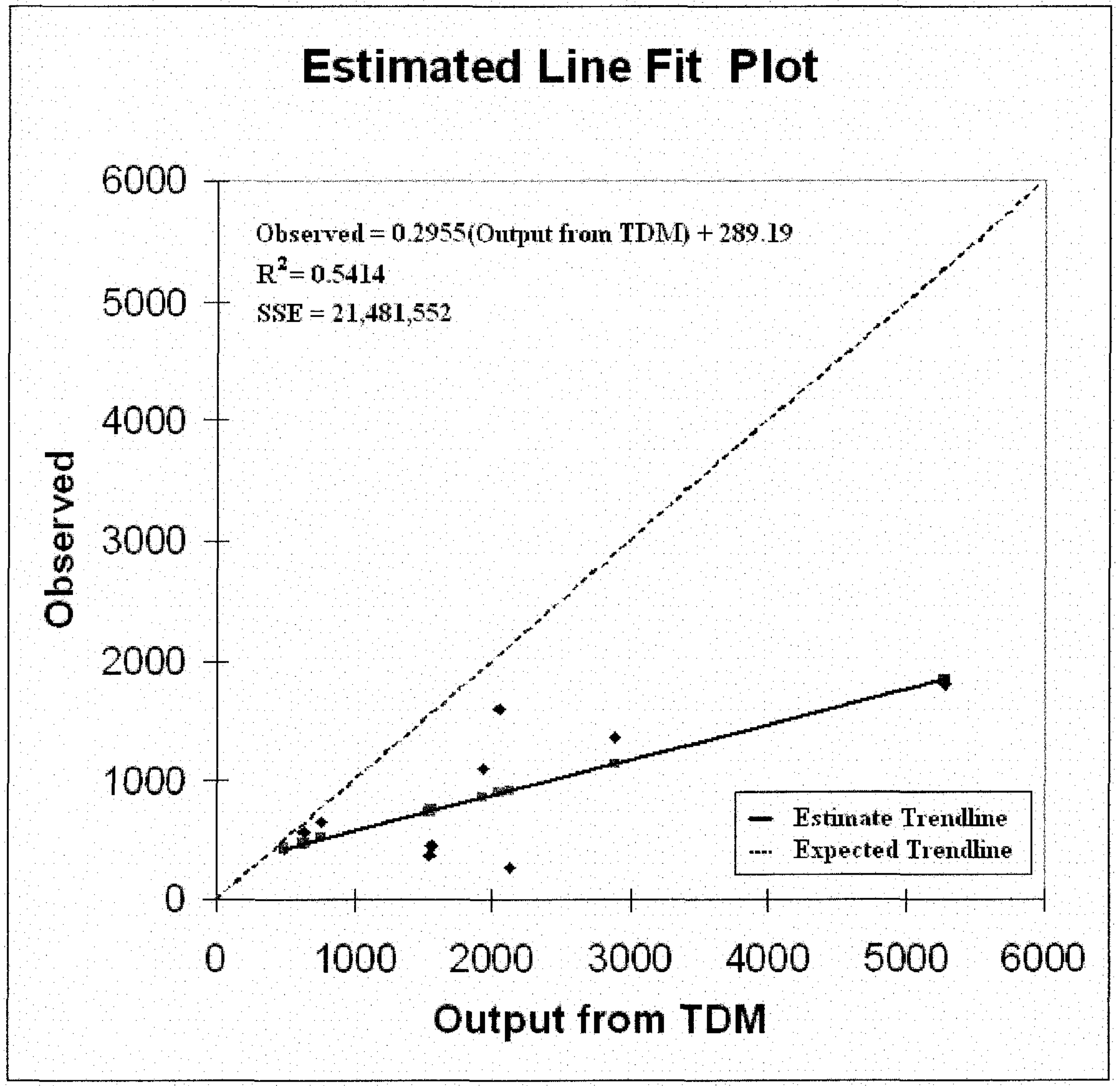

Figure 4.10: Observed Local Traffic Volumes versus TDM Estimates in York County

In all cases the volumes were significantly overestimated with errors ranging from 11% to over 700%. This reinforces the indication that traffic did not get widely assigned to the road network; only 65% of roads were assigned traffic and thus traffic volumes on these roads were significantly overestimated. To test this theory, trip assignment was performed again after increasing the number of centroid connectors from three to ten. Figure 4.11 shows the York County road network with increased centroid connectors.

Another possible reason is the balanced trip generation method used. The area east of Fredericton is not included (e.g. Oromocto, Lincoln, etc.) in the study area, so a large number of attractions generated in Fredericton that would normally be paired with trips produced in the Oromocto area got paired with trips produced within the study area, particularly to the west. The large overestimations (over 300%) on Routes 610 and 615 clearly indicate this because they became corridors for traffic flowing from the west of the county to Fredericton in the east.

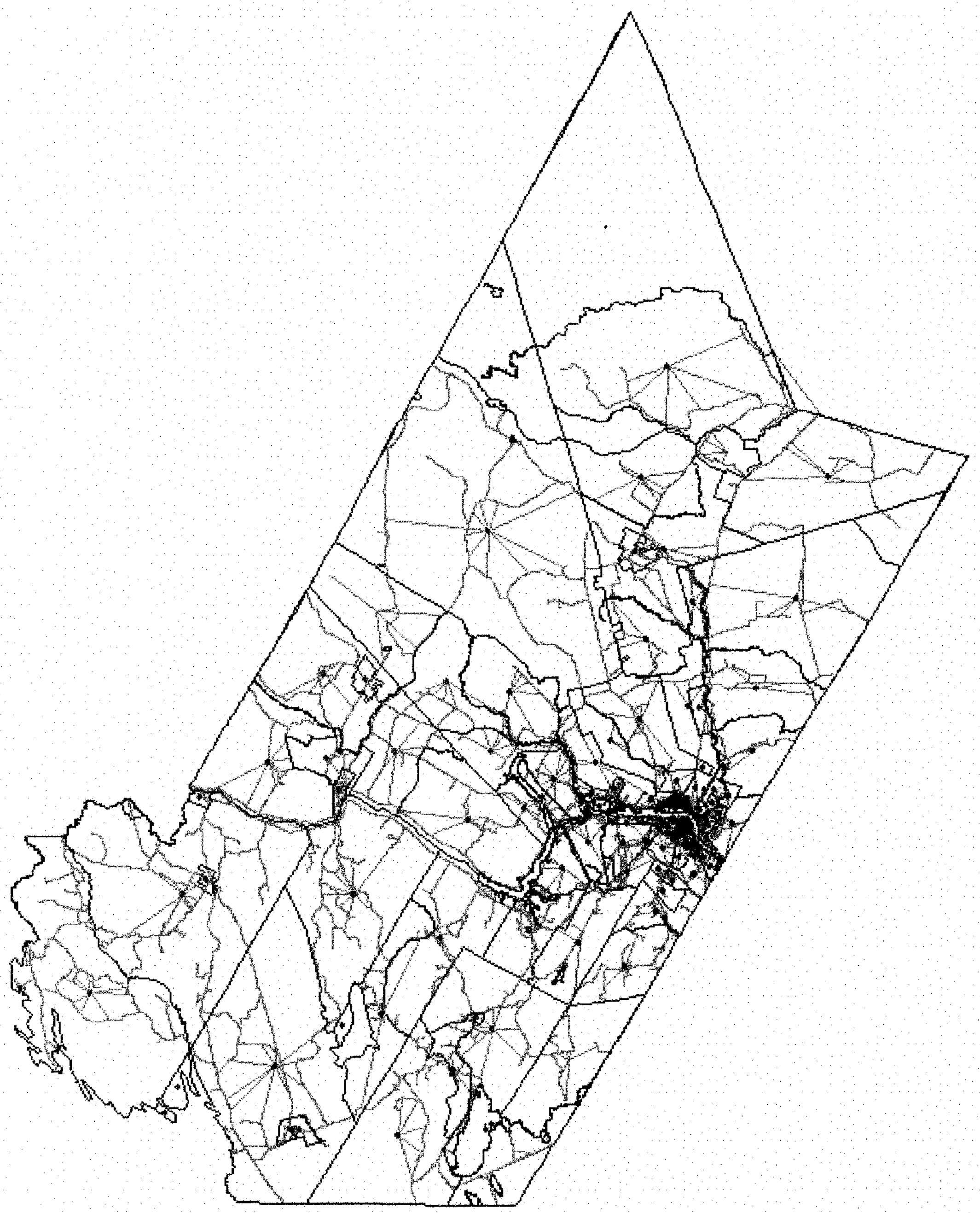

Figure 4.11: York County Road Network with Ten Centroid Connectors

Table 4.6 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for the modified simulation.

Table 4.6: Estimated Local Numbered Traffic Volumes and Percentage Error with Increased Centroid Connectors

Route	Observed	Estimated	Abs % Error	Over/Under	Improved
595	650	1145	76.15%	O	No
605	570	779	36.67%	O	No
610	370	1803	387.30%	O	No
615	260	2965	1040.38%	O	No
616	1600	1950	21.88%	O	Yes
617	1100	2895	163.18%	O	No
620	1370	3147	129.71%	O	No
640	1800	4011	122.83%	O	Yes
635	440	962	118.64%	O	Yes
636	430	828	92.56%	O	No
		Avg	218.93%		
		P50	120.73%		
		P75	154.81%		
		P90	452.61%		

Adding centroid connectors decreased the percentage errors on three of the road segments and increased the errors on seven compared to Table 4.5. The overall average error was increased. This indicates that the physical connections of the centroid to the road network are not the issue here. The large overestimation can likely be attributed to two main sources.

Trip assignment was performed with an all or nothing type of assignment using the shortest path on the network. This means that the majority of travel between zone centroids will be assigned to one path regardless of the number of centroid connectors. There are two possible solutions to this problem. The number of generating sites within each TAZ could be increased or a different assignment scheme could be developed. Although both solutions increase the amount of manual input to the model, which may make large scale implementation impractical, changing the trip assignment method is likely the easiest solution.

To test this theory, the number of centroids was reduced back to three and the assignment method was changed to 'Stochastic User Equilibrium', which incorporates capacity constraints into the trip assignment. The observed values of collector traffic from the NBDOT hardcopy map were manually added to the corresponding road segments as the capacity in the road network file. The traffic assignment was performed and the estimates on the local numbered roads were compared with the observed values. Table 4.7 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for the modified simulation and the adjusted results from the regression analysis.

Table 4.7: Estimated Local Numbered Traffic Volumes and Percentage Error with User Equilibrium Traffic Assignment

Route	Observed	Estimated	Abs % Error	Over/ Under	Improved
595	650	775	19.23%	O	Yes
605	570	550	3.51%	U	Yes
610	370	1158	212.97%	O	Yes
615	260	1765	578.85%	O	Yes
616	1600	2713	69.56%	O	No
617	1100	2252	104.73%	O	Yes
620	1370	2960	116.06%	O	Yes
640	1800	5818	223.22%	O	No
635	440	1568	256.36%	O	No
636	430	538	25.12%	O	Yes
		Avg	160.96%		
		P50	110.39%		
		P75	220.66%		
		P90	288.61%		

Generally traffic volumes were still largely overestimated, but the implementation of a user equilibrium traffic assignment improved the overall predictions on local numbered roads. The average error was reduced by about 14% and the 90th percentile error was reduced by 59%. The results from the regression analysis, shown in Figure 4.12, were also improved. The R-squared value increased to 0.6965, which indicates a stronger correlation between the estimated and observed values. The SSE for the TDM output was reduced by 97% from 25,424,339 to 861,461 based on the adjusted estimates.

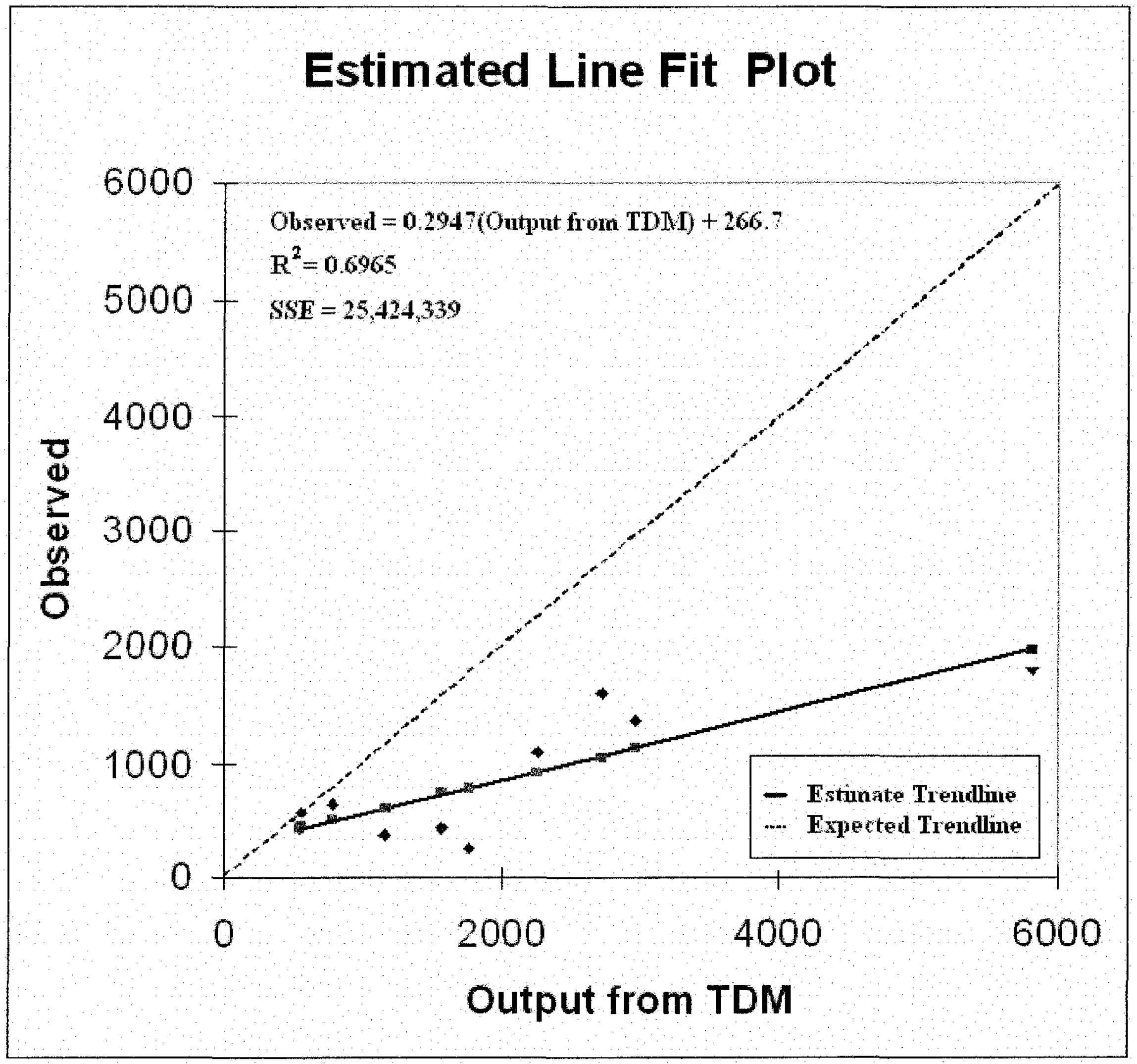

Figure 4.12: Observed Local Traffic Volumes versus TDM Estimates in York County with Capacity Constraints

The addition of observed collector traffic volumes as capacity constraints reduced the error in the estimates for local numbered roads which suggests that estimation error on local named roads would also be reduced. Intuitively this makes sense; however this cannot be confirmed without additional traffic count data on local named roads. Even though the results of the user equilibrium assignment method were better than the original stochastic method, the resulting error was still fairly large due to the inherent bias toward overestimation.

The large reduction in SSE (97%) indicates that regression could be used to improve the accuracy of local road estimates from the TDM. Four traffic counts were removed so they could be used for model validation and the regression analysis was performed on the remaining six which produced the following equation:

$$Observed = 0.4375 \times Output\ from\ TDM + 67.237 \qquad [4.2]$$

Table 4.8 shows the individual link accuracy as well as the average error, P50, P75, and P90 percentile error for the test group estimates from the TDM and regression model.

Table 4.8: Estimated Local Numbered Traffic Volumes from the Regression Model

Route	Observed	Estimated from TDM	Abs % Error	Estimated from Regression	Abs % Error
620	1370	2960	116.06%	1362	0.57%
640	1800	5818	223.22%	2613	45.15%
635	440	1568	256.36%	753	71.19%
595	650	775	19.23%	406	37.49%
		Average	153.72%		38.60%
		P50	169.64%		41.32%
		P75	231.51%		51.66%
		P90	246.42%		63.38%

The average error for the test group estimates was reduced by 115% to 38.6%. The P50, P75, and P90 percentile errors were all reduced by over 120%. These results clearly show that using regression to modify the TDM estimates on local roads with no traffic data can increase the accuracy and reduce the overall error in the estimations on these roads.

One explanation for the large overestimation on local roads could be that the trip distribution step was not done effectively. Trips generated in a zone were forced to end in another zone, meaning there was no internal zone traffic. While this was not a problem in urban areas where the DAs were small, in rural communities where DAs were larger, inter-zone travel was over-represented. This traffic was then distributed to areas with large attractions, mainly Fredericton's business districts. Since a large portion of the greater Fredericton area in the east of the zone was not included in the model (e.g. the town of Oromocto), there was a surplus of trip attractions generated in Fredericton that would normally have been paired with productions from the missing area. In order to keep productions and attractions balanced, productions from other parts of the zone were paired with the surplus attractions. Combine this with the apparent over-representation of rural inter-zone trips, and an overestimation of traffic volumes on local roads can be expected. Therefore, the study results indicate that selection of an appropriate study boundary which includes the influencing areas of adjacent cities or towns is critical.

Instead of defining the study boundary as a county, a more natural border should be established so that it encompasses the entire urban influencing area. The development of a more complex scheme for creating an impedance matrix or adjusting the parameters of the gamma function could provide a more accurate representation of the trip distribution. Particularly in rural areas, a method to assign internal zone traffic to the road network should be investigated.

There are 345 km of local named roads in York County. The TDM estimated traffic volumes for 231 km (67%) of these roads. In order to address the issue of variability in the estimates, roads could be classified into a volume range rather than be assigned a specific number. Table 4.9 provides an example of this type of classification by showing the breakdown of estimated traffic volumes on local named roads in the zone.

Table 4.9: York County Local Named Roads by Traffic Volume

Estimate Traffic Volume (veh/day)	Kilometres of Road	% of Total
0-500	150	43
500-1000	30	9
1000-2000	41	12
2000+	124	36

This can be useful for identifying high priority road segments within roads of the same class. According to these results, 36% of local named roads have traffic volumes greater than 2000 vehicles per day, which is quite high. Factoring the local named traffic volume estimates using the regression equation obtained from the local numbered regression analysis should reduce the overall error. Another solution could be to use a relative classification system (i.e. low-high priority) rather than assigning a specific value or range to a road segment.

4.1.2 – Discussion

Comparisons between predicted and observed traffic volumes had to be done manually using a hardcopy map. Since the road network in York County was fairly dense, it was difficult to accurately distinguish where exactly the traffic counts were taken. Estimated traffic volumes on separate links of the same road varied significantly, particularly on local roads, so some discretion was needed in assigning observed traffic volumes to the appropriate road segment.

Traffic count data were not available for local named roads. Even though the model estimated traffic volumes for 182 km of local named roads, there was no base for comparison, so the accuracy of these estimates cannot be quantified. The performance of the model had to be evaluated using traffic count data from local numbered roads.

A portion of the road network was not assigned traffic. No matter how many centroid connectors were added and which traffic assignment method was used, the maximum coverage attained was 67% of the road network. While this was a large improvement in the amount of traffic data than currently available, it most likely contributed to an overestimation of traffic volumes on low-class roads as the others were not assigned any traffic at all. This did not seem to affect high class roads.

Through traffic was not accounted for in any of the comparisons. Because of the large zone size, it was assumed that all of the traffic in the zone originated from within the zone. The boundaries of York County encompass the city of Fredericton and most of the area that it serves. The one major exception is the town of Oromocto, which is located to the east of Fredericton just outside of the analysis zone. Since the majority of traffic between Fredericton and Oromocto travels on the TransCanada Highway, it was decided that through trips would not introduce a significant amount of error. It should be noted that this may have created an artificially high number of trip attractions to Fredericton. Since the productions and attractions were balanced, some attractions to Fredericton that would normally be paired with trips generated in the Oromocto area would have been assigned to productions from an area within York County. This could contribute to an overestimation in the amount of rural traffic traveling to Fredericton.

4.2 – Case Study 2: Beresford CCS

In order to examine the Travel Demand Model at a smaller scale, the analysis area was reduced to the Census Consolidated Subdivision level. The CCS of Beresford encompassed an area for which available traffic counts could be intuitively linked to local traffic, that is, it encompassed the central business district and surrounding residential area. The region has an area of 194 square km, comprises 22 DAs, and had a population of approximately 10,000 (Statistics Canada, 2001). The communities of Petit Rocher, Nigadoo, and Beresford are included within the CCS.

There are a total of 224 km of road in the Beresford area. The NBDOT manages 178 km of these roads. The breakdown of roads by classification is shown in Table 4.10.

Table 4.10: Beresford Area Roads by Functional Class

Road Type	Kilometres of Road (km)	%
Arterial	13	7
Collector	16	9
Local Numbered	16	9
Local Named	72	41
Other	61	34

Traffic count data were available for the one arterial, one collector, and two local numbered roads. This represented 45 km (25%) of the provincial road network which comprised one permanent count site and two short term count sites on the arterial highway; two short term count sites on the collector; and one short term count site on each of the local numbered roads. The travel demand model implemented in the study produced traffic volumes for 110 km (62%) of the provincial road network in the Beresford CCS. This represents an increase in available data of 65 km (144%) compared to the existing traffic count data. Figure 4.13 shows the Beresford area road network and DAs. Arterial highway 11 is labeled and highlighted in dark red. Collector highway 134 is labeled and highlighted in purple. Local numbered highways 315 and 322 are labeled and represented by a red dashed line.

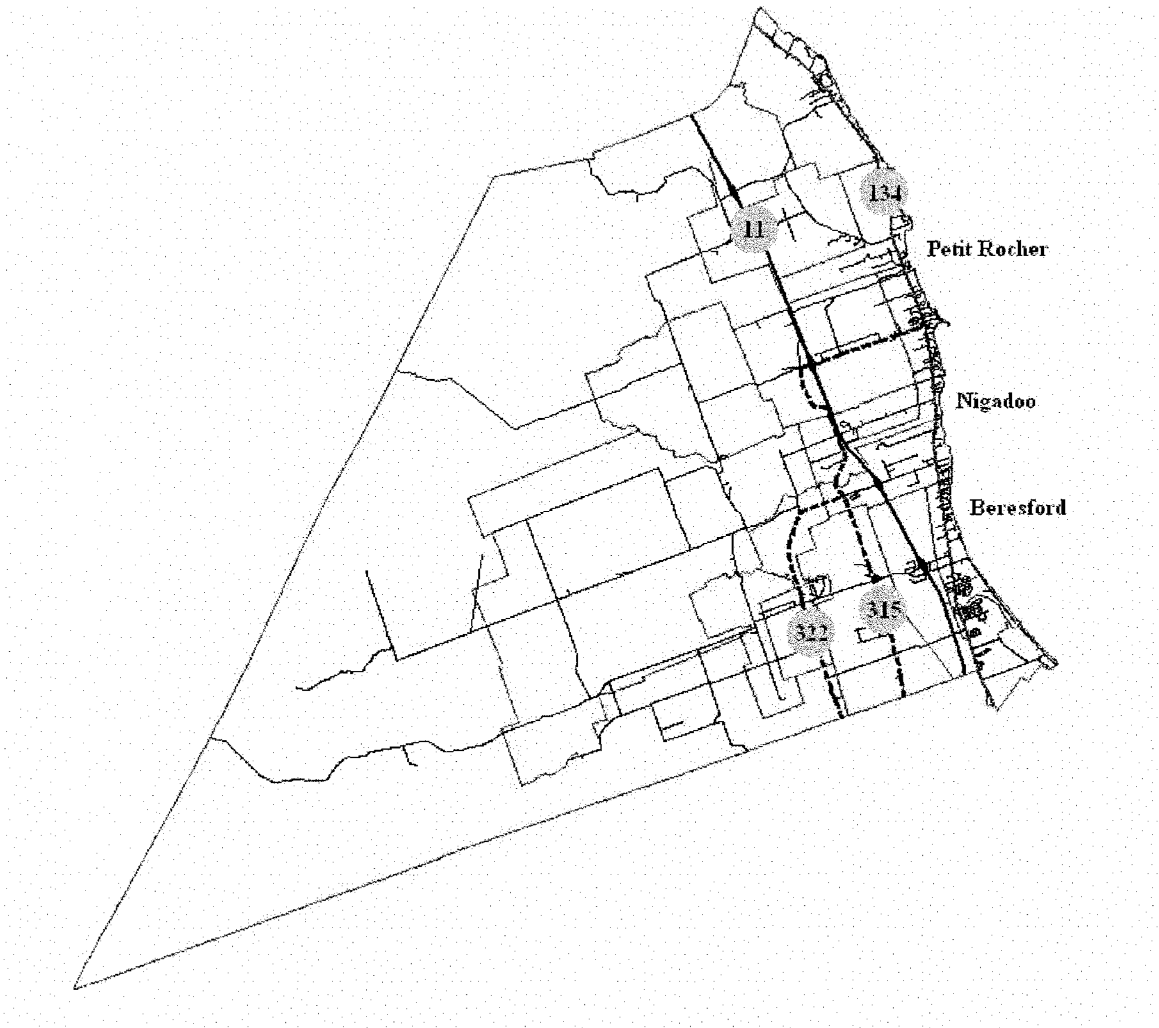

Figure 4.13: Beresford Area Road Network

4.2.1 – Study Results

The analysis zone was chosen so that it would encompass an area for which the majority of the traffic in the region was generated within that zone. The Beresford area is located on the waterfront of the Baie des Chaleur. The main road, which services the central business district, is collector highway 134 which runs North-South along the waterfront. The population density is highest close to the water on the east side of the zone and becomes progressively lower heading west. Arterial highway 11 runs through the zone parallel to highway 134.

On both highways, observed traffic volumes on sections to the north and south of the zone were significantly lower than traffic volumes in the center of the zone, particularly on the collector highway, where the traffic volume went from 1240 vehicles per day just north of the zone to 12,400 vehicles per day in the central business district. This indicates that the majority of traffic is being generated within the zone.

In order to compare the observed traffic volumes with the estimated traffic volumes, it was necessary to account for through trips in this case due to the fact that both highway 11 and highway 134 traverse the entire zone. Since observed traffic volumes to the north of the zone were lower than volumes to the south of the zone, the volumes to the north of the zone were taken as a better representation of through traffic. On highway 134, the observed value of 1240 vehicles per day on the north section was used as the through traffic value. On highway 11, the observed value of 3510 vehicles per day from the permanent count station at the north of the zone just before the first interchange was used as the through traffic value.

Figure 4.14 shows the locations of the traffic counts on the road network and whether the value was over or underestimated.

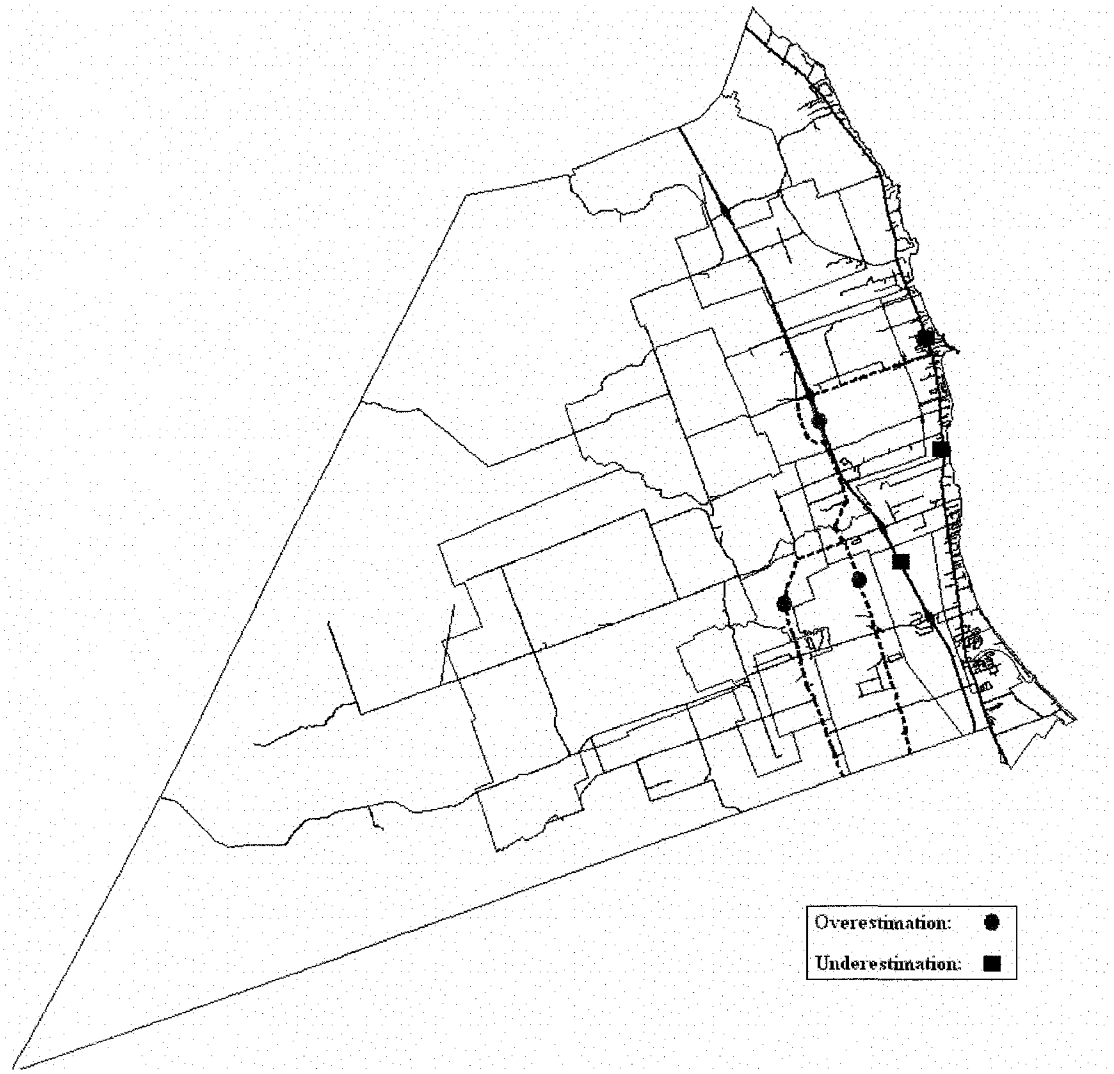

Figure 4.14: Traffic Count Locations on Highways in Beresford CSS

The individual errors, average, and percentile errors are summarized in Table 4.11.

Table 4.11: Estimated Beresford Traffic Volumes and Percentage Error

Route	Observed	Estimated	Abs % Error	Over/Under
134 (North)	8190	6290	23.20%	U
134 (South)	11160	9925	11.07%	U
11 (North)	990	1032	4.24%	O
11 (South)	3550	3132	11.77%	U
322	1400	1951	39.36%	O
315	2660	2992	12.48%	O
		Average	17.02%	
		P50	12.13%	
		P75	20.52%	
		P90	31.28%	

The observed traffic volumes at the two short term count sites on highway 134 were 9430 and 12400 vehicles per day respectively. With through traffic removed, the expected volumes on these two segments were 8190 and 11160 vehicles per day. The traffic volumes estimated using the travel demand model were 6290 and 9925 vehicles per day. Volumes in both cases were underestimated with respective errors of 23% and 11%. This may indicate that through trips were slightly underestimated at both locations. It is reasonable to speculate that additional traffic was generated between the edge of the analysis zone and the location of the base count used to estimate through traffic.

The observed traffic volumes at the two short term count sites on highway 11 were 4500 and 7060 vehicles per day, respectively. With through traffic removed, the expected volumes on these two segments were 990 and 3550. The traffic volumes estimated using the travel demand model were 1032 and 3132 vehicles per day. In the first case traffic was overestimated with an error of 4%; in the second case traffic was underestimated with an error of 12%.

There are two local numbered highways in the zone: highways 315 and 322, both running north-south. Highway 322 branches off 315, runs parallel, and then rejoins 315. The short term count sites were both located at the southern juncture of the two highways. This juncture was located just south of the analysis zone. The observed traffic volumes were 1400 vehicles per day for highway 322 and 2660 vehicles per day for highway 315, respectively. Since these were local roads, no through traffic modifier was applied. The traffic volumes estimated using the travel demand model were 1951 vehicles per day on highway 322 and 2992 vehicles per day on highway 315. Both volumes were overestimated, with an associated error of 39% for highway 322 and 12% for highway 315.

Three of the six comparisons made were above the observed value and three were below. This suggests that the model does not have a clear tendency to overestimate or underestimate. The lowest error occurred on the arterial highway, which is consistent with the York County case. Since highway 11 is a controlled access highway, and there was a permanent traffic count site located at the entrance of the highway, the volume of through traffic could be easily identified. Traffic at both locations on highway 134 was underestimated. This was most likely due to an underestimation in through traffic. The traffic count used to identify through traffic was taken several kilometres north of the analysis zone. Since there are residential dwellings along the highway between the count site and the edge of the analysis zone, a slight underestimation is expected as this traffic is not taken into account.

The largest error occurred on highway 322. Traffic on both local numbered roads was overestimated. This could be attributed to the location of the short term counts. The counts were taken at the junction of the two roads, which occurred south of the analysis zone. Since there are residential dwellings along these roads, and several intersecting local named roads, these counts may not be indicative of actual traffic volumes on the road segments within the zone because traffic that has entered or discharged from the road before the location of the estimate will not be captured.

Again, a regression analysis between observed and estimated traffic volumes is shown in Figure 4.15. The R-squared value for all predictions was 0.9785. This indicates a strong correlation between observed and estimated traffic. Again, such information could be used in the future as a factor to apply to estimates for other links within the area. In this case, the small sample size makes this impossible and therefore no analysis was carried out.

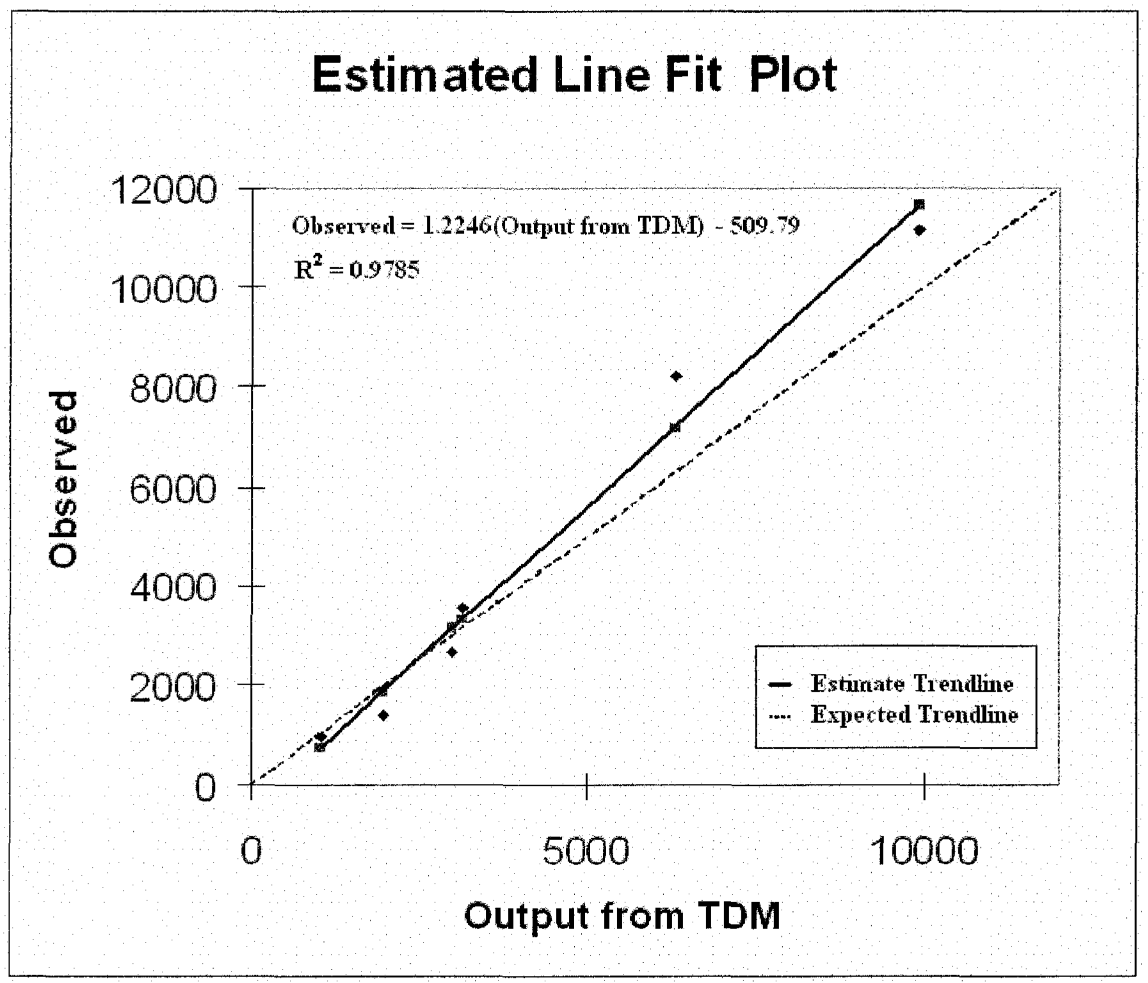

Figure 4.15: Observed Traffic Volumes versus TDM Estimates in Beresford

Overall, the travel demand model was able to capture the travel patterns of the zone fairly well. Intuitively, highway 134, which serves as the main street for the central business district, should have the highest traffic volumes in the zone. This behavior was successfully captured by the TDM and confirmed by the observed traffic counts. The estimated volume of locally generated traffic was also fairly close to observed values.

Surface treated local named roads under the jurisdiction of the province represented 84 km of road in the analysis zone. The travel demand model used in this study estimated traffic volumes for 50 km (60%) of these roads. There is currently no way to assess the accuracy of individual estimations on local named roads without taking additional traffic counts for comparison. It should be noted that with a reduced study area size, the magnitude of the estimation error on low-class roads will be reduced, as it is the case here.

The analysis on the higher class roads indicates that the model has provided a good estimate of the total volume of traffic generated by the zone and has captured the overall pattern of traffic movement in the zone. Since these local named roads feed this traffic from the generating sites to the higher class roads, it can be inferred that the estimated traffic volumes on these links are indicative of the actual traffic volumes. Regardless of whether or not the error in the estimated traffic volumes can be quantified, this process has made data available for a significant portion of the road network for which no data were previously available.

In order to address the issue of variability in the estimates, roads could be classified into a volume range rather than be assigned a specific traffic volume. Table 4.12 provides an example of this type of classification by showing the breakdown of estimated traffic volumes on local named roads in the zone.

Table 4.12: Beresford Local Named Roads by Traffic Volume

Estimate Traffic Volume (veh/day)	Kilometres of Road	% of Total
0-500	45	54
500-1000	7	8
1000-2000	19	23
2000+	13	15

Unlike the York County case, the majority of these roads are low-volume (54%). This indicates that the model is providing a better representation of actual road traffic. It is clear from Table 4.12 that the relative traffic volumes on these roads can vary significantly. This can be useful for identifying high priority road segments within roads of the same class. Rather than assigning a specific value or range, a relative classification scheme could also be used (e.g. low-high) to describe road links. Prioritizing these roads based on the estimated traffic volumes could significantly improve operations from an asset management perspective.

4.2.2 – Discussion

Comparisons between predicted and observed traffic volumes had to be done manually using a hardcopy map. This made it difficult to assign the observed traffic volumes from the map to the appropriate road segment in TransCAD.

Although the two local numbered roads have observed traffic volumes assigned to them, the short term counts were taken at the ends of the two roads, located just outside of the analysis area. This may affect the validity of any comparisons made to these numbers.

Only 62% of the provincial road network was assigned with traffic. This suggests that while some road links have no estimated volumes, there may be an overestimation in the predicted values on other road segments. Since there are no traffic count data available for most of the network, this cannot be confirmed or quantified.

Chapter 5 – Conclusions and Recommendations

This chapter discusses the conclusions and recommendations resulting from this study. Section 5.1 addresses the study objectives outlined in Chapter 1 and presents the study conclusions. Section 5.2 provides recommendations for both practical application and for future research. Section 5.3 offers some general conclusions about the overall study.

5.1 – Conclusions

A total of 35 traffic counts were estimated and analyzed in York County. Counts were divided by functional class into three analysis groups. Estimates for arterial roads had an average error of 9%. Estimates for collector roads had an average error of 45%. Estimates for local numbered roads had an average error of 174%. Capacity constraints were added and a user equilibrium trip assignment method was implemented which reduced the average error for local numbered roads to 160%. Traffic estimates for both the collector and local numbered highways were consistently overestimated.

The calibration regression models were developed based on the estimates from the TDM and the observed traffic counts. These calibration models were proven to be effective to remove consistent estimation bias. Their applications to York County reduced the overall average error for the collector roads to 36%, and that for local roads was limited to 40%.

The study area size was reduced and the model was implemented in the Beresford Census Consolidated Subdivision level. The traffic patterns on the roads surrounding the CCS indicated that most of the traffic in the region was generated internally. The CCS contained four roads that had traffic count data available for comparison which comprised six observed traffic volumes. The overall average error in the zone was reduced to 17% and in particular the average errors for the local numbered roads were limited to less than 40%.

The following conclusions were made based on the study results:

1. Travel demand modeling for estimating traffic on low-class/low-volume roads is practical and useful. For local roads, the relative magnitude of traffic estimates is more important than the accuracy of individual links. TDM provides an effective way to identify high priority segments within the local road class. That is, those roads with assigned traffic, especially high volume, should be given priority.
2. Using a TDM increases the amount of traffic count information available for a road network. Traffic count information does not exist for the majority of low-class roads in New Brunswick. A TDM is non-invasive financially feasible method to obtain these data. Classifying these roads based on traffic volume, volume range, or relative volumes will help decision-makers allocate resources amongst these roads more effectively from an asset management perspective.

3. The TDM should be implemented for a small area rather than county or province-wide. The majority of local road traffic is generated within the same zone, or from neighboring zones. Reducing the study area size is the best way to model local traffic behavior and reduce the magnitude of estimation errors.

4. Study area boundaries should be chosen to reflect the urban influencing area. Using an arbitrary jurisdictional area, such as a county, may result in inaccurate areawide travel patterns as it is shown by the "York County" study in this thesis. Boundaries should be chosen such that the majority of local traffic in the area can be assigned to one or more central business districts, regardless of whether the area is urban or rural.

5. The TDM approach does not assign traffic to some roads and tends to overestimate traffic on the rest. Regression can be used to adjust the estimates in order to remove this bias and increase the overall accuracy, particularly for lower class roads.

6. Travel demand modeling achieves very good estimations for higher functional class roads. Low estimation errors for these roads indicate that the TDM generates the total traffic volume for the area fairly accurately.

7. Modeling accuracy for low-class roads is still fairly large. For example, the lowest average error for local roads achieved in this study was still around 40%. Refinements to the traffic assignment method need to be done in order to reduce these errors.

8. Dissemination areas provided the highest resolution possible of disaggregated data. Socioeconomic information used in the model (Total

Number of Households, Average Income per Household, Retail Employment, and Non-Retail Employment) is available for all DAs in the province. This means that the model can be applied to any region, and that transferability has been achieved.

9. Through-trips are typically not an issue when estimating local road traffic as long as the study area boundaries are chosen appropriately. The majority of local road traffic is generated within the study area as there is little external traffic on these roads.

10. Increasing the number of connections to a single generating site does not improve the distribution of traffic on the network or the accuracy of individual estimations. The study found that using more than three centroid connectors diminished overall accuracy.

11. Choosing an appropriate method of traffic assignment is very important. The Stochastic User Equilibrium assignment method provides a better distribution of traffic on the road network than traditional all-or-nothing methods. The addition of available traffic counts as capacity constraints improves the model accuracy.

12. The model should be implemented using an iterative 'top down' approach. Each iteration should apply the following process:

    - Trip Generation
    - Trip Distribution
    - Trip Assignment
    - Identify Issues

- Refine/Calibrate Model
- Repeat

The initial focus should be on higher class roads such as arterials or major collectors. Once the activity on these roads has been modeled correctly the focus should shift to lower class roads. This iterative approach will result in higher accuracy in low-class road traffic estimations.

5.2 – Recommendations for Future Work

Despite representing the majority of the world's road network, low-volume/low-class roads have not received much attention from either the public or research sectors. This section suggests some improvements that could be implemented by highway agencies, and provides a direction for future research in this area.

5.2.1 – Practical Application

Typically, highway agencies focus on maintaining a high level of service on a core number of roads. The percentage of total roads included in this core varies by jurisdiction and is usually linked directly to the amount of funding available for transportation. As asset management programs continue to advance, highway agencies are beginning to realize the long term advantages of maintaining a comprehensive inventory of assets and applying preventative maintenance using pavement deterioration models to aid in scheduling. Resources are often not available to obtain the traffic statistics necessary to include low-class roads into these models, even though the benefits of their inclusion are becoming more apparent.

Travel demand modeling can provide a non-invasive, financially feasible method to obtain useful traffic information. Since it was designed to be transferable, the method presented in this study could be adopted and implemented province-wide fairly easily. This would create a significant amount of previously unavailable information that decision-makers could use to help manage assets and allocate resources more effectively. This method may be favored over blanket approaches as the estimated traffic for roads within the same class allows for the user to identify high priority road segments.

It was assumed that the relationship between the observed traffic counts and the estimates from the TDM for local numbered roads would be representative of the relationship between the observed traffic counts and the estimates from the TDM for local named roads. This is likely true since, local named or local numbered, they are all classified as local roads and serve similar land uses; however, it may be useful to confirm this by taking a selected number of short-term counts on local named roads. Additional traffic counts could also help to calibrate or validate local road estimates for a particular area.

5.2.2 – Future Research

This study uncovered several key issues associated with modeling local traffic on a large scale. Low-class road traffic can be modeled most effectively by reducing the size of the analysis zone; however, this limits the model's application. It may be desirable for areas with a well established province-wide TDM to find a way to incorporate local estimates into the province-wide model. This could be done by developing an advanced assignment scheme. A method to assign a percentage of zone traffic to local roads based on factors such as functional class, roadway density, and proximity to trunk roads could be developed. Including other characteristics that may be available, such as the number of driveways per kilometre or resource road access, may also be useful for estimating local road traffic.

A comprehensive model could also be created by increasing the resolution of trip generating sites. Further disaggregation of socioeconomic data to the household level and create a virtual 'real world' model would serve as the most accurate and versatile method. Rather than assigning traffic to road links based on trips from a single generating site, trip generations could be spread among the road network. While detailed models like this exist, they are typically fairly difficult to develop. The use of GIS and land-use information from remote sensing data could play a significant role in developing detailed models quickly and effectively.

5.3 – Concluding Remarks

This study investigated the feasibility of using travel demand modeling to estimate traffic volumes on low-class/low-volume roads. The literature identified low-class/low-volume roads as representing a large portion of the road network. The long-term potential savings of including these roads into provincial or state asset management programs is significant. In order to effectively manage these additional roads, additional data, such as traffic volumes, are needed. This study has outlined a method to estimate traffic on low-class/low-volume roads that can be implemented over a province-wide area. It is hoped that this study will prove useful to highway agencies in providing a method to access a wealth of new information that could aid in the decision-making process.

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Appendix A – Responses to Survey

E-mail communications to the author used in the literature review.

Received: Tue, 20 Feb 2007
Subject: FW: Asset management and low-class roads

Hello Brody,

Alberta Infrastructure and Transportation has jurisdiction over about 30,000 kilometres of numbered highways. All of these highways are inventoried, have their traffic monitored, and are subject to ongoing preventative maintenance programs.

Non numbered highways or local roads are generally the responsibility of the local municipality in Alberta. These municipalities such as counties would be responsible for this work.

There are a few exceptions as the province does help in the case of local roads that go through Metis Settlements for example.But these are done on an ad hoc basis so no systematic scheduling of maintenance or priorities are done.

I trust that this helps with your thesis on the estimation of traffic volumes on low-class roads at a statewide level.

Sincerely,
Peter Kilburn, P.Eng.,M.Sc.E.
Traffic Data and Forecasting Engineer
Alberta Infrastructure & Transportation
peter.kilburn@gov.ab.ca
(780) 415-1359

Received: Tue, 20 Feb 2007
Subject: RE: Traffic Data Website Feedback

Hello,

Here in BC, for roadway maintenance purposes, we classify our highways by traffic volumes as follows:

Summer Classification:
Class 1 - >10,000 ADT
Class 2 - >5,000 to 10,000
Class 3 - >1,000 to 5,000
Class 4 - >500 to 1,000
Class 5 - >100 to 500
Class 6 - >10 to 100
Class 7 - >0 to 10
Class 8 - Unconstructed R/W - no vehicle traffic.

Winter Classification:
Class A - > 5,000 WADT or commutor routes; certain freeways and expressways with>2,500 WADT, ski hill routes etc.
Class B - > All trunk & main routes/portions thereof not in class A, with a cut-off traffic volume of >1,000 WADT
Class C - School bus routes and industrial traffic routes (>25% trucks) not included in class A or B.
Class D - All other regularly maintained winter routes.
Class E - All other irregularly maintained winter routes.
Class F - Not maintained in winter..

Our maintenance services are provided by contractors, who must maintain the highways to the standard prescribed in our Road and Bridge Maintenance Contracts, (R&B Contracts) for a highway of that classification.

We use both permanent traffic count stations on our numbered highways, and portable traffic counting devices on both main highways and lesser routes to determine AADT, SADT and WADT. For our low-volume subdivision streets we estimate their volumes using local knowledge and the number of residences along / serviced by them.

On treated roads, we sometimes will install a counter on a bridge deck or such location to get a count.

In BC, we manage approx 83,400 lane km of highway. ~24,000 lane km are numbered routes, the rest are lesser routes. Approx 1,200 ln km of our numbered routes are seal coat wearing surfaces over gravel grade (Hwys

37 and 77 to the Yukon.)

Overall, our lane km by surface type can be summarized as follows:

lane km	Quick Facts book - October, 2004
35,652	hot mix
4,455	cold mix
149	concrete
40,256	total paved
8,643	treated
48,899	total hard surfaced
32,884	gravel
1,505	dirt
63	other - cleared / uncleared (this number is low)
34,452	total gravel and dirt
83,351	provincial highway system - paved and unpaved
24,569	lane km hard surfaced side roads
42%	of the side road system is hard surfaced
34,389	lane km gravel and dirt surfaced side roads
58%	of the side road system is gravel or dirt

Our R&B Contractors have to maintain the roads to meet contract requirements. While we do have some 'quantified maintenance activities' generally speaking they must do whatever is required to meet the contract requirements and we do not decree what works they must do, or when they must do them, except to define the standards and response times they must meet.

As a Ministry, we undertake the major rehabilitative works required on our highways and bridges ... work that is outside the scope of the R&B Contracts. We prioritize the proposed works and undertake the works that can be undertaken within the funding allotted. We use sophisticated pavement management and bridge management systems to help us manage these assets. Our current goal is to hold the condition of the highway system overall. While we assess the pavement condition of our numbered highways on a scheduled recurring basis, we assess the condition of only a representative same of our lesser roads. With this information we can monitor trends in condition over time at a network level.

In 1994 we developed the 'simple and user friendly' - 'District Road Upgrading Warrants System' which can be used to determine the relative ranking of one 'minor' highway improvement project as compared to another. This system takes into consideration the cost of the anticipated works; the service life expectancy of the improvement; the traffic volumes and mix of truck traffic being served by the improvement; the anticipated change in time saved/lost by motorists if we undertake the improvement; the potential reduction in accidents (various costs are assigned to fatals, injury and property damage accidents) and any changes in anticipated maintenance costs over status quo are considered. All this works out to a benefit / cost ratio with the projects getting the highest benefit for cost ratio being considered first, assuming all other factors (asset mgt, political considerations etc.) are equal. I can fax you a copy of our manual for this if you like... just send me your fax number... I'd attach it, but unfortunately it is not available in electronic format.

Brian Barker
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Received: Mon, 12 Mar 2007
Subject: TR: Asset management and low-class roads

Dear Mr. Hanson,

The Quebec Ministry of Transportation has a Pavement Management system provided by the US firm Agile Assets (http://www.agileassets.com/) in order to manage all roads under his responsibilities. The responsibility of the major part of our low-class roads has been transferred to the cities during the MTQ's reorganization period in 1993. MTQ has about 29000km of roads under his responsibility and our two lowest classes' roads are called "collectrice" which is 7000km long and the "Accès aux resources" which is about 1500km long. We need to compare the definition of your low-class roads with our class of roads in order to be able to well compare these classes. Our "collectrice" roads are all paved roads (numbered) and the major parts of our "Accès aux resources" roads are unpaved and non-numbered.

The Quebec preventive maintenance program for paved roads is made up of using 5% of the total budget (investment) in a preventive way (all kind of preventive maintenance such as thin overlay, crack sealing etc...). The preventive sections are selected by the regional managers with our PMS. The system can select the sections according to the road characteristics (cracks type severity and extent, IRI and rut depth and type, pavement age). The prioritization process can be made by running 3 different types of scenarios according to the management needs (condition based scenarios, quality expected with budget restriction and benefit cost ratio) and other regional constraint's.

We do not have official and nationwide preventive maintenance program for unpaved roads. Each territorial area has the responsibility to manage their own network. However, we are planning to manage these unpaved roads with our PMS soon.

Feel free to contact me if you need more information,

Sincerely,
Mathieu Grondin
Chief – Road survey and pavement management division
Quebec Ministry of Transportation

Received: Thu, 18 Jan 2007
Subject: Re: Statewide TDM

Hi Brody,

Our urban models generally contain any road that is classified as a collector and above. We occasionally include local roads if they are needed for connectivity in the network, but the vast majority are not included.

Karen Faussett
Transportation Planner
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faussettk@michigan.gov

Received: Mon, 5 Feb 2007
Subject: RE: Provincial Road Network GIS

Hi Brody,

Sorry for the delay. We will try to provide some information to you in the near future. In the meantime I have listed some Kms by classification for surface treated highways in the province. Please note that these are approximate.

Arterials	Rtes 1-95	2,100 km
Collectors	Rtes 100-190	3,000 km
Numbered Locals	Rtes >200	3,000 km
Named Locals		6,700 km
Total of surface treated roads		14,800km

Jay Cunningham
Assistant Director
Planning and Land Management Branch
NBDOT

Appendix B – Provincial Road Network Hardcopy Map

See attached hardcopy of provincial road map with traffic counts.

Appendix C – Estimated Traffic Volumes

Table of estimated traffic volumes for each road segment (sample from York County).

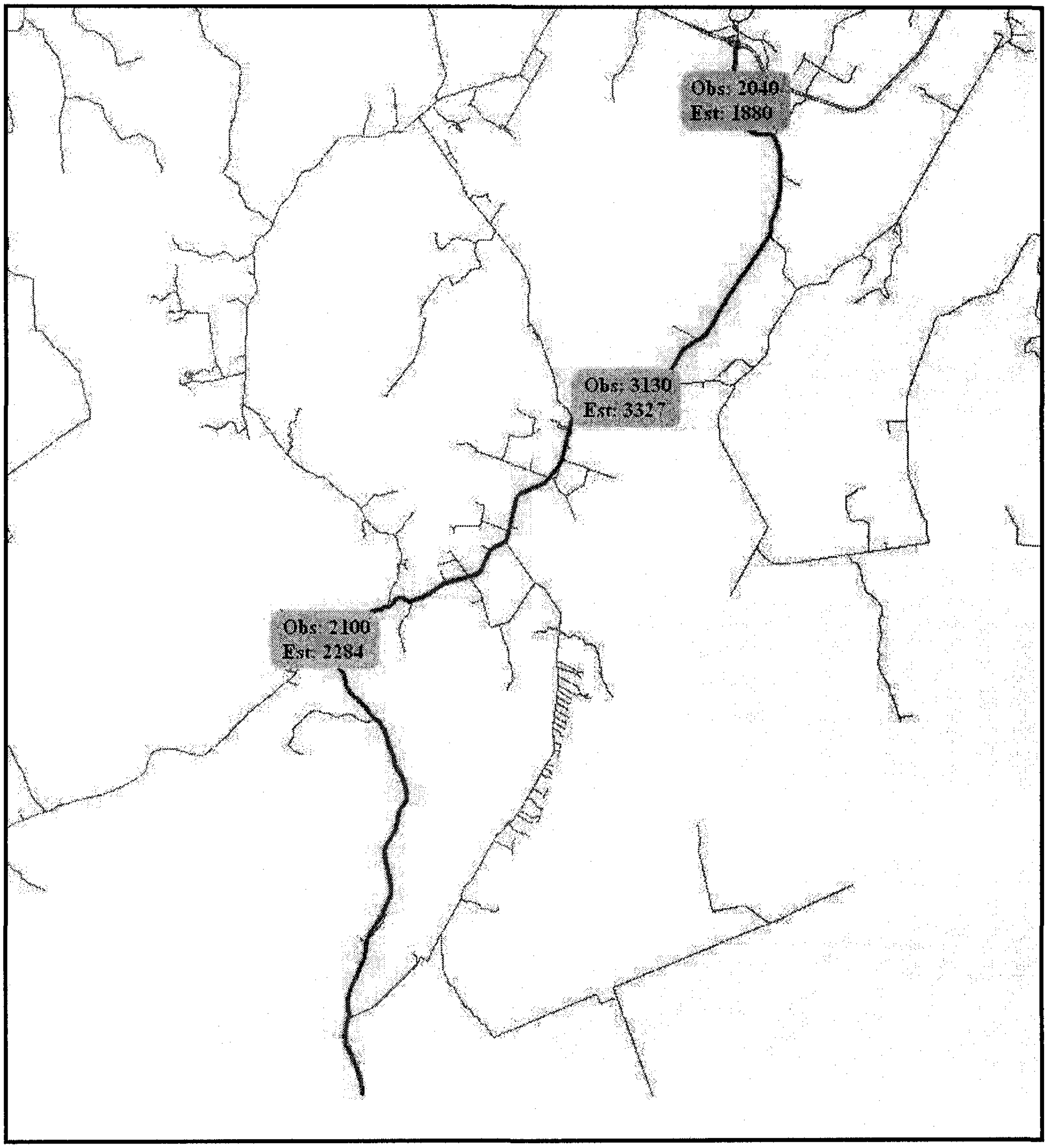
ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow
1	2911	518	0	1227	0	1798	2788	2490	4401	3049	0	3701	3984
2	0	520	2788	1231	32	1821	18517	2501	328	3057	11366	3710	0
3	0	534	0	1245	2672	1841	0	2502	328	3058	0	3713	2055
17	3102	546	133	1250	0	1844	19002	2509	1129	3071	0	3726	5392
20	280	547	3674	1265	87	1884	0	2511	3841	3075	0	3729	0
35	0	554	1106	1276	3575	1886	0	2521	440	3089	11713	3744	622
46	0	560	0	1289	4092	1887	607	2528	440	3091	0	3750	0
47	5800	562	0	1290	280	1895	0	2529	440	3102	995	3756	6316
89	0	565	3415	1296	8831	1899	3398	2532	5745	3109	0	3764	1528
93	0	566	0	1324	0	1903	4	2547	13277	3110	0	3769	29663
96	0	578	0	1329	6042	1914	2314	2548	10870	3111	473	3779	2526
99	0	581	1391	1336	0	1921	0	2554	0	3127	1427	3788	294
112	0	605	0	1343	7703	1924	2404	2555	8384	3135	0	3806	0
116	0	635	6724	1344	0	1930	0	2556	440	3137	0	3807	0
135	0	636	1223	1360	2875	1934	6042	2565	7535	3138	0	3808	0
137	0	641	0	1361	2875	1938	1725	2566	0	3189	3287	3825	2906
140	592	645	791	1363	0	1939	2262	2569	5227	3194	28328	3826	0
158	0	653	66	1368	0	1940	1532	2571	1821	3196	0	3827	2820
189	0	654	0	1369	0	1949	0	2583	3961	3201	45	3828	2820
192	0	655	0	1371	1341	1961	4591	2597	3941	3208	0	3857	0
194	0	659	0	1379	0	1967	0	2600	0	3209	10470	3858	6061
202	0	660	275	1381	1240	1968	17776	2605	17841	3218	0	3864	27002
207	0	661	275	1383	0	1971	18712	2606	17841	3225	0	3867	60
219	607	676	0	1384	4308	1974	0	2609	923	3234	0	3872	1700
220	607	688	5331	1386	0	1980	4886	2614	2160	3293	5647	3874	183
225	0	689	5331	1388	0	1989	0	2616	2160	3297	0	3877	0
226	0	698	0	1402	0	2027	0	2619	0	3299	913	3879	9635
230	0	701	7326	1414	0	2032	0	2623	0	3307	0	3890	351
239	0	706	0	1421	0	2037	0	2624	0	3334	0	3896	0
245	0	715	0	1425	0	2042	1713	2630	3081	3336	0	3901	0
259	0	727	15122	1426	1350	2058	1225	2635	0	3341	0	3918	0
265	100	730	0	1469	0	2062	4431	2636	5445	3342	0	3923	0
267	1574	739	0	1478	0	2064	0	2648	1148	3356	0	3925	0
270	0	740	0	1500	5199	2075	151	2652	14792	3373	4539	3934	16705
271	0	748	0	1504	1779	2078	5249	2660	0	3376	1656	3943	687
272	0	749	1826	1505	3345	2085	1305	2695	0	3398	343	3944	0
288	82	757	11451	1523	4697	2086	0	2712	2271	3402	15534	3948	0
293	2153	769	947	1527	0	2089	0	2713	2271	3404	4146	3952	0
297	0	788	3841	1535	0	2117	0	2715	1679	3405	372	3958	3712
300	0	802	3405	1537	0	2119	100	2720	5977	3410	0	3963	2331
306	0	819	16314	1539	10222	2123	11795	2726	0	3411	0	3967	0
312	0	889	10565	1544	0	2125	0	2734	3044	3420	5764	3968	106
315	0	915	13313	1550	0	2136	305	2742	5977	3451	8178	3972	799
319	0	942	0	1567	0	2172	9196	2751	2618	3461	0	3982	0
339	257	960	3352	1571	0	2173	0	2755	1003	3474	0	3983	3927
340	0	962	6642	1574	4507	2190	0	2757	3178	3481	0	3985	4871
342	845	964	8794	1578	0	2207	145	2787	0	3486	9260	4005	9108
350	0	982	0	1585	0	2222	3793	2796	5344	3490	202	4017	103

ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow
4298	3681	5075	0	5844	3867	6581	0	7298	0	8045	0
4304	13454	5088	1252	5861	3679	6584	0	7302	1469	8046	1247
4309	11	5089	0	5888	0	6599	256	7327	2437	8055	0
4315	1547	5091	189	5892	712	6612	764	7330	1255	8058	2119
4337	0	5110	0	5896	2440	6614	7997	7333	0	8060	639
4340	2389	5114	0	5903	0	6626	0	7348	122	8067	1446
4353	760	5124	0	5913	0	6658	750	7349	0	8078	5834
4356	3748	5125	5382	5940	13872	6670	0	7357	0	8082	0
4359	730	5133	658	5949	0	6672	0	7365	0	8084	545
4367	0	5135	0	5950	0	6677	0	7369	0	8119	0
4376	0	5181	6011	5962	0	6685	71	7375	0	8121	106
4383	0	5185	0	5966	913	6697	0	7377	4536	8129	0
4388	0	5199	1583	5969	1892	6698	1680	7383	245	8153	309
4389	6211	5205	5135	5971	2882	6717	557	7388	12701	8162	4720
4391	752	5206	935	5975	71	6718	557	7393	5286	8172	1609
4405	2160	5217	5281	5976	24105	6733	0	7397	2149	8173	0
4408	8513	5227	5060	5977	0	6735	1276	7398	0	8188	0
4422	0	5232	2351	6005	11669	6744	0	7416	0	8202	0
4423	0	5235	0	6029	0	6745	2878	7418	8507	8205	3315
4441	3766	5238	2243	6051	4578	6756	0	7425	14530	8229	4350
4442	0	5256	0	6052	8506	6765	1577	7438	9635	8231	0
4458	17460	5263	0	6062	0	6783	0	7445	6642	8232	238
4461	0	5270	3857	6066	0	6785	0	7459	0	8259	100
4478	0	5271	13300	6067	5154	6815	1720	7475	6470	8285	319
4493	329	5278	889	6069	3467	6818	12199	7480	4025	8299	1302
4494	228	5279	0	6070	3467	6824	0	7517	0	8305	1239
4516	4136	5293	0	6075	0	6825	527	7519	0	8316	0
4522	0	5298	5632	6076	8997	6835	0	7533	0	8318	3891
4532	0	5307	1346	6079	1043	6836	0	7550	0	8326	2201
4533	0	5314	7292	6104	3669	6837	0	7552	13749	8332	1041
4543	1390	5330	3857	6112	1835	6842	902	7553	13749	8348	0
4549	15079	5337	8565	6113	1835	6843	902	7582	0	8355	0
4556	0	5338	6278	6114	1835	6844	902	7583	0	8356	0
4565	3265	5344	0	6120	5632	6851	3741	7584	0	8391	1984
4567	28328	5360	0	6125	1314	6855	0	7591	1572	8413	0
4590	406	5367	0	6154	12748	6860	226	7593	0	8417	0
4595	0	5380	6011	6167	0	6868	1252	7603	0	8418	0
4601	3205	5382	1774	6174	0	6876	0	7605	1392	8426	423
4609	0	5386	71	6192	0	6894	0	7618	0	8428	1385
4627	12141	5395	1823	6195	8341	6935	6316	7619	0	8432	0
4645	0	5426	155	6216	488	6936	0	7627	552	8435	902
4665	0	5428	0	6229	0	6937	3467	7633	1902	8464	4392
4668	1170	5434	910	6233	284	6938	0	7645	3520	8469	0
4678	786	5436	347	6262	0	6954	0	7654	0	8479	0
4685	7515	5467	0	6270	0	6966	1496	7659	6042	8480	0
4696	0	5470	9762	6288	2001	6976	2306	7668	17466	8492	0
4748	0	5474	0	6289	2160	6986	15706	7688	0	8498	7614
4752	0	5481	626	6304	0	6988	0	7710	1751	8502	23445
4757	4662	5483	0	6323	0	6999	0	7711	0	8562	764
4793	6093	5511	3881	6326	0	7024	0	7724	0	8563	764
4797	0	5519	15122	6327	0	7038	3709	7734	0	8564	764
4808	0	5525	3520	6333	5812	7040	0	7737	15	8574	33
4809	89	5526	3190	6341	0	7062	1725	7745	0	8582	0
4828	115	5529	2974	6349	764	7073	5811	7747	2	8607	2
4830	1427	5531	0	6381	764	7085	1566	7754	2065	8608	2

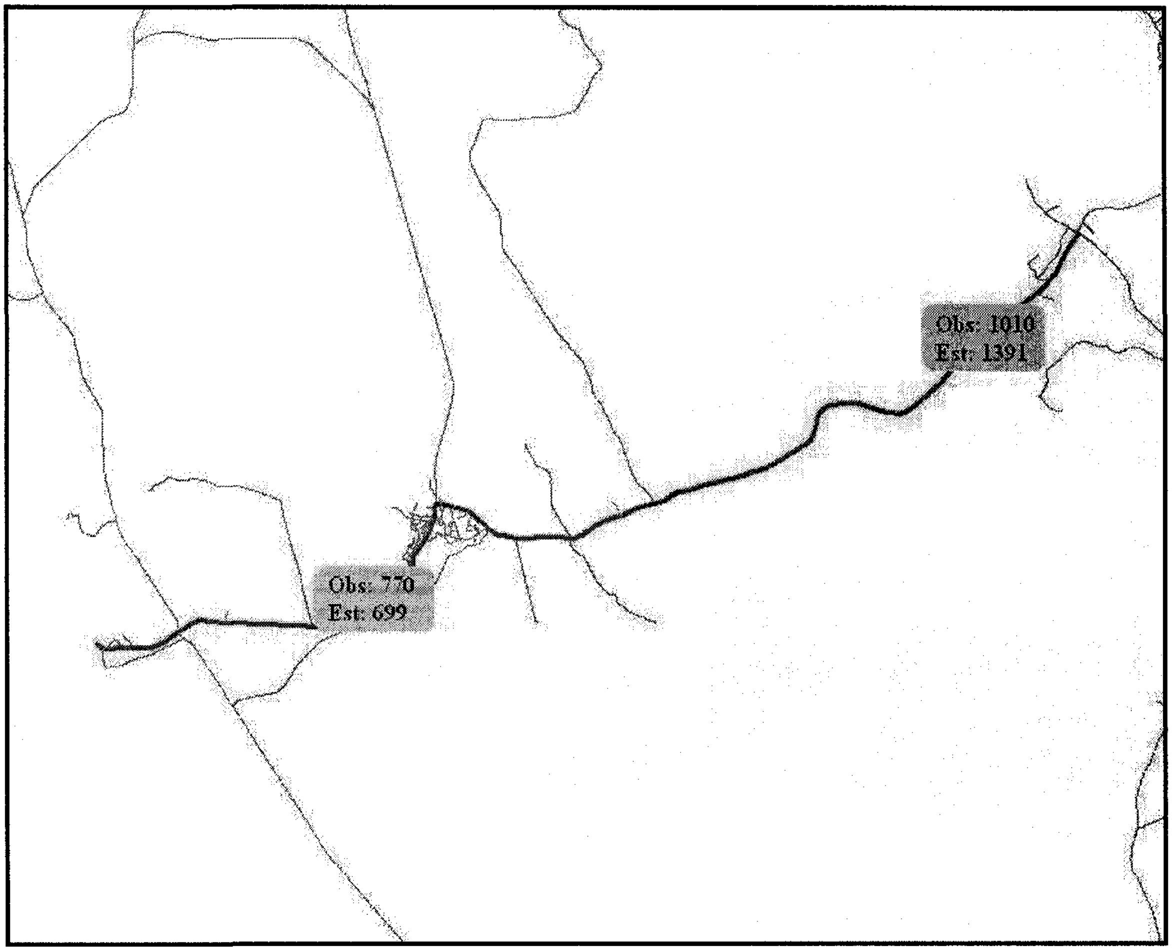
ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow	ID	Flow
12168	42	12972	4912	13612	41713	14429	8251	15276	0	15840	7871
12172	0	12975	0	13619	0	14436	6784	15285	0	15870	20388
12173	0	12988	0	13635	0	14438	0	15290	3720	15879	0
12178	0	12997	6723	13641	0	14482	0	15292	0	15882	3295
12181	8402	13017	0	13643	2271	14492	628	15305	64	15884	673
12203	2953	13045	0	13659	7531	14497	0	15310	1400	15885	41
12257	0	13047	297	13660	4333	14528	0	15319	601	15897	255
12264	8412	13051	0	13662	1409	14542	3405	15321	5744	15912	910
12282	0	13054	2321	13663	2546	14550	0	15332	14463	15924	2918
12283	238	13057	28	13665	0	14598	3311	15338	14671	15933	3674
12284	2177	13059	0	13666	4265	14599	5281	15344	1069	15937	3613
12291	1528	13060	0	13683	0	14607	70	15347	0	15950	827
12292	183	13084	0	13696	13078	14613	1472	15362	6290	15959	647
12293	0	13100	702	13721	0	14627	0	15368	33878	15960	2530
12294	0	13121	0	13725	13078	14644	1455	15372	7034	15980	0
12303	0	13127	0	13739	1151	14662	2442	15384	0	15992	0
12315	0	13137	1164	13741	0	14667	103	15397	4321	15993	1565
12317	882	13145	7768	13743	5462	14683	57	15406	2562	16018	1345
12325	8770	13167	0	13748	13078	14705	0	15413	1877	16019	8537
12326	0	13174	4228	13759	1572	14706	0	15441	0	16020	8537
12335	0	13179	237	13770	470	14711	0	15445	1176	16032	0
12342	0	13181	235	13771	5870	14715	57	15449	1121	16033	0
12347	16620	13187	134	13776	15022	14723	0	15450	0	16036	0
12349	28	13188	0	13789	0	14727	0	15451	0	16043	290
12382	5076	13189	137	13796	2121	14740	20	15466	1042	16049	66
12390	790	13193	0	13798	399	14745	58	15467	0	16059	0
12393	0	13200	3621	13805	0	14747	0	15473	4805	16062	0
12398	0	13210	5888	13820	0	14751	10158	15478	0	16064	470
12412	0	13216	1679	13831	0	14757	1106	15480	478	16067	0
12414	0	13224	0	13833	11795	14767	1366	15484	0	16068	0
12430	4450	13233	0	13834	0	14804	0	15487	0	16082	6231
12432	4450	13243	815	13844	11795	14807	0	15503	7409	16091	1565
12476	0	13255	11612	13847	1612	14816	0	15509	14294	16094	1961
12477	27	13273	12991	13871	291	14830	1274	15518	0	16103	0
12479	0	13274	12991	13887	0	14841	1255	15522	1252	16117	133
12489	1673	13282	608	13893	0	14843	7967	15535	89	16123	108
12498	0	13289	0	13895	0	14852	45	15537	0	16178	0
12509	252	13310	1297	13896	4496	14859	8980	15538	0	16181	108
12525	0	13311	1297	13909	0	14872	0	15544	0	16194	0
12531	183	13320	4050	13925	1530	14882	3214	15548	1205	16205	0
12547	0	13321	0	13931	0	14902	849	15565	6028	16206	0
12561	1442	13323	0	13941	233	14918	980	15572	0	16207	0
12562	1442	13324	0	13955	0	14919	3190	15578	1545	16233	0
12588	363	13335	0	13960	0	14921	6344	15592	8523	16241	0
12595	3811	13337	291	14002	3310	14945	12141	15600	7510	16244	1730
12597	0	13340	0	14003	1170	14947	1826	15602	5494	16248	0
12602	5946	13357	3080	14022	1899	14957	423	15612	3707	16249	5812
12610	7219	13360	0	14078	0	14979	0	15613	6426	16254	163
12617	3569	13366	0	14088	0	14995	1097	15615	5556	16255	4508
12621	0	13369	1267	14117	0	14997	6994	15621	6921	16256	3470
12638	0	13370	0	14119	5549	14999	3949	15622	0	16261	163
12639	764	13378	1306	14125	0	15003	0	15628	769	16262	163
12641	1122	13383	2669	14197	0	15021	0	15633	2918	16266	598
12644	0	13384	701	14203	0	15032	0	15642	10243	16268	0
12645	0	13399	5720	14217	909	15033	0	15651	3847	16269	0

Appendix D – Detailed Observed Traffic Volumes

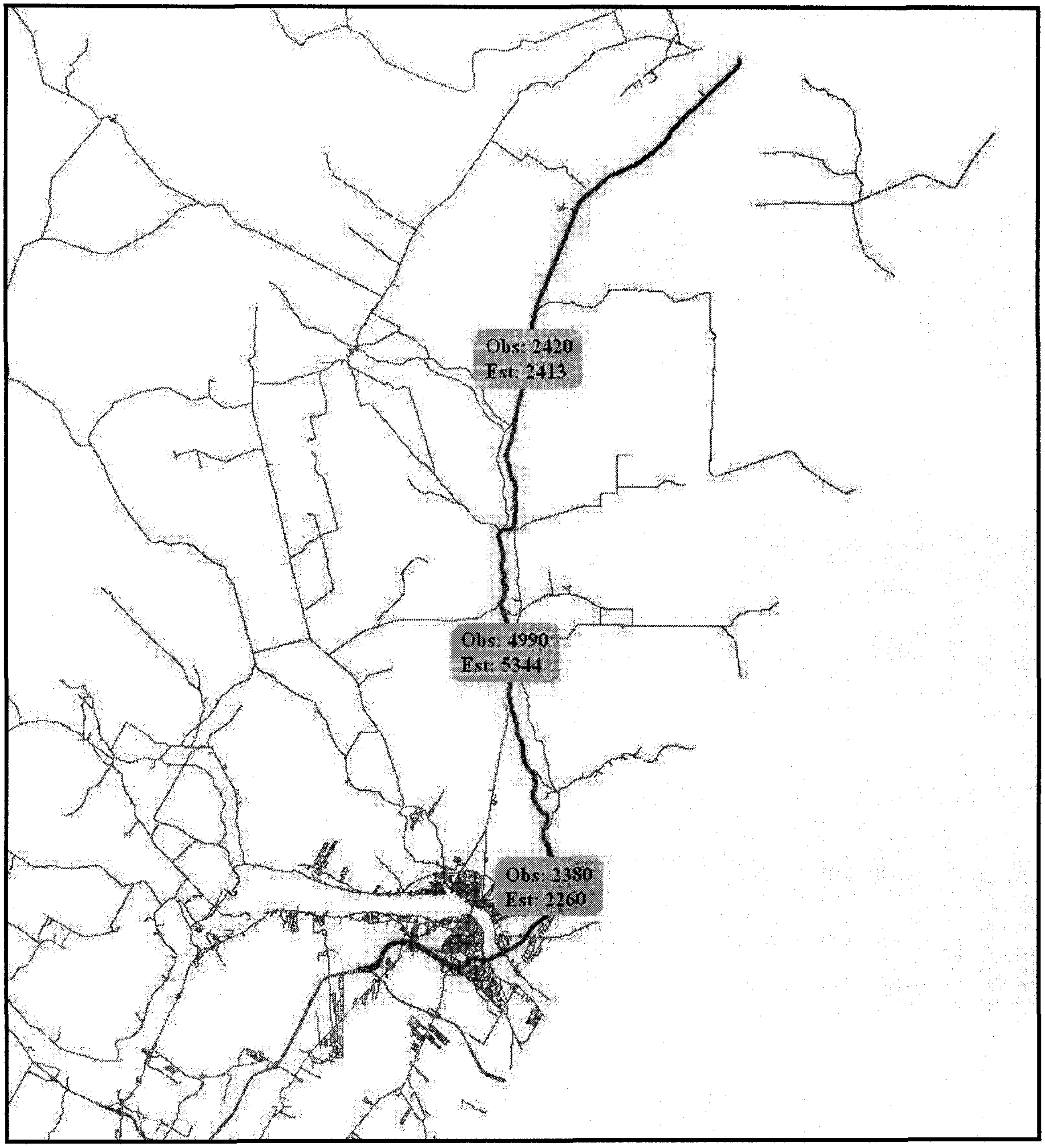
Detailed view of traffic count locations in York County with estimated/observed values.



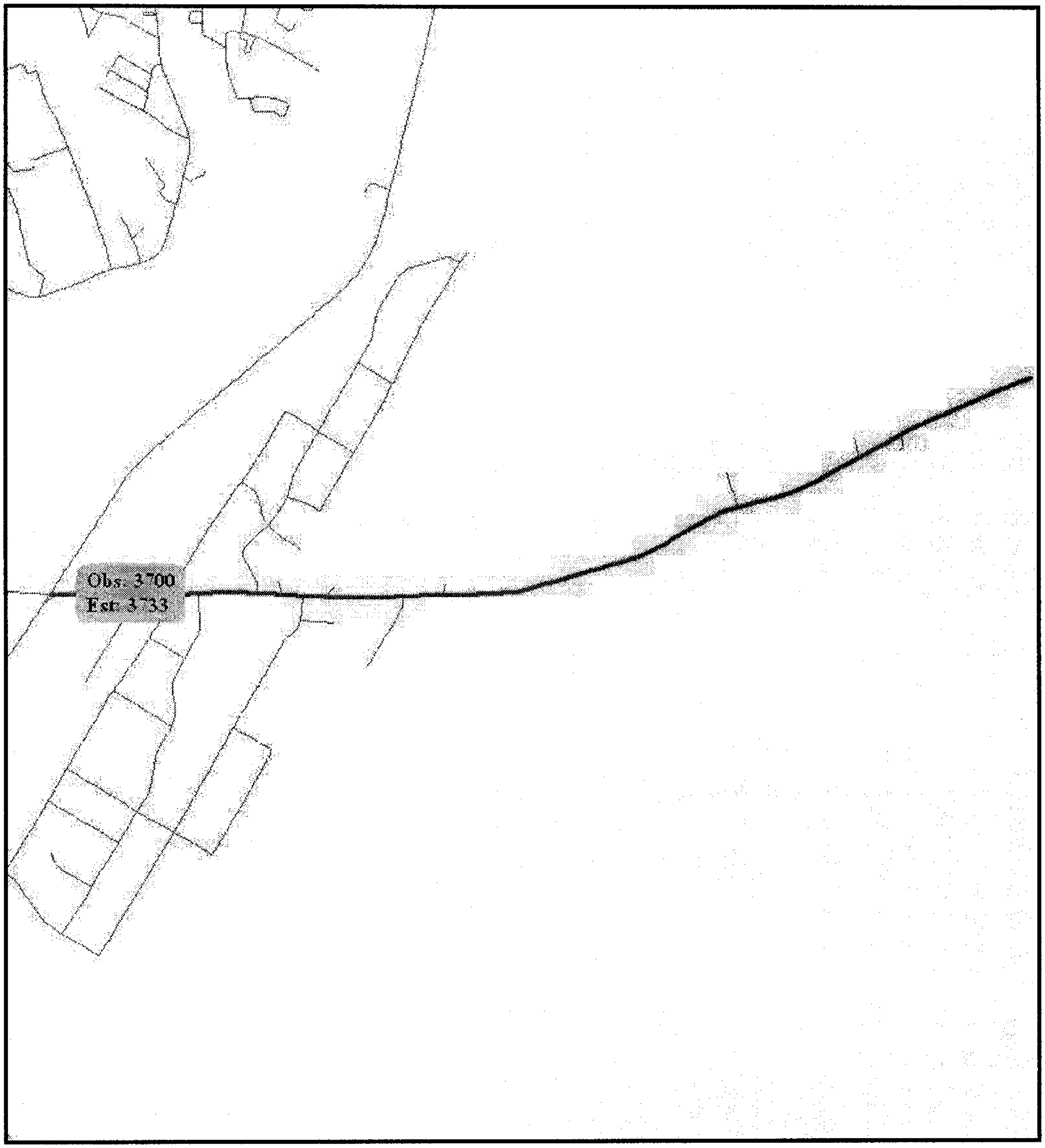
Highway 3



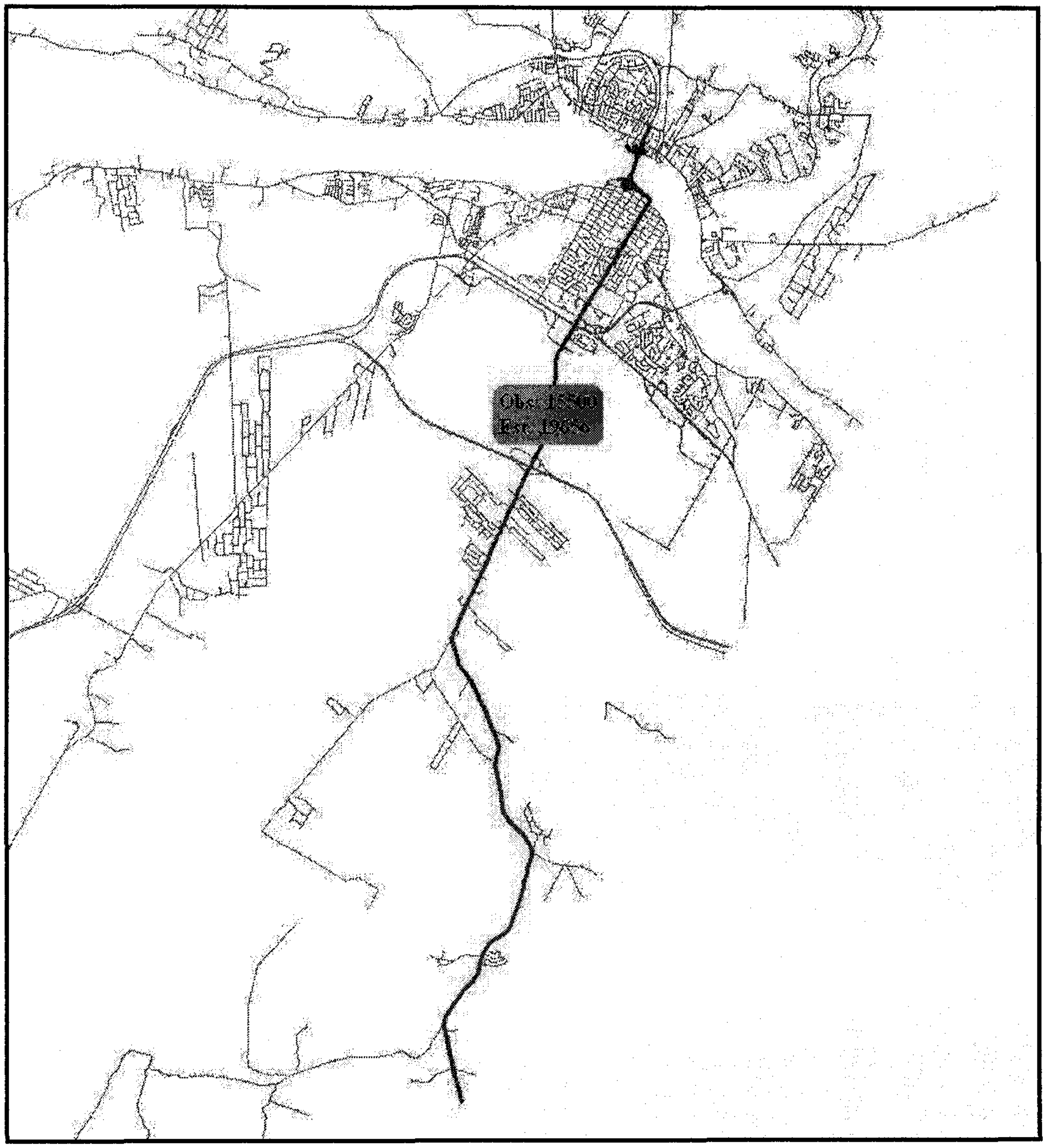
Highway 4



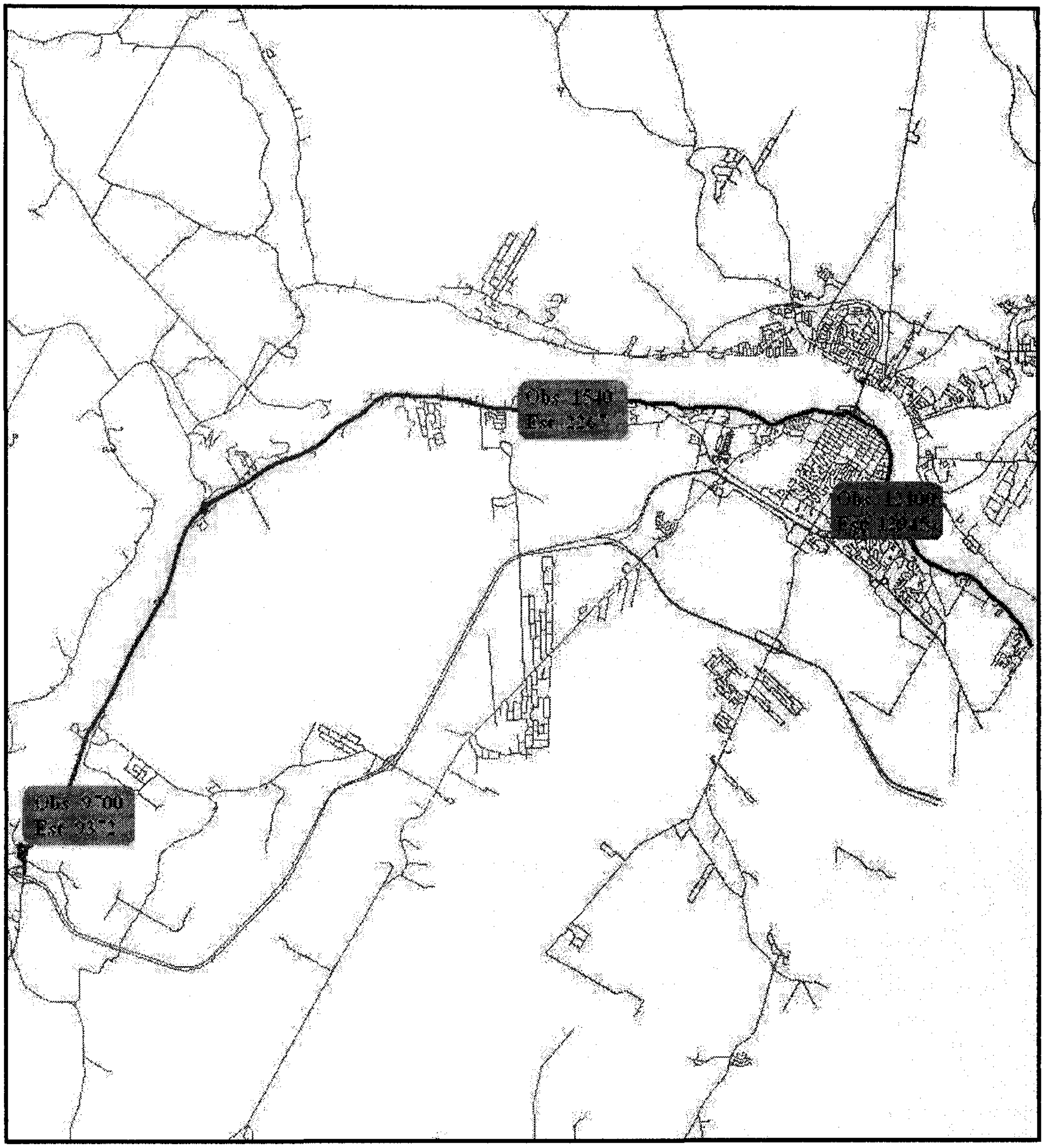
Highway 8



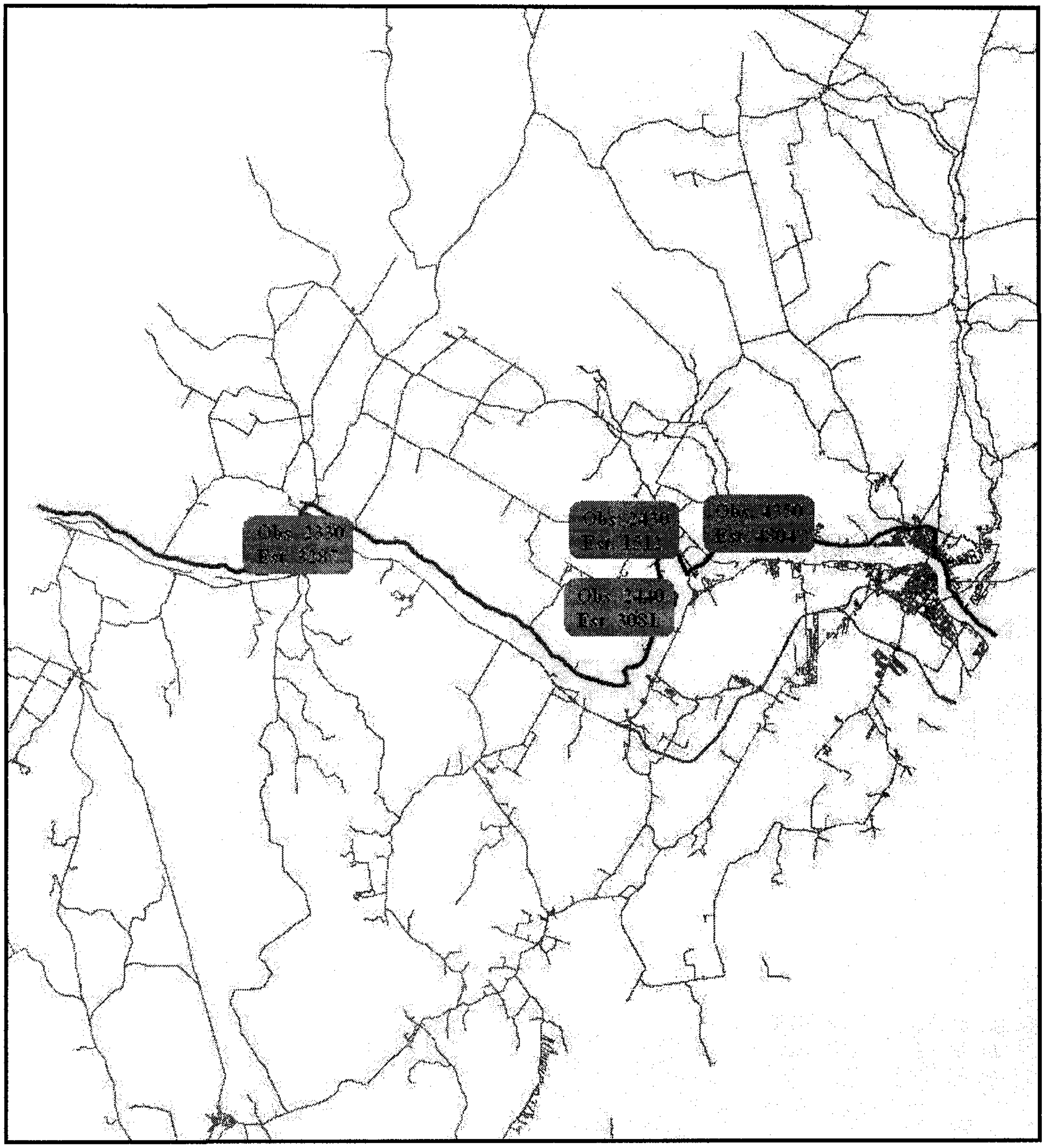
Highway 10



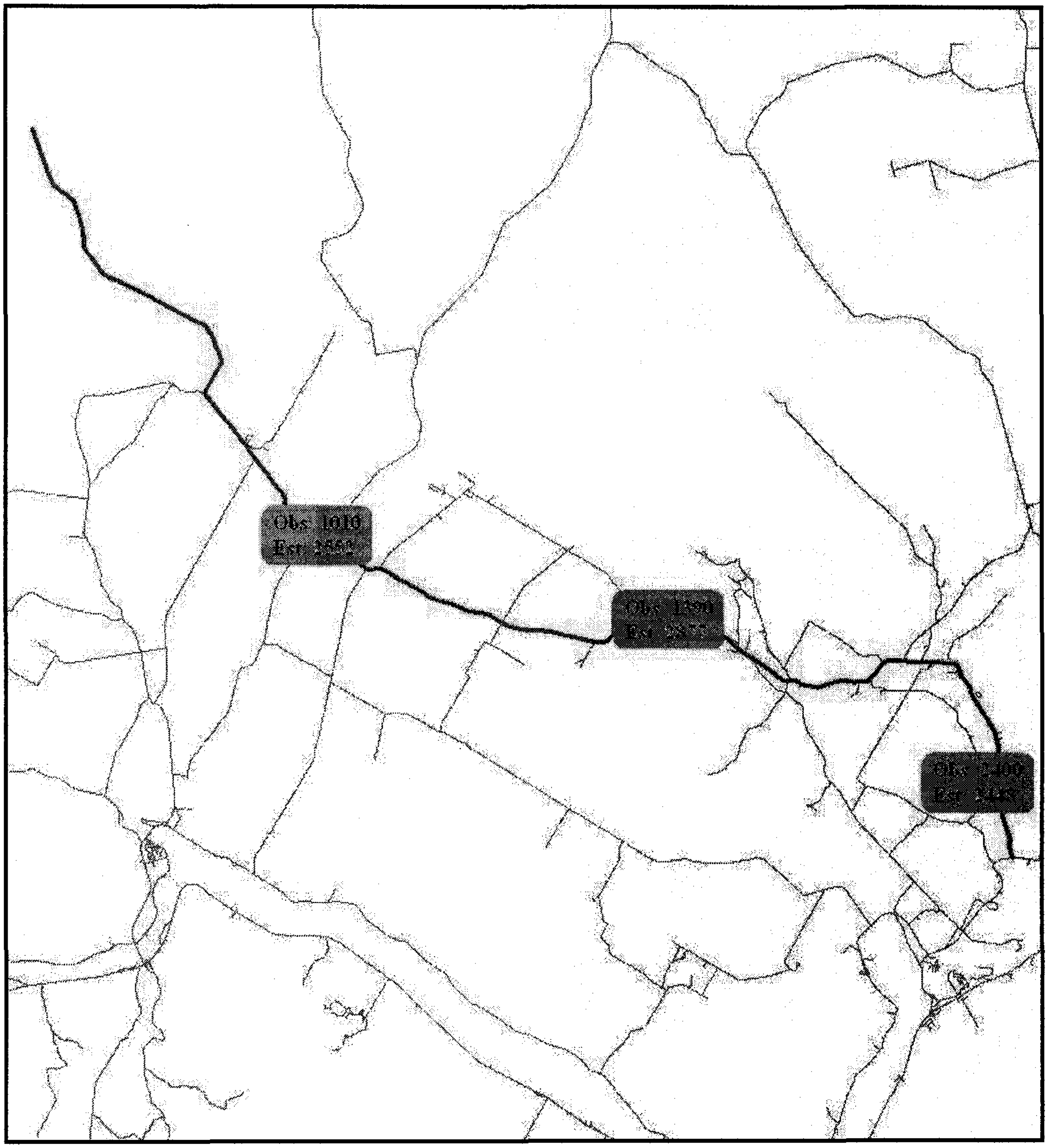
Highway 101



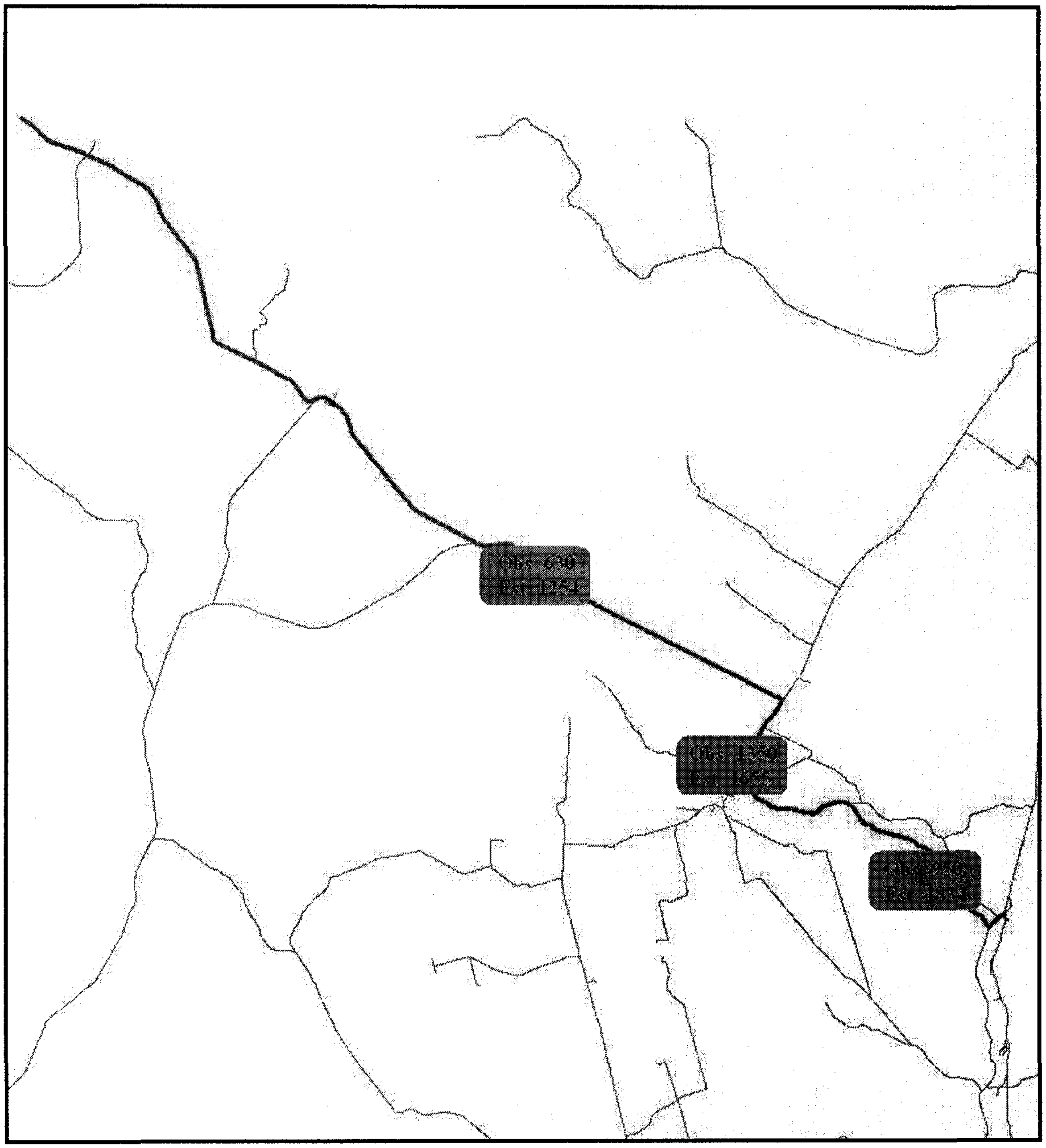
Highway 102



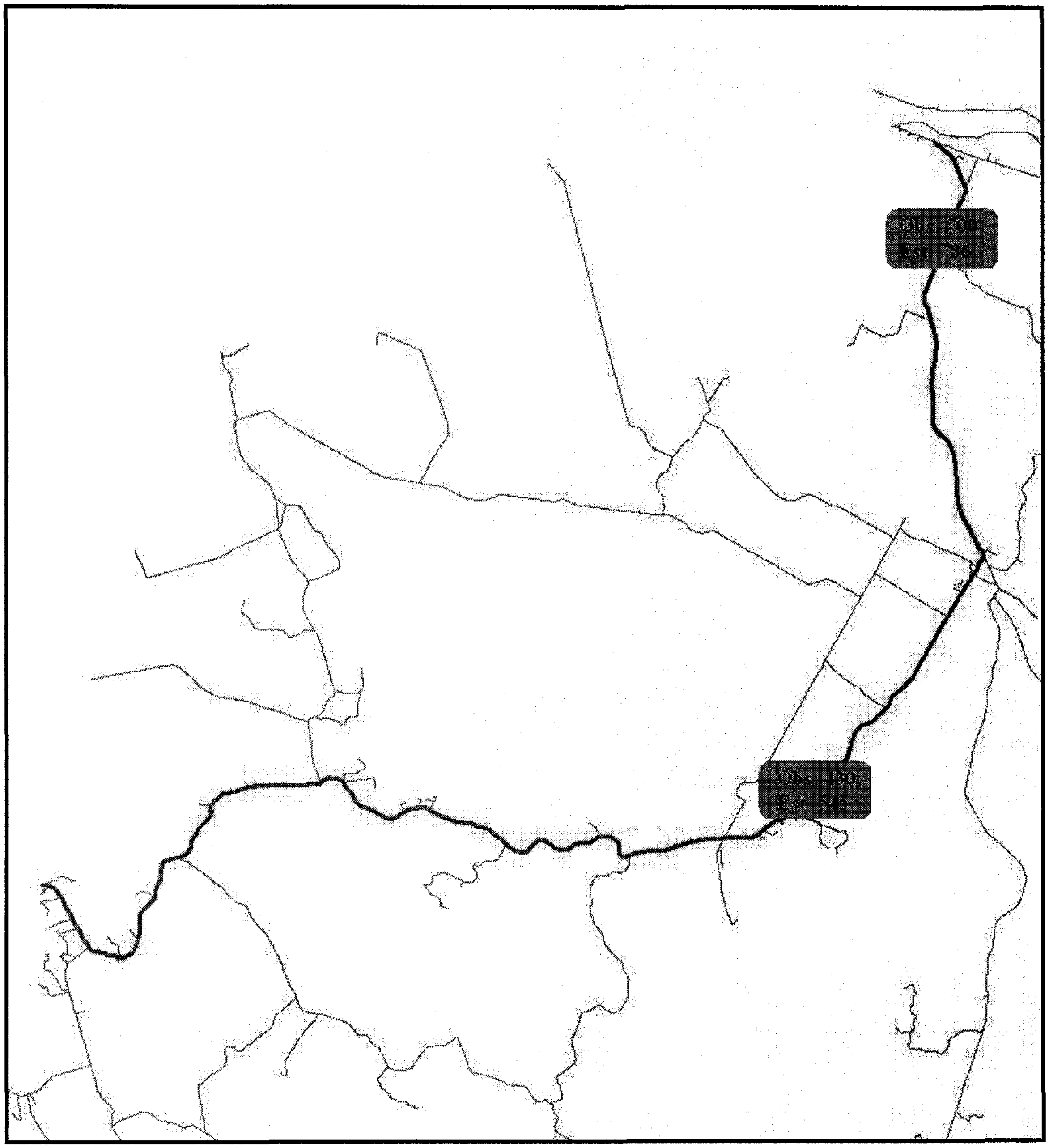
Highway 105



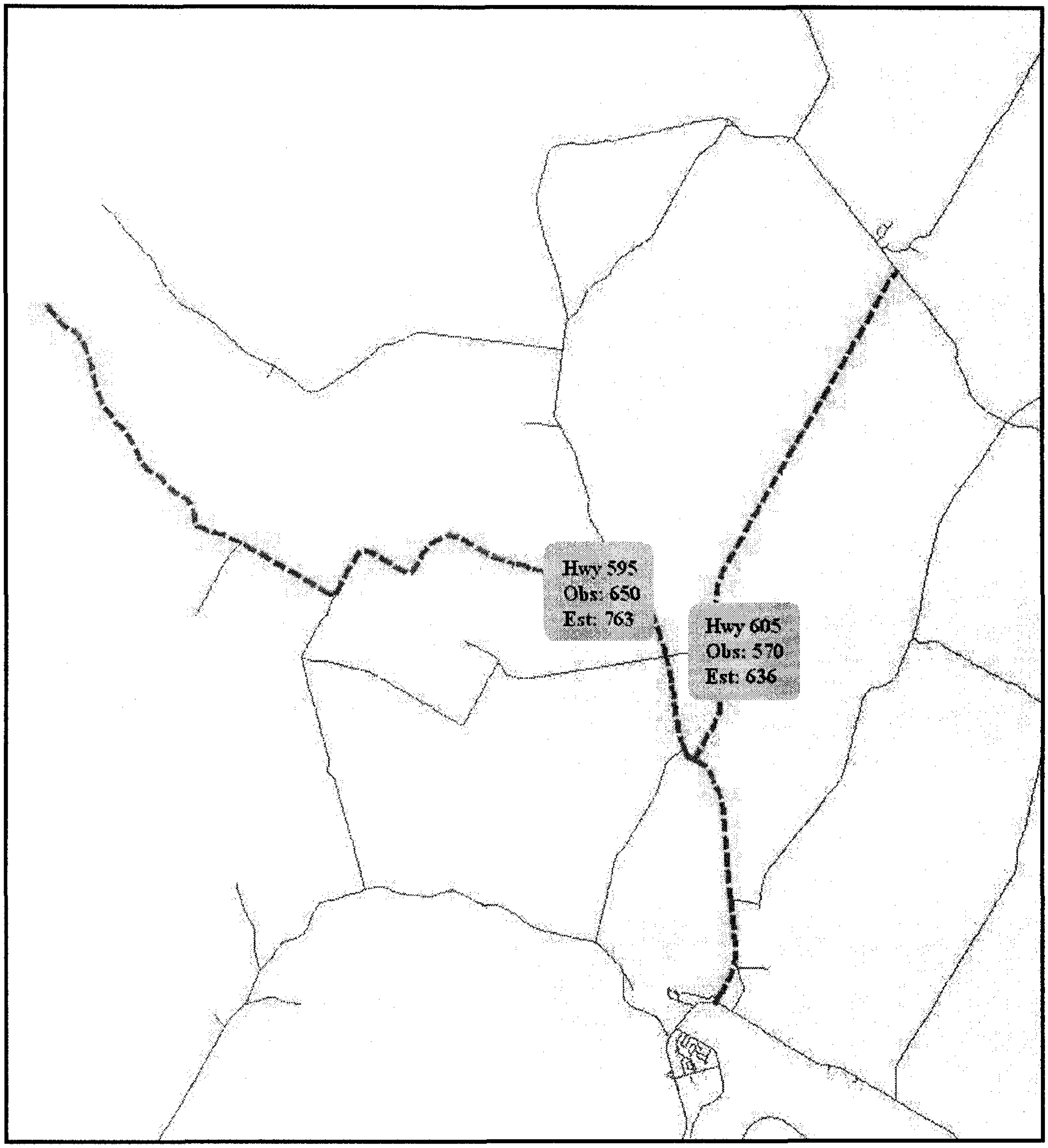
Highway 104



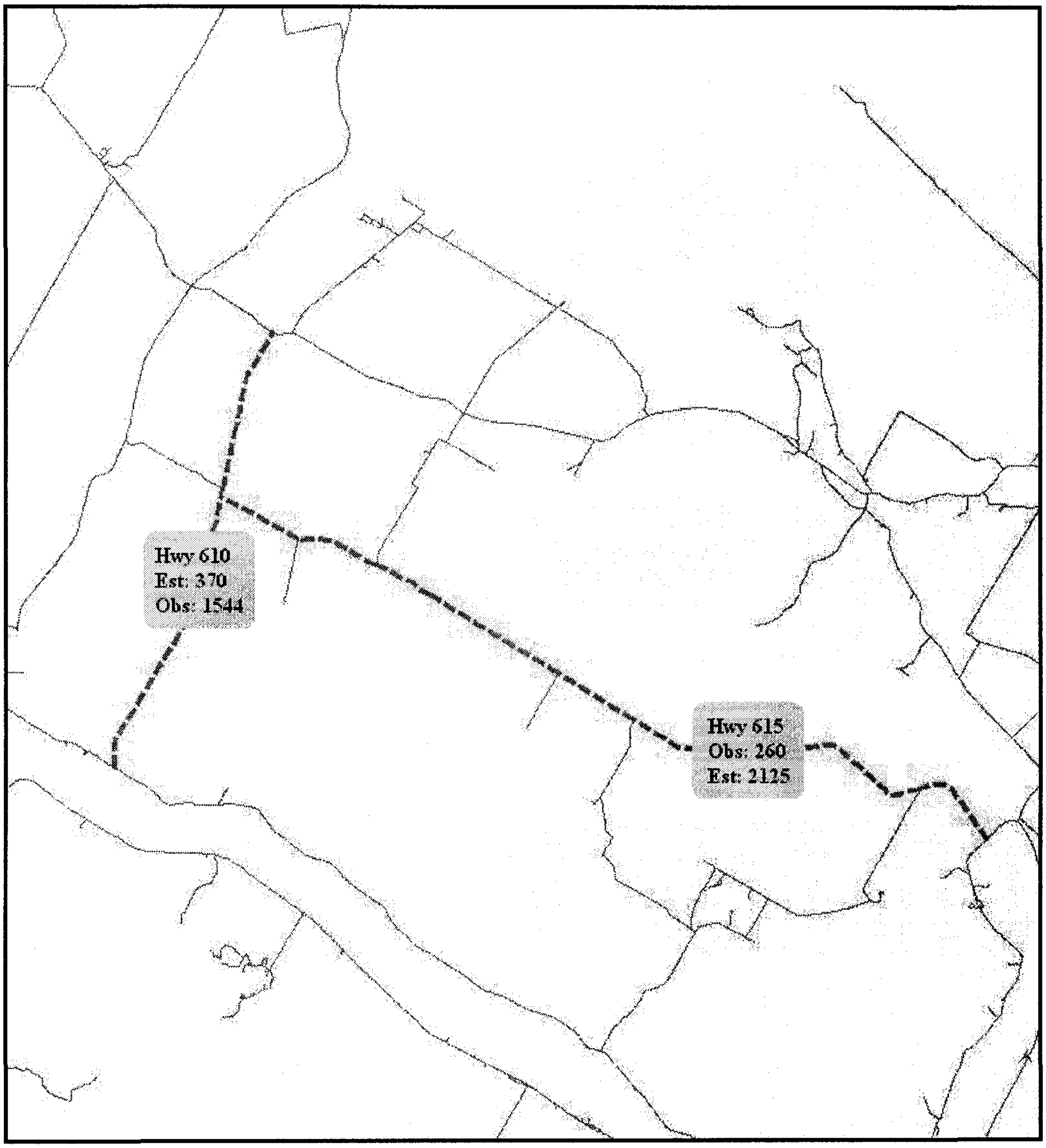
Highway 107



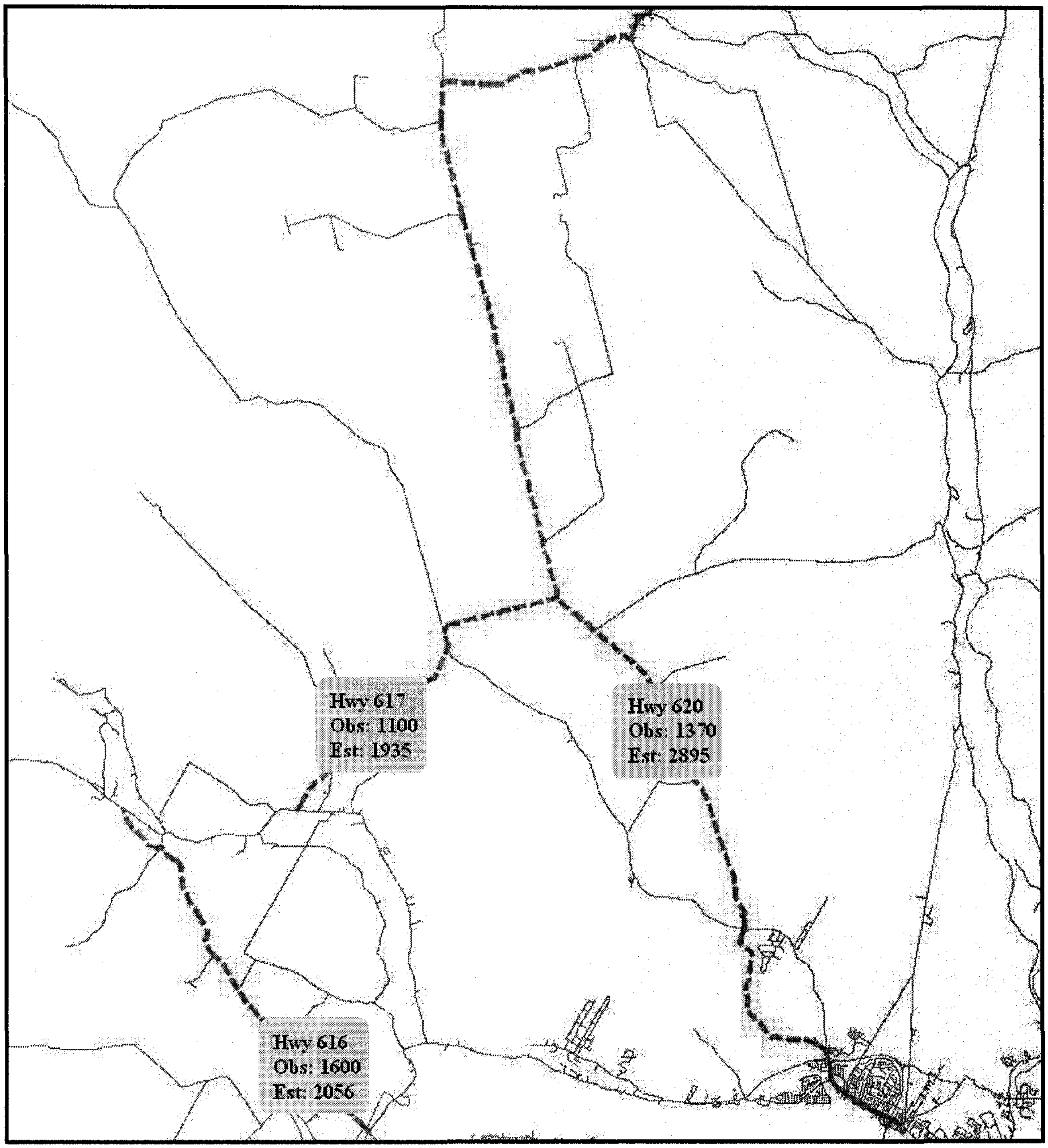
Highway 122



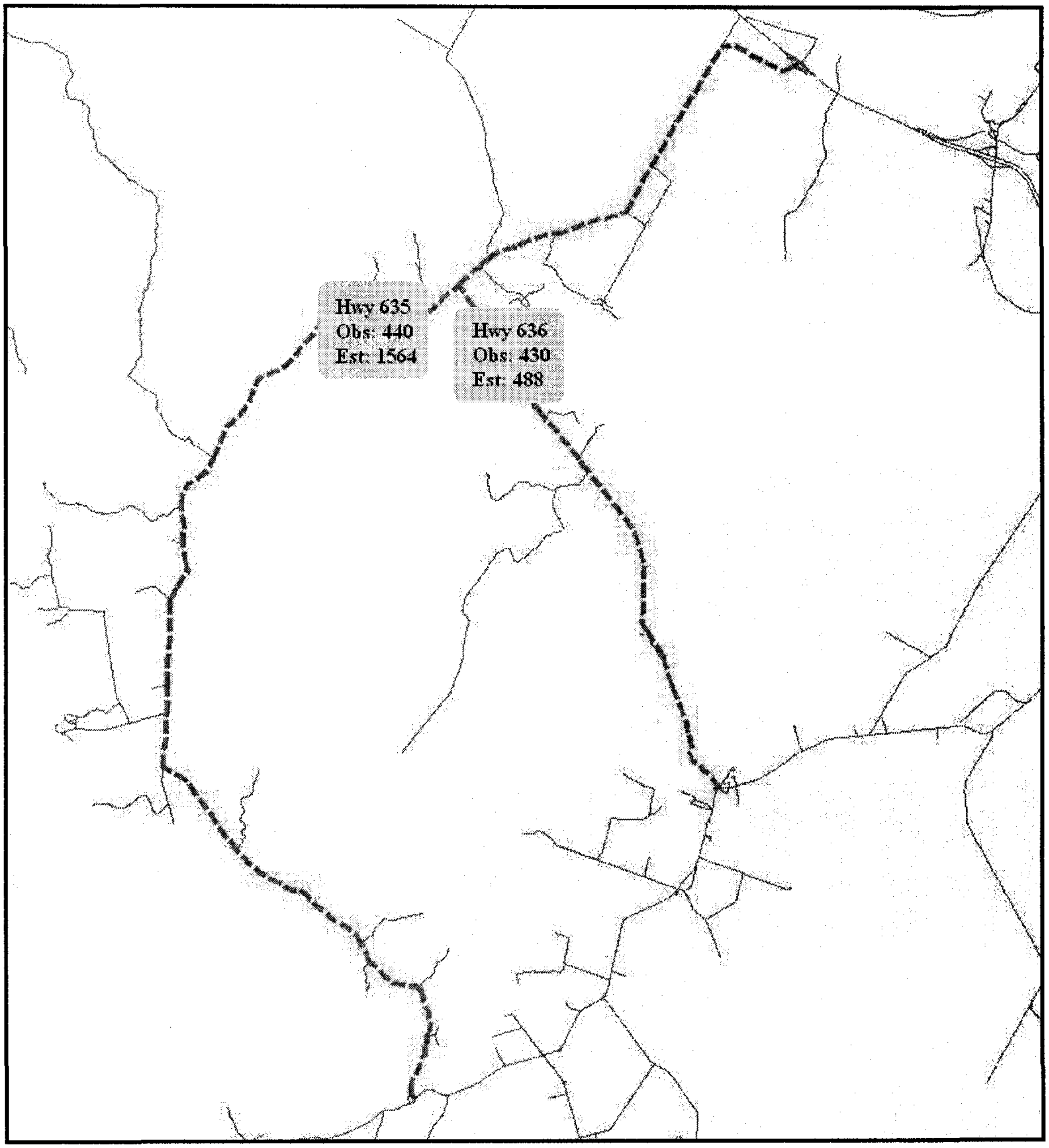
Highway 595 and 605



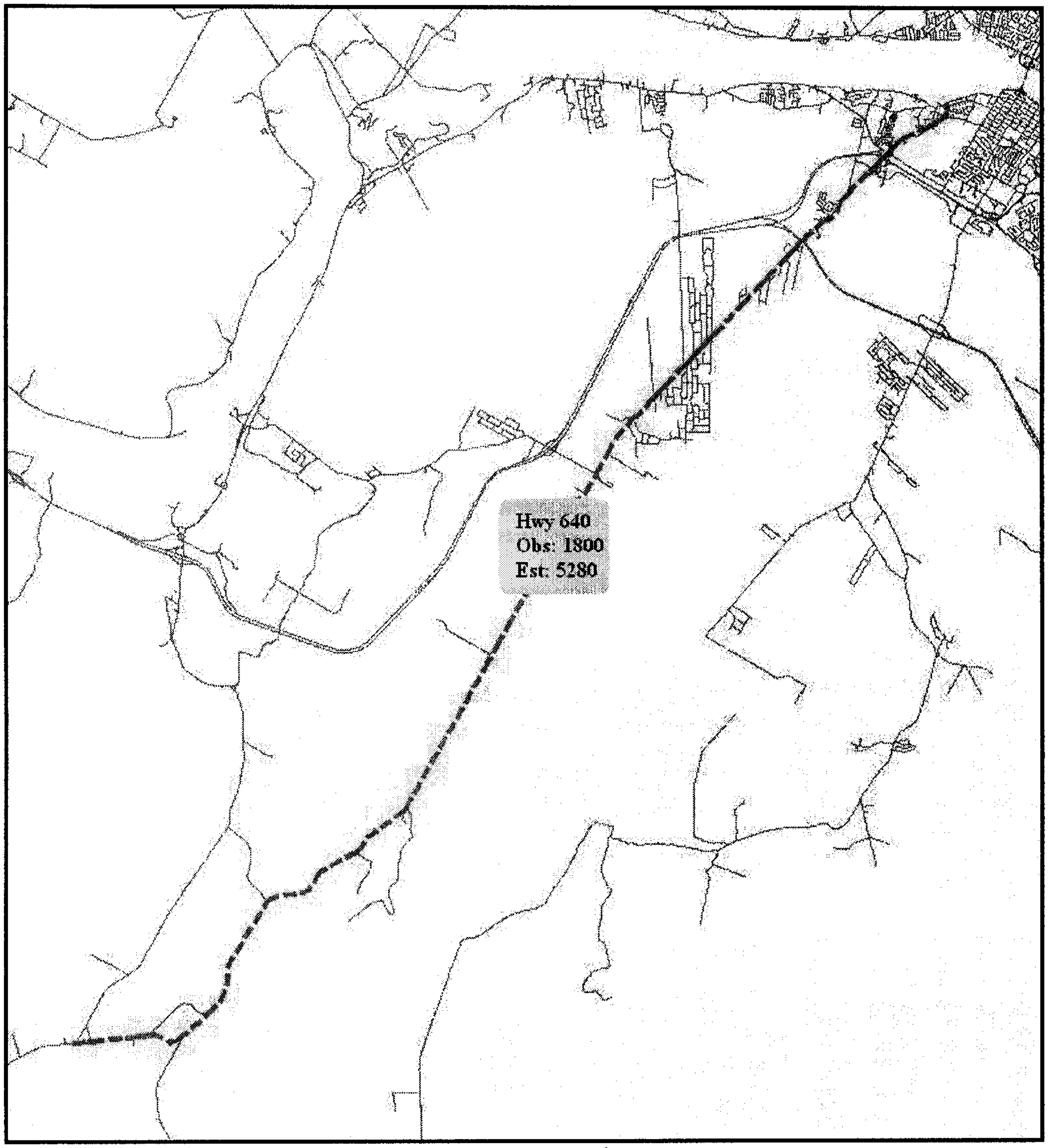
Highway 610 and 615



Highway 616, 617, and 620



Highway 635 and 636



Highway 640

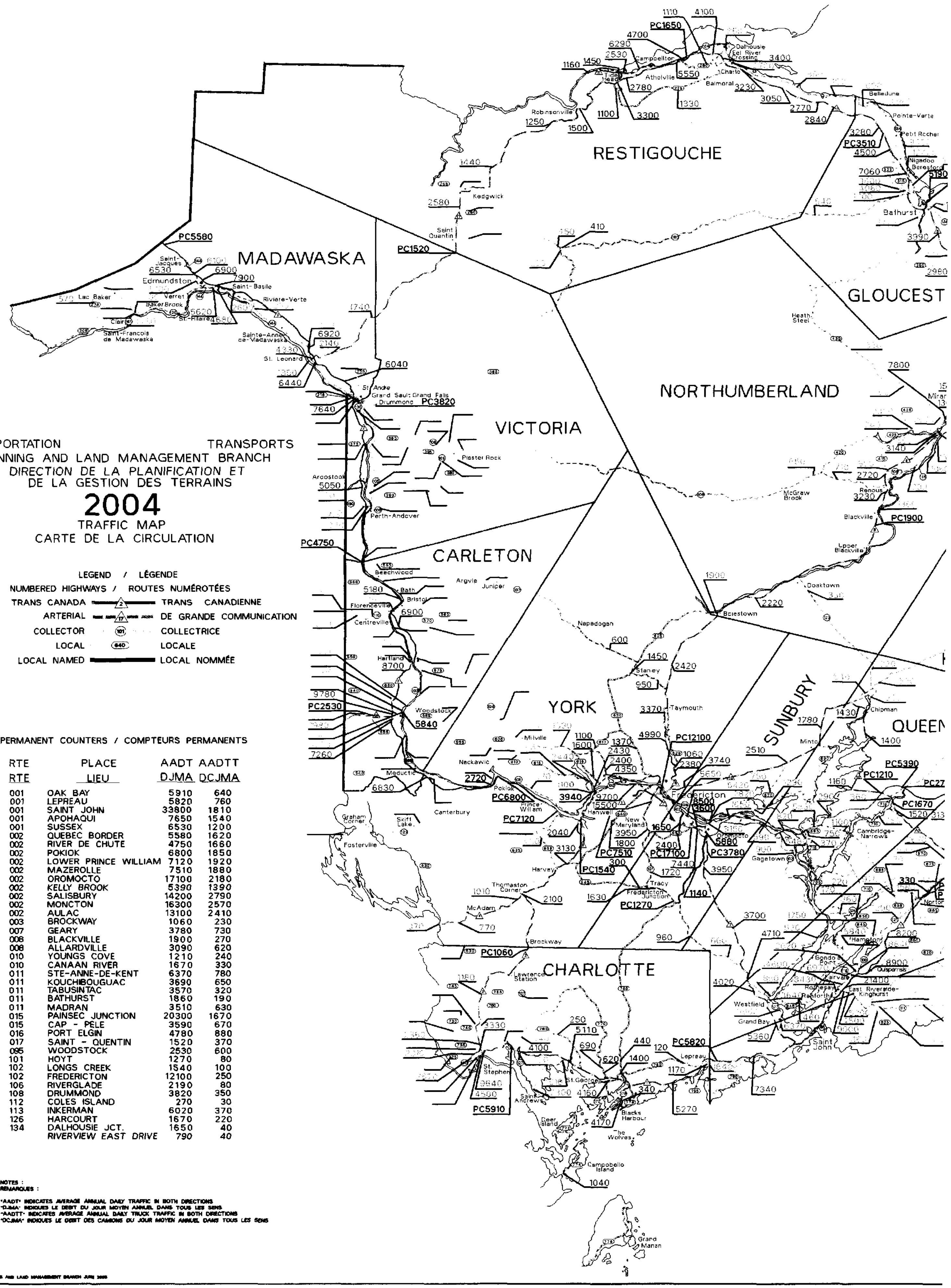
VITA

Candidate's full name: Brody Larry Hanson

Universities attended: University of New Brunswick, Bachelor of Science in Engineering, 2005

Publications: None

Conference Presentations: None



TRANSPORTATION PLANNING AND LAND MANAGEMENT BRANCH

TRANSPORTS DIRECTION DE LA PLANIFICATION ET DE LA GESTION DES TERRAINS

2004

TRAFFIC MAP
CARTE DE LA CIRCULATION

LEGEND / LÉGENDE

NUMBERED HIGHWAYS / ROUTES NUMÉROTÉES

TRANS CANADA	TRANS CANADIENNE
ARTERIAL	DE GRANDE COMMUNICATION
COLLECTOR	COLLECTRICE
LOCAL	LOCALE
LOCAL NAMED	LOCAL NOMMÉE

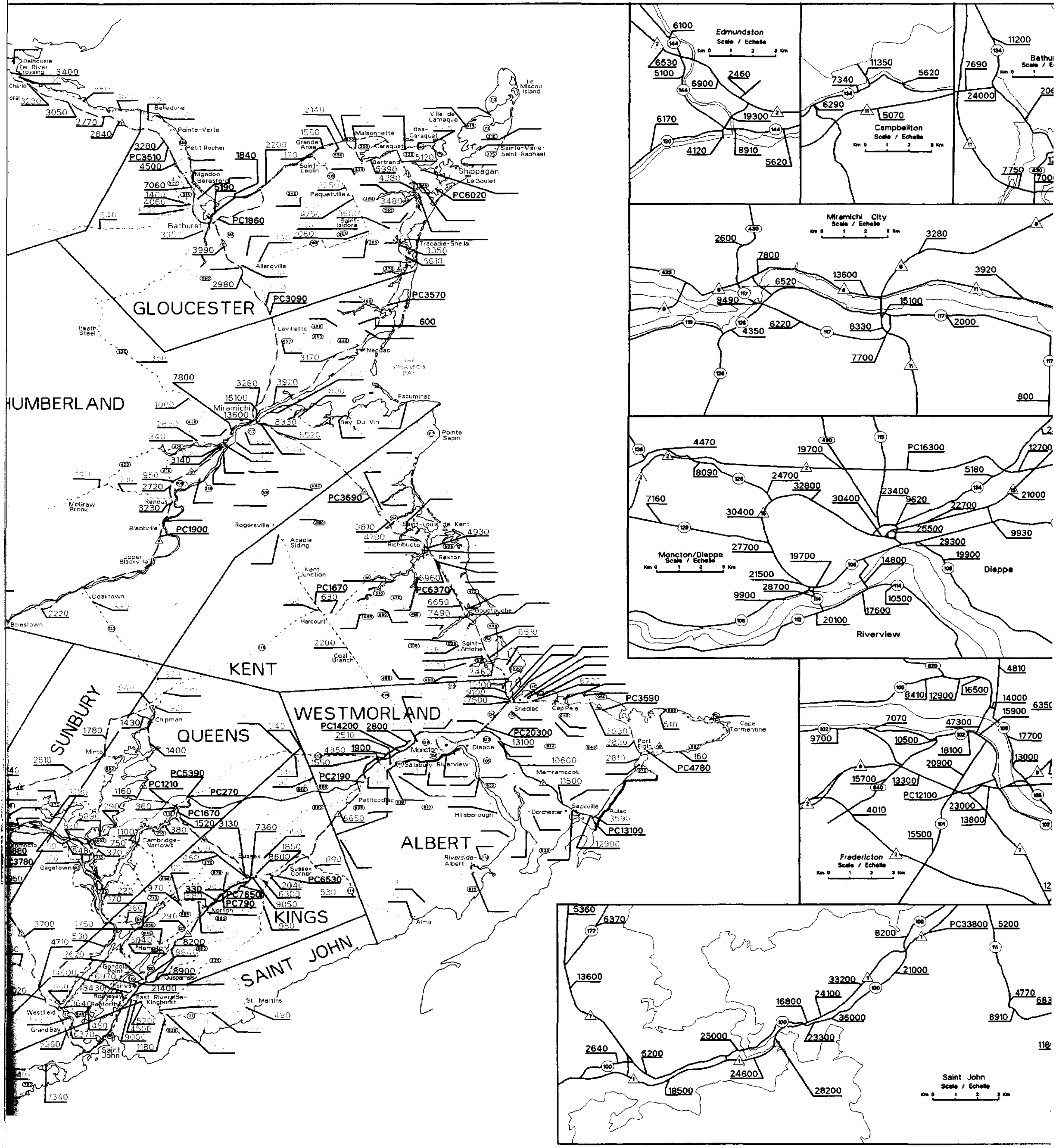
PERMANENT COUNTERS / COMPTEURS PERMANENTS

RTE RTE	PLACE LIEU	AADT DJMA	AADTT DCJMA
001	OAK BAY	5910	640
001	LEPREAU	5820	760
001	SAINT JOHN	33800	1810
001	APOHAQUI	7650	1540
001	SUSSEX	6530	1200
002	QUEBEC BORDER	5580	1620
002	RIVER DE CHUTE	4750	1660
002	POKIOK	6800	1850
002	LOWER PRINCE WILLIAM	7120	1920
002	MAZEROLLE	7510	1880
002	OROMOCTO	17100	2180
002	*KELLY BROOK*	*5390*	*1390*
002	SALISBURY	14200	2790
002	MONCTON	16300	2570
002	AULAC	13100	2410
003	BROCKWAY	1060	230
007	GEARY	3780	730
008	BLACKVILLE	1900	270
008	ALLARDVILLE	3090	620
010	YOUNGS COVE	1210	240
010	CANAAN RIVER	1670	330
011	STE-ANNE-DE-KENT	6370	780
011	KOUCHIBOUGUAC	3690	650
011	TABUSINTAC	3570	320
011	BATHURST	1860	190
011	MADRAN	3510	630
015	PAINSEC JUNCTION	20300	1670
015	CAP - PELE	3590	670
016	PORT ELGIN	4780	880
017	SAINT - QUENTIN	1520	370
095	WOODSTOCK	2530	600
101	HOYT	1270	80
102	LONGS CREEK	1540	100
102	FREDERICTON	12100	250
106	RIVERGLADE	2190	80
108	DRUMMOND	3820	350
112	COLES ISLAND	270	30
113	INKERMAN	6020	370
126	HARCOURT	1670	220
134	DALHOUSIE JCT.	1650	40
	RIVERVIEW EAST DRIVE	*790*	*40*

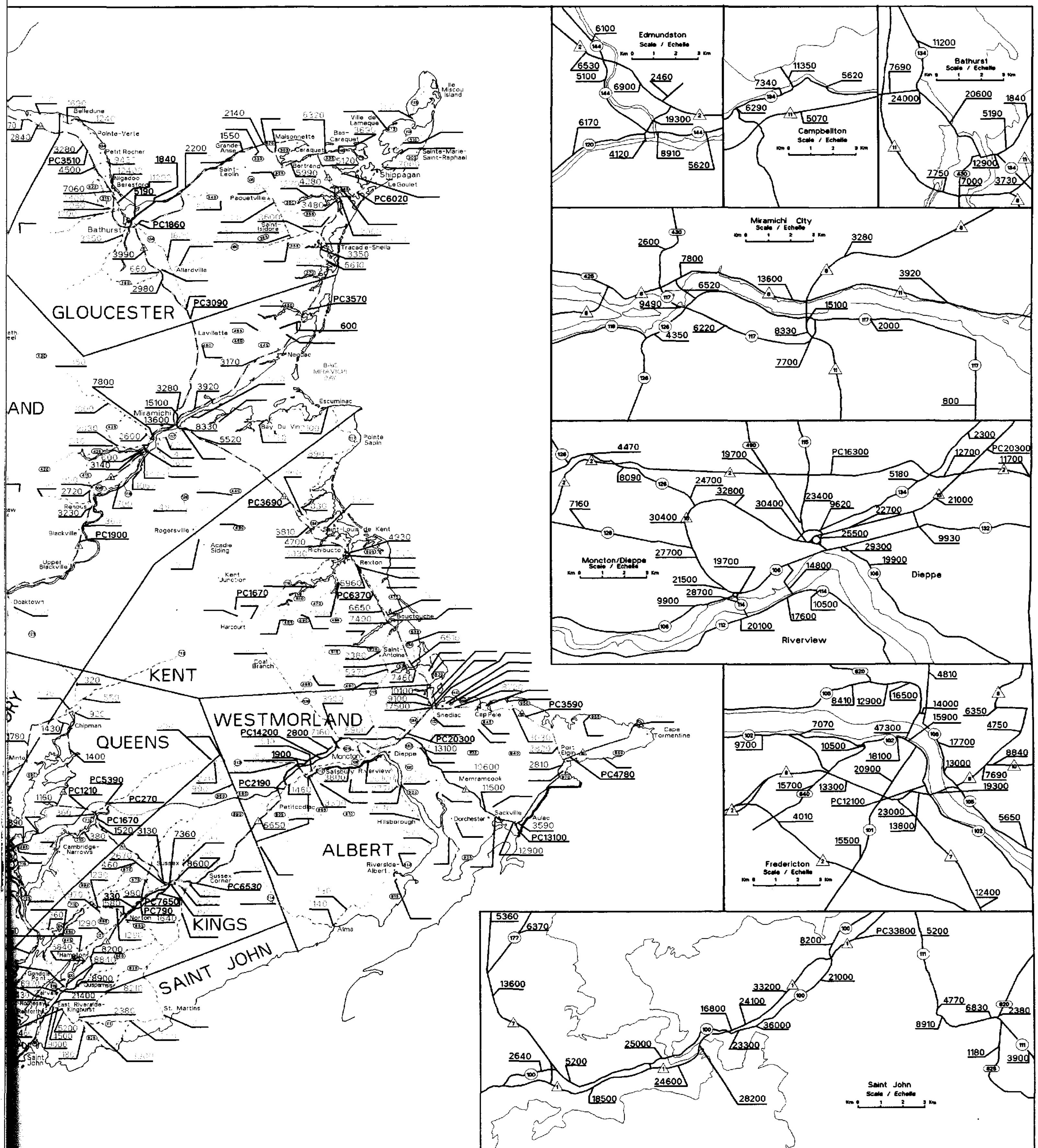
NOTES :
REMARQUES :

1 "AADT" INDICATES AVERAGE ANNUAL DAILY TRAFFIC IN BOTH DIRECTIONS
1 "DJMA" INDIQUES LE DEBIT DU JOUR MOYEN ANNUEL DANS TOUS LES SENS
2 "AADTT" INDICATES AVERAGE ANNUAL DAILY TRUCK TRAFFIC IN BOTH DIRECTIONS
2 "DCJMA" INDIQUES LE DEBIT DES CAMIONS DU JOUR MOYEN ANNUEL DANS TOUS LES SENS

PREPARED BY PLANNING AND LAND MANAGEMENT BRANCH JUNE 2005



New Nouveau Brunswick



New Nouveau Brunswick