**The County of Perth**

# Winter Maintenance Modernization

Modernization and Network Integration Options

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# 1. Executive Summary

The County of Perth with its member municipalities North Perth, Perth East, Perth South, and West Perth, and the Town of St Marys, currently operate independent winter maintenance services. The agencies requested assistance to identify opportunities and recommend actions to modernize winter maintenance practices. This report presents findings of study to facilitate consultation on current practice, gaps in comparison with industry benchmarks, recommendations on modernization options, and implementation plan with estimated costs and savings.

Modernization options were classified into three priority levels according to the degree of risk reduction, ease of implementation and cost implications**. Priority 1** indicates feasibility for implementation within one year, **Priority 2** within three years and **Priority 3** more than three years. Cost implications of modernization practices are estimated to a first approximation where information was available. The process was applied to the following elements of the winter maintenance process:

- Legislative requirements
- Route optimization and network integration
- Weather information
- Patrolling
- Winter materials
- Fleet
- Record keeping
- Sidewalks
- Parking lots
- Service delivery
- Public communications
- Drifting snow hazards

The study findings and overall recommendations for each of the above categories are presented in the following. Readers are referred to **Section 5** for the recommended priority actions (i.e., Priority 1, 2, and 3) associated with each of the above winter maintenance process elements and to **Section 6** for a costed implementation plan that addresses the recommendations through five key initiatives.

***Legislation***

In terms of legislations, it was found that key Minimum Maintenance Standards (MMS) are met by all agencies, but gaps were found regarding rules of practice and documentation of actions that provide additional support to defense of claims and promote effective and consistent operations. These can be addressed through the development of documents and related policies such as a Level of Service and Winter Operations Plan (WOP). Gaps in comparison with benchmark documents and practices were found relating to weather monitoring, patroller training, patrolling routes, rules of practice, implementation of winter liquids with road salt, electronic tracking of operations, and equipment calibration. The gaps impact on defense of claims, cost-effectiveness of snow clearing operations and record keeping. Harmonized rules of practice would provide more consistent levels of service across the network and facilitate future network integration.

All agencies are in compliance with Sourcewater Protection requirements of the Ontario Clean Water Act related to road salt. One agency lacks a Road Salt Management Plan (RSMP) as required in the Canadian Environmental Protection Act, and all existing plans are deficient in not being updated annually and in not reporting performance measures to Environment Canada annually. Development of a harmonized plan for all agencies is recommended.

### *Route Optimization and Network Integration*

A route optimization study was undertaken to assess whether savings are possible by optimizing existing routes to reduce deadheading. A network integration analysis was undertaken to assess the feasibility in maintaining roads to the same level of service with a reduced number of maintenance yards aiming to reduce the overall real estate footprint. The analysis predicted that in order to achieve significant cost savings, level of service would need to be reduced on some roadways.

The route optimization study used a computer-based system to predict the shortest possible route network while meeting MMS service time requirements and spreader capacity limitations. The network integration analysis used four approaches; first, current routes were optimized. Second, current routes were optimized without regard to municipal boundaries. Third, yards were sequentially removed according to their rating on key functions until one of the two route optimization criteria was no longer met and fourth, yards were added to a blank network at optimal locations, starting from one yard, until the two route optimization constraints were met. In the municipal boundary removal and subsequent reduced yard analyses, the route precedence system was simplified from the six level MMS system to a two-level system based on MMS Class 1 and 2, and MMS Class 3 through 6. The plow/spreaders currently associated with each removed yard were also removed, reducing the equipment from an initial complement of 44 to a final of 37. Changes in level of service due to network integration in comparison with the current condition were estimated using two indicators; the buffer capacity of spreaders to complete their assigned routes without reloading, and the buffer in service time indicated by the difference between predicted service time and the MMS requirement for that route.

The route optimization program was found to predict impractical routes at some complex locations and as a result, it is necessary to review the predicted routes and make practical adjustments before implementing specific routes as presented. There are many decision rules and localized factors that are challenging to account for in the optimization process, especially with optimizing routes for six large municipalities. As such, some of the computer-generated solutions may be regarded as infeasible or untenable, particularly for St. Marys as it entails a very complex road network. Necessary adjustments impact on individual routes and do not invalidate the overall network integration analysis.

Despite the above limitations, the optimization results are valid at the scale of planning a future maintenance yard network. The analysis of existing routes demonstrated that they are *efficient as currently operated*, in comparison with the optimal routes, and no changes were recommended. In other words, the current truck routing scenarios are running in a very efficient manner, as visually demonstrated in **Section 4.3.2**.

The removal of municipal boundaries with current maintenance yard network showed a marginal increase in service level compared with the current routes.

The yard removal analysis demonstrated the feasibility to retire up to three existing, lower-functioning yards (ten remaining) and their service trucks while still meeting the minimum MMS and spreader capacity requirements. This scenario resulted in a predicted annual cost saving exceeding $300,000 but with undesirable reductions in level of service.

The clean slate analysis demonstrated the feasibility to further reduce the network to six yards if they are ideally situated for route coverage rather than based on the functionality of the existing yards. The predicted ideal locations indicate the possibility to retain existing yards in the ideal network rather than starting from greenfield. The predicted savings of this scenario are lower than the ten-yard scenario due to longer travel routes, and the undesirable reduction in service level is more severe.

Both network integration studies considered only the efficiency of route coverage. Additional planning studies are recommended to establish fleet characteristics of a reduced yard network that can maintain the current levels of service and, to estimate property costs associated with maintenance yard upgrades and repurposing.

### *Weather Information*

Some agencies use the basic OGRA weather app or a similar commercial app. It is recommended to use the OGRA Enterprise level Weather Tracker that meets MMS requirements and to include weather information procedures in the Winter Operations Plan. In addition, three agencies have access to the MTO Road Weather Information System (RWIS) that provides road-based forecasts. It is recommended to expand this to all agencies at no additional cost, to evaluate the additional benefit of RWIS in planning winter operations and to implement a County-based RWIS to support more efficient use of winter materials.

### *Patrolling*

Patrolling was found to exceed OGRA guidelines in some cases, although Perth East and North Perth are recommended to reduce liability by meeting patrolling length guidelines. A review of patrolling training and of winter operations plans, and fully implementing patrol tablet or app technology is recommended to ensure consistent operations and strengthen defense of claims. Implementation of a webcam network to enhance patrolling is recommended as part of the public communications plan. Integrated patroller operations are recommended as a pilot project in the service delivery assessment.

### *Winter Materials*

The selection and rates of application of winter materials, road salt, sand and sand:salt mix, were found similar to comparable agencies and benchmarks, and the use of pre-treated and pre-wet salt by Perth County and Perth East are advanced in comparison with some similar agencies. Pre-wet and pre-treated salt have the potential to reduce material costs up to 20% and reduce salt use up to 30% and expanded implementation is recommended. The development of harmonized rules of practice is recommended to provide consistent road conditions and enhance defense of claims. This should include a review of the relative benefits of salt, sand, and salt: sand mix with a view to modernizing winter materials practices in a harmonized Winter Operations Plan.

### *Fleet*

The roadway maintenance fleet was found to be modern and generally well suited to the service requirements. Additional outfitting to apply pre-wet salt is recommended, as is full implementation of electronic spreader controllers and AVL to meet Environment Canada recommendations for controlling and reporting salt usage. Consideration is recommended to upgrade the few single-use spreaders to combination units where possible to reduce the overall equipment complement.

### *Record Keeping and AVL*

Automatic Vehicle Location (AVL) is an industry benchmark for tracking winter maintenance operations and material application. It is implemented by only two Perth County agencies for information management purposes. AVL has the potential to improve timeliness and reduce clerical effort in materials management, fleet management, communication to the public and other business processes, and to aid in defense of claims. Future work to develop standard reporting tools and processes and to integrate AVL with existing business processes is recommended as a priority, with future work to review the best service delivery option for AVL across all agencies.

### *Sidewalk Operations*

Sidewalk operations utilize modern, state of the art equipment. All agencies have a policy on sidewalk clearing but not all include the state-of-the-art aspects of priority levels or storm severity in setting levels of service. Sidewalk materials and application rates are comparable with industry practice but vary among County agencies. Harmonization of policies to use similar priority levels, criteria for service and materials practices could provide more consistent levels of service and stronger defense of claims. Sidewalks are clustered in urban areas with long distance between them, resulting in higher costs and slower operations when staff are diverted from roadway operations. Resourcing of sidewalks services independent of roadway operations and integrated across agencies could provide a more consistent level of service and more efficient matching of equipment to route characteristics. It is recommended to include sidewalk operations in consideration for a Service Integration Pilot Project.

### *Parking Lots*

Industry guidelines for parking lot maintenance are in the formative stages, with industry groups only recently beginning to develop consistent approaches and policies. Client agencies service parking lots after roadways using modern and well-suited equipment, but lack detailed policies or guidelines. Parking lots in Perth East are widely distributed, making service more difficult. Harmonization of parking lot service policies is recommended, along with a review of service delivery by dedicated in-house crews, possibly integrated across agencies. It is recommended to include parking lot operations in consideration for a Service Integration Pilot Project.

### *Service Delivery*

A small proportion of roadway, sidewalk, and parking lot routes are contracted to other agencies or private operators to meet specific needs. In some cases, it has been difficult to obtain competitive bids for contracted services due to the cost of road liability insurance. Expansion of contracted services is not recommended as a general policy, but only in response to specific needs. A pilot project on integration of services is recommended, beginning with patrolling, sidewalks or parking lots.

### *Public Communications*

The benchmark for public information on winter operations includes web-access to service policies and priorities, general description of equipment, service areas, materials and practices, contact information, and a web link to the commercially operated Municipal511 web site that displays current reported road conditions and incidents. Three agencies do not currently subscribe to Muncipal511 but can be added to the existing County agreement at no additional cost. Implementation of a webcam network is recommended to provide real-time road condition information through Muncipal511 and to enhance patrolling efficiency.

### *Drifting Snow*

Drifting snow hazards are found at many sites in Perth County, and research by other agencies has demonstrated that maintenance costs can increase by 30% at sites susceptible to it. Accident risk is also increased dramatically. Relatively low-cost remedial measures such as snow fencing, or longer-term measures such as snow hedge, have been demonstrated to reduce the hazards dramatically but are not implemented on County or municipal roads. A review of hazard sites, implementation of short-term solutions and planning of long-term solutions is recommended.

# 2. Background and Introduction

The County of Perth with its member municipalities North Perth, Perth East, Perth South, and West Perth, and the Town of St Marys, currently operate independent winter maintenance services. The agencies provide winter service for a total of 4,400 km of roadway, 120 km of sidewalks and trails and 46 parking lots, operated out of 13 different maintenance yards.

The agencies requested assistance to identify opportunities and recommend actions to modernize winter maintenance practices and service delivery, and enhance efficiency of snowplow and patrolling routes, as well as operations on sidewalks and municipal parking lots. Other opportunities were to generate synergies in fleet, material and facilities, consistent service levels, review compatibilities of policies, procedures, protocols and standards, evaluate contracting vs in-house service delivery, provide a cost model for proposed implementations and strategy, risk assessment of current operations and, identify impediments to modernization. It is recognized that modernization options may have different implementation horizons depending on expected benefits and financial or organization impacts.

This study follows a winter maintenance process model developed through experience with Canadian and international road maintenance agencies. The process flows from desired goals of road safety and mobility to the operational procedures, equipment and materials used to meet level of service goals under a set of winter weather operating conditions (**Figure 1**).

This report presents findings of the study to facilitate the consultation on current practice, gaps in comparison with industry benchmarks, and initial recommendation on modernization options. Following discussion with the participating agencies, a list of modernization operations will be selected, and implementation plans will be developed.

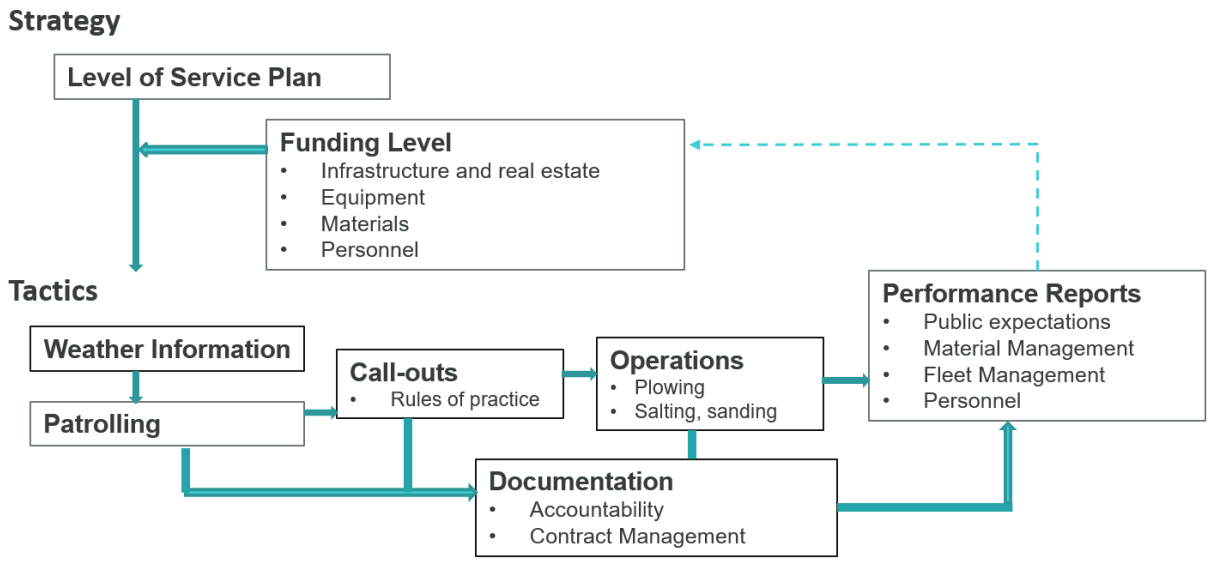



**Figure 1: Typical Winter Maintenance Management Process**

# 3. Methodology

The study includes six key phases, as illustrated in **Figure 2**.

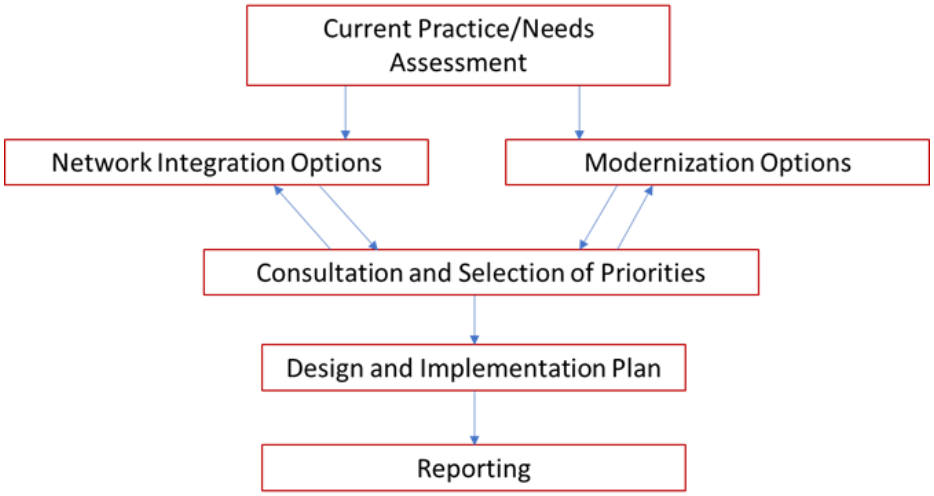



**Figure 2: Study Phases**

The first phase, *Current Practice and Needs Assessment*, is intended to create a better understanding of the current winter maintenance processes, assets and procedures currently employed by each of the agencies. The second phase, *Modernization Options*, develops a benchmark for each of the processes, assets or procedures and identifies gaps, if any, between the benchmark and the Perth County agencies, the risks associated with the gaps, and modernization approaches to reduce the gaps. The third phase, *Network Integration Options*, focuses on the maintenance yard and road maintenance route network, employing computer-based prediction models to optimize current maintenance routes within a single, integrated boundary and to evaluate the potential for reduced numbers of maintenance yards by elimination of municipal boundaries and one or more existing yards, and using a reduced number of maintenance yards ideally situated for road network coverage. This process is followed by Consultation and Selection of Priorities with the participating agencies. Based on the inputs received, a Design and Implementation Plan was developed.

The following subsections discuss the approach taken for each of the first three phases.

## 3.1. Current Practice and Needs Assessment

Current practices were assessed using a questionnaire submitted to each client agency (**Appendix A**), and multiple follow up interviews to drill down to further details. The questionnaire and interviews topics listed below were used to formulate topics of inquiry:

- Service Policies;
- Deployment Practices;
- Maintenance yard characteristics;
- Winter Materials;
- Vehicles and Related Equipment;
- Winter Operations Staffing and Shift Plan;
- Patrolling and Winter Condition Reporting;
- Record Keeping;
- Service Delivery Type;
- Winter Season Resource Use;
- Snow fences or hedges; and
- Road Salt Management Plan.

## 3.2. Modernization Options and Gap Analysis

The assessment of modernization options involved the identification of benchmarks for comparison with current practices, identification of gaps between benchmarks and practice, risks associated with the gaps, and suggestion of modernization options to fill the gaps and reduce risks. Benchmarks were derived from key legislative requirements, industry best practice derived from published sources or surveys undertaken for this study, state-of-the-art methods, consultation with industry experts, and practical experience of our analysts. Benchmarks are identified specifically in the Study findings section of the report. The above process was applied to the following components of the winter maintenance process:

- Legislative requirements;
- Maintenance yard functional assessment;
- Route optimization and network integration;
- Weather information;
- Patrolling;
- Winter materials;
- Roadway fleet;
- Record keeping;
- Sidewalk operations;
- Parking lots;
- Service delivery;
- Public communications; and
- Drifting snow hazards.

Modernization options were classified into three priority levels according to the degree of risk reduction, ease of implementation and cost implications. **Priority 1** findings are feasible to be implemented within one year, **Priority 2** within three years and **Priority 3** in more than three years. Cost implications of modernization practices are estimated to a first approximation in the Implementation Plan section of this report (**Section 6**).

## 3.3. Route Optimization and Network Integration Options

A separate analysis was applied to investigate the feasibility of integrating maintenance yards to a smaller, more efficient network and to optimizing roadway service routes to the yard configuration. This analysis had several steps; the first to establish a logical procedure for retirement of yards from the existing network and the second to analyze the feasibility of various scenarios of yard and route configuration.

A functional analysis was used to provide a logical basis for removal of yards from the existing network. In this analysis, a series of nine factors was identified that independently impact yard functionality. Clients were surveyed on the status of each of their yards on the identified factors, and the yards were rated on each factor using a scale of 0-5. Clients were then surveyed on the relative importance of each rating factor using a scale of 1-5, with 5 being the most important factor, identifying a consensus weight for each factor. The factor ratings were multiplied by the weights and then summed to result in a weighted rank. The factors, rankings, weightings and other details are presented in **Appendix B**.

A unique modelling approach was used in this study to assist in analyzing the feasibility of a future, integrated network of maintenance yards and roadway routes that is optimized in terms of the number and location of yards. The modelling approach has two key benefits; first, it allows for the prediction and testing of alternative future scenarios of maintenance yard network through the retirement of individual yards or groups of yards, or the addition of yards; and second, it allows for the prediction and testing of alternative maintenance routes based at the yards associated with each scenario. Maintenance routes are optimized for each scenario of maintenance yard numbers and locations, and statistics for the predicted routes are estimated to quantify the travel distance, turnings, route service time, and total material application. Directional route maps were generated for all optimized scenarios.

Scenarios were constrained such that service times do not exceed the MMS requirement for each road class on a route, and that spreader routes do not exceed the capacity of the assigned spreader, whether spreading salt, sand, or mix. Operating costs for each scenario were estimated at a later stage using standard unit costs for annual yard rental based on building area, and for hourly equipment rental by equipment type, as obtained from Perth County (**Appendix I, J**). Annual values for equipment rental were based on the estimated hours per deployment and the estimated number of annual deployments. While the estimated values may differ from actual costs of yard and fleet operation, they provide a common basis of comparison among network optimization scenarios.

The network scenarios included in this study include:

- The current network using MMS road class priorities;
- Current network and with routes optimized to reduce deadheading using MMS road class priorities;
- Current network with elimination of municipal boundaries and using a simplified two-level road class priority system (MMS 1-2 and MMS 3-4-5-6);
- Yard removal network with yards and their associated service vehicles retired in stages according to the functional priority rankings explained previously, using the simplified two-level road class priority system. A yard was eliminated according to functional priority and then routes were re-optimized at each yard removal step and the plow and spreader vehicles based at the removed yar were also removed from service. The yard removal process was repeated until service time and spreader capacities could no longer be met; and
- A clean slate network based on yards that are ideally located to service the network with the least overall distance travelled. This analysis started with a single, ideally located yard and added yards sequentially with locations re-optimized at each step. This scenario used the lowest number of viable service vehicles (37) from the yard retirement scenario and the two-level priority system to ensure comparability of results between the two approaches. The number of service vehicles at each yard was assigned according to the proportion of network distance associated with that yard, and routes were then optimized. The yard addition process was repeated until sufficient ideally-located yards were added that the service time and spreader capacity requirements were met.

Route optimizations used a computer-aided heuristic analysis employing an algorithm designed to make logical choices among competing constraints, in attempting to find the optimal routes.[1, 2, 3, 4] The analysis was used to develop the shortest possible network operating distance while meeting legislative and operating requirements including road class priorities, turning restrictions, MMS requirements, material usage and loading capacities, and hotspots (locations deemed to require more intensive service than other road sections). Inputs to the analysis include plow/spreader operating constraints, rules of precedence and assumptions to simulate the logical rules that an analysist could follow manually to create and test out alternative routing options. The rules were developed through an iterative process in consultation with the client group (**Appendix D, E**).

[1] Guan, M. 1962. Graphic programming using odd and even points. Chinese Math., 1: 237–277.
[2] Malandraki, C., and Daskin, M.S. 1993. The maximum benefit Chinese postman problem and the maximum benefit traveling salesman problem. European Journal of Operational Research, 65(2): 218–234.
[3] Perrier, N., Langevin, A., and Amaya, C.-A. 2008. Vehicle routing for urban snow plowing operations. Transportation Science, 42(1): 44–56.
[4] Ahr, D., and Reinelt, G. 2006. A tabu search algorithm for the min–max k-Chinese postman problem Computers & operations research, 33(12): 3403–3422.

The initial input to the optimization and network integration analysis consisted in pdf format maps provided by clients showing maintenance yards and all associated routes with directional arrows and annotations. These were geocoded to create map layers and additional layers were created showing MMS classes, municipal boundaries, hotspots, and a second, two-class priority system; spreader or plow/grader type and capacity; material types and application rates; posted speed and typical spreader or plow operation speed; paved and unpaved areas were added. Locational information for hotspots requiring higher priority, cold spots with service constraints, and restrictions or allowance of left turns or U-turns was added.

Routing precedences (**Appendix E**) were used to make automated decisions where conflicts arise in the decision rules, guided by the principle of minimizing the total distance travelled over the entire maintenance route network. Examples of such a decision rule is choosing between a left-hand turn or adding a long distance of deadheading, or servicing a small distance of lower MMS class road segment before a higher class road segment at the start of a route. The automated, rule-based decisions and the simplifying assumptions have practical limitations and may result in routes that, while minimizing the overall distance travelled in the route network, are not adjusted to all local conditions or to features not shown on the input maps. Several optimized routes, especially in complex urban areas like St Marys, resulted in excessive turns or infeasible routes and it is essential that all predicted routes be verified and adjusted prior to implementation.

This practical limitation in the automated route optimization process does not significantly affect the overall findings of the network analysis and it has the benefit in applying rules consistently to provide results that are comparable across the network. It has the additional benefit in being able to change inputs, assumptions or constraints to try out different scenarios or to meet different analysis objectives. Examples of other scenarios could include the introduction of a more effective de-icing chemical with lower application rates, or a different road classification and priority system, or elimination of snow drifting hazard spots by implementing snow fence, or changing the number, capacity, or operating speed of service vehicles. The positive effects and cost implications of each of these innovations on winter maintenance routes can be assessed through computer-based route predictions.

# 4. Study Findings and Analysis

## 4.1. Legislation

Winter maintenance operations for municipalities in Ontario are governed by three key pieces of legislation, provincial legislation supporting road safety and mobility, and federal and provincial legislation supporting environmental protection. Key aspects of legislation are described below, and gaps identified in **Table 1**.

### 4.1.1. Ontario Municipal Minimum Maintenance Standards (MMS)

The Ontario Municipal Act of 2001 includes Regulation 238/02 (amend 366/18), Minimum Maintenance Standards for Municipal Highways (MMS)[5], which defines the types and frequency of maintenance operations through which municipal highways of Class 1 through 5, bicycle lanes and sidewalks can be described as being in a state of good repair in relation to winter storm events. The activities include:

[5] https://www.ontario.ca/laws/regulation/r18366

- Patrolling;
- Weather monitoring;
- Treatment for snow accumulation; and
- Prevention of ice formation.

The frequency of treatments varies with road classification and with the declaration of a significant weather event. The initiation of road treatments may be delayed until the end of significant weather event.

Conformance to MMS requirements are reviewed in later sections of this report.

A statement of MMS as the service objectives does not guarantee protection from claims unless it is backed by a Level of Service (LOS) policy and a Winter Operations Plan[6]. A level of service policy demonstrates that the resources are available to meet or exceed the minimum standards. Resources include funding, staff, equipment, materials, etc. A Winter Operations Plan describes the specific procedures to be followed by using the resources and that will result in standards being met. A winter event response table or operating guidelines may be used to define the sequence of actions and decisions to be followed in a particular type of winter event, and the expected result. In defence of claims, a municipality must be able to demonstrate with written records that a plan was in place, resources were available to follow the plan, and that reasonable efforts were made to meet the LOS or the standards. This requires documentation of the LOS policy, resources applied, and actions taken. The LOS, Winter Operations Plan and response tables may also be incorporated in a Road Salt Management Plan.

### 4.1.2. Canadian Environmental Protection Act (CEPA)

The Canadian Environmental Protection Act (1999) provides for the assessment of substances that could pose risks to the natural environment. Road salts were included in the Priority Substances List as a substance of concern in 2001. Following an extensive stakeholder review a Code of Practice was instituted to reduce the environmental impacts of salts used for winter maintenance. The Code of Practice applies to any organization in Canada that uses more than 500 tonnes of road salt per year or having salt vulnerable areas within its jurisdiction.[7] The code includes an annual requirement to report on key indicator of a road salt management plan including: road length, weather severity, materials, storage, spreading equipment and application practices, snow disposal, training, salt vulnerable areas and environmental monitoring.

Agencies are recommended to develop and maintain a Road Salt Management Plan (RSMP) that includes an organizational commitment and support for the principles of salt management, management practices for salt storage, application, and disposal of salt-contaminated snow, and identification of salt vulnerable areas such as sensitive wetlands near roadways, remediation for contamination issues, training and continuous improvement. The best management practices generally promote efficient winter maintenance operations that reduce the potential for liability for contamination of roadside soil, surface or groundwater and living species.

[6] https://www.ogra.org/files/Winter/A%20Guideline%20for%20Developing%20a%20Level%20of%20Service%20Policy.pdf
[7] https://ec.gc.ca/lcpe-cepa/default.asp?n=26A03BFA-1

In response to the Environment Canada recommendation, the Transportation Association of Canada developed a Synthesis of Best Practices for Road Salt Management[8]. It was intended to be a model with which local agencies can develop a plan specific to their situation. The key elements of the TAC Synthesis include:

- Salt Management Plans;
- Training;
- Road, Bridge and Facility Design;
- Drainage;
- Pavements and Salt Management;
- Vegetation Management;
- Design and Operation of Maintenance Yards;
- Snow Storage and Disposal;
- Winter Maintenance Equipment and Technologies; and
- Salt Use on Private Roads, Parking Lots and Walkways.

The implementation of a Road Salt Management Plan includes annual reporting of key performance indicators on general improvement in the management of road salt. As of 2018, 225 government agencies in Canada provided an annual report on their salt management practices to Environment Canada. The key performance indicators are:

- Review their salt management plan annually;
- Salt is stored under a permanent roof and on an impermeable pad;
- Treated winter abrasives are stored under cover;
- Spreaders are equipped with groundspeed electronic controllers;
- Use pre-wet or pre-treated salt;
- Vehicles are equipped for pre-wetting; and
- Have identified salt vulnerable areas and have prepared an action plan.

The Environmental Protection Act focusses on Best Management Practices to promote the effective use of road salt and does not regulate the application rates, nor the total quantities used.

Perth County, Perth South, West Perth, and St. Marys have a published Road Salt Management Plan, and Perth South and West Perth update their plans annually as is required.

### 4.1.3. Ontario Clear Water Act (OCWA)

Regulation 287/07 of the Clean Water Act (2006) regulates activities that pose a threat to drinking water in Ontario. The act designates Sourcewater Protection Areas (SPAs) for the management of threats to source areas for drinking water. Source Protection Plans for each SPA are developed under the leadership of Conservation Authorities with representation from affected municipalities and other stakeholders. Specific criteria are used to designate and map threat levels from many sources, and to develop and implement mitigation plans. Road salt is a designated threat to drinking water under Regulation 287/07, in certain circumstances.

SPAs follow watershed boundaries and parts of Perth County fall under one of the Upper Thames River, Grand River or Maitland Valley SPAs.

Management Plans are administered by Risk Management Officers assigned to each area. Threat levels are defined principally by the rapidity with which contaminants can travel to and enter water supplies. Threats relevant to winter maintenance including handling storage and application of road salt, and

[8] https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-1.pdf

handling and storage of salt-laden snow. Several well-head areas are designated for protection in Perth County (**Figure 3**). All agencies currently meet the requirement for wellhead protection under OCWA.[9]

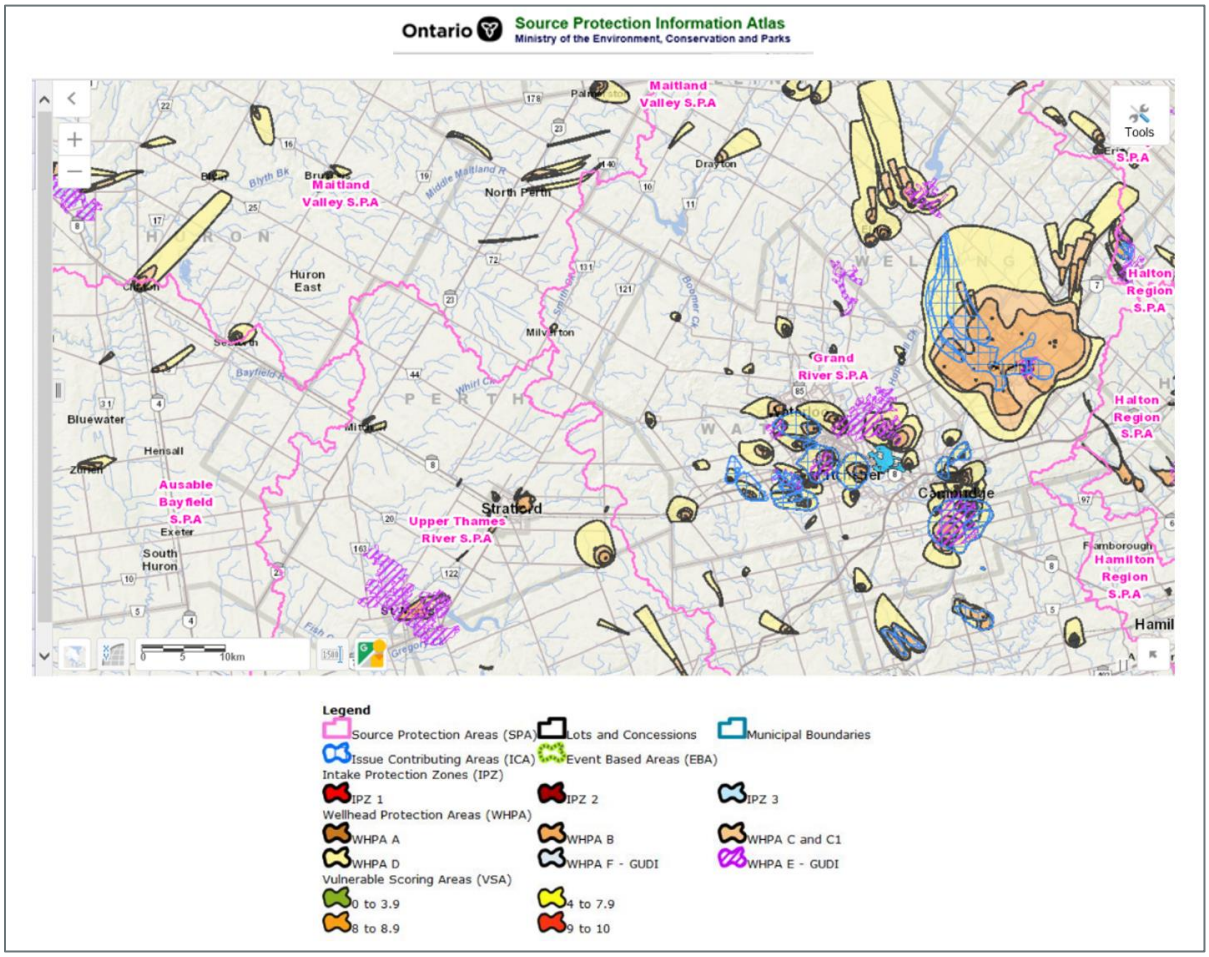



**Figure 3: Source Protection Areas in Perth County**

### 4.1.4. Gap Analysis and Recommendations

**Table 1** presents a summary of winter maintenance policy comparison and conformance to legislative requirements discussed above.

**Table 1: Winter Maintenance Policy Comparison and Conformance to Legislative Requirements**

| Benchmark \ Agency | Perth County | St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|
| Written and defined service levels (MMS) roads | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

[9] Personal communication, J. Allain, Thames River Conservation Authority.

| Agency / Benchmark | Perth County | St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|
| Written and defined service levels (MMS) sidewalks | N/A | ✓ | ✓ | contracted | ✓ | ✓ |
| Written and defined service levels (MMS) patrolling | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Weather Monitoring (MMS) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Road Salt Management Plan | ✓ | ✓ | NO | ✓ | ✓ | NO |
| Best Management Practices | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Sourcewater Protection Plan (road salt) | N/A | N/A | N/A | N/A | N/A | N/A |

The agency policies conform with requirements of MMS and OCWA. This is an essential first step to limiting road liability. Providing a strong defence to claims requires consistent, up to date documentation on level of service policy and on specific operating practices. A consistent approach to documentation was not found across all agencies and this is identified as a gap explored in more detail in later sections of this report. Gaps are also noted in updating of Road Salt Management Plans.

Gaps related to a Road Salt Management Plan do not have a direct consequence in legislation. The key benefit in a Plan is in providing specific goals and support for continuous improvement of salt management practices to use winter materials effectively and to reduce the risk in contaminating land and water sources adjacent to roadways and maintenance yards. Specific recommendations relating to details of road salt management appear later in this report.

The harmonization of Levels of Service and Winter Operations Plans, and of Road Salt Management Plans are recommended as **Priority 1 Actions** to reduce future environmental and road liability and to promote efficient winter maintenance operations.

## 4.2. Maintenance Yard Functional Assessment

The factors used in the functional assessment of existing maintenance yards and the factor weights assigned by the client groups are as follows:

- Storage capacity (5);
- Availability of fueling facilities (5);
- Yard acreage (5);
- Building condition (4);
- Use of facility for other purposes/seasons and availability of amenities (4);
- Access to services (3);
- Environmental sensitivity (2);
- Road class of the adjacent road (2); and
- Land use/zoning (1).

The original functional ranking of each yard and the ranking after weights were applied are shown in **Table 2**. Details of the ranking process are provided in **Appendix B**.

**Table 2: Maintenance Yard Functional Rank**

| Yard Name | Unweighted Rank (Initial Assessment) | Weighted Rank (Assessment After Applying Weightings) |
|---|---|---|
| **Milverton (PE)** | 2 | 1 |
| **Mitchell (PC)** | 3 | 2 |
| **St Marys** | 1 | 3 |
| **Stratford** | 4 | 4 (tied) |
| **Wallace** | 5 | 4 (tied) |
| **North Easthope** | 6 | 5 |
| **Elma** | 7 | 6 |
| **Listowel** | 8 (tied) | 7 |
| **Mitchell (WP)** | 8 (tied) | 8 |
| **Downie** | 11 (tied) | 9 |
| **MTO Listowel** | 9 | 10 |
| **Milverton (PC)** | 10 | 11 |
| **Blanshard** | 11 (tied) | 12 |

The rankings were divided into three tiers to provide qualitative guidance to a phased implementation of yard integration:

- Priority 1 (most value to be retained based on functional rating): Milverton (PE), Mitchell (PC), St Marys, Stratford, and Wallace.
- Priority 2 (some value to be retained based on functional rating): North Easthope, Elma, Listowel, and Mitchell (WP).
- Priority 3 (least value to be retained based on functional rating): Downie, MTO Listowel, Milverton (PC), and Blanshard.

The three tiers are illustrated (**Figure 4**) with a 20 km radius around yards in the highest tier.

The analysis provides a rationale for yard rationalization from a functional perspective but does not give consideration to the feasibility of route coverage or service standards. It is recommended that functional rating be used to provide guidance to a network integration and route optimization analysis as a **Priority 2 Activity**.

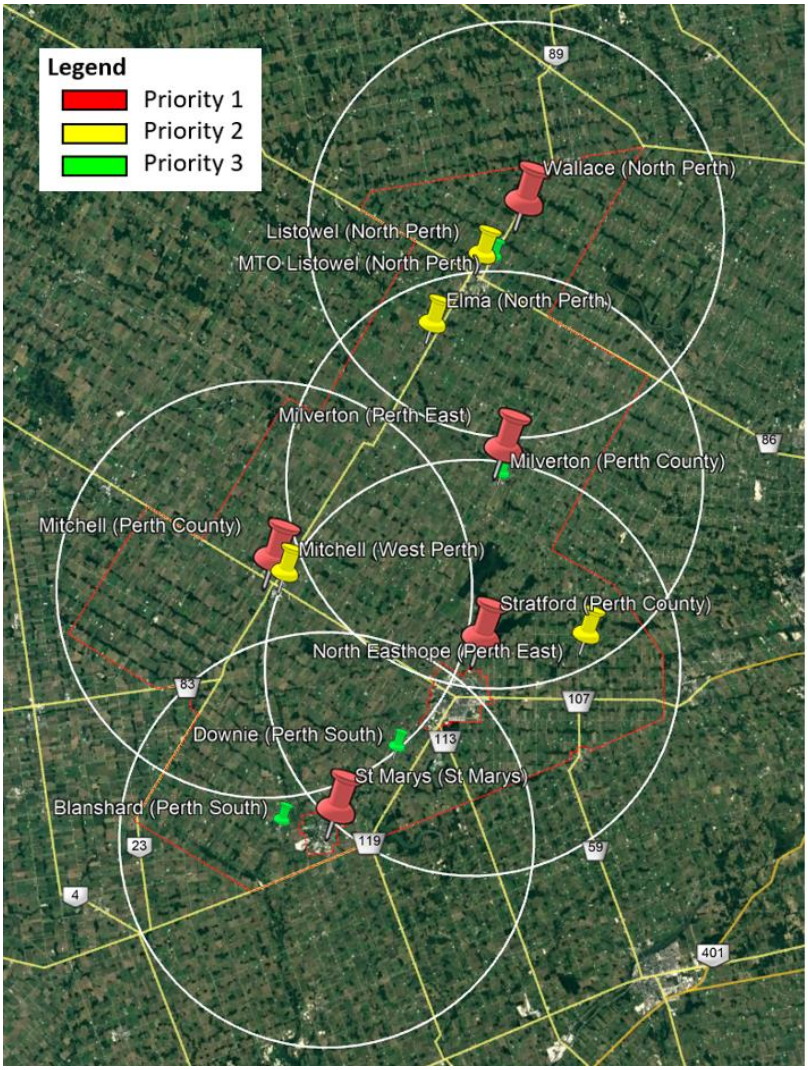



**Figure 4: Maintenance Yard Network Priority Levels**

## 4.3. Route Optimization and Network Integration

### 4.3.1. Current Network Characteristics

The MMS classification of all maintenance routes in Perth County is illustrated in **Figure 5** and the proportion of each road class by agency is shown in **Figure 6**. Road classification varies geographically with the County having highest class roads and St Marys and West Perth the larger proportion of lower class roads.

Reported circuit times in the current network, illustrated by an example for Perth County in **Figure 7**, provide a high level of service compared with the most stringent requirement of MMS, typically with 20% to 80% buffer in route completion time (**Appendix E**). The illustration uses the most demanding criterion; icy conditions based on the highest road class on the route. Similar service times are predicted by the route optimization model for the current condition (**Appendix E**), supporting the conclusion that a high level of service is provided. Likewise, the spreader capacity exceeds the estimated material usage

for each route by an average of 40%, providing a buffer for operations under severe conditions when higher application rates are needed (**Appendix E**). All routes exceed MMS service requirements with a significant margin.

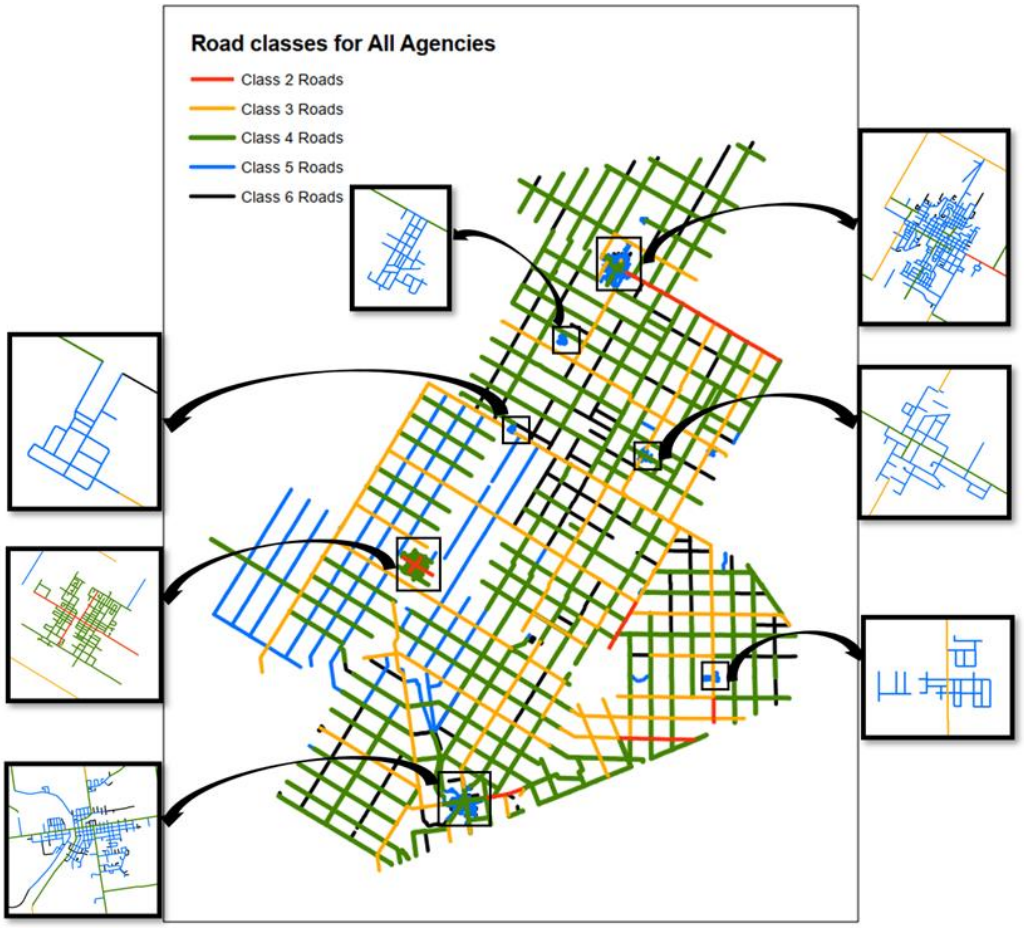



**Figure 5: Perth County Road Classes**

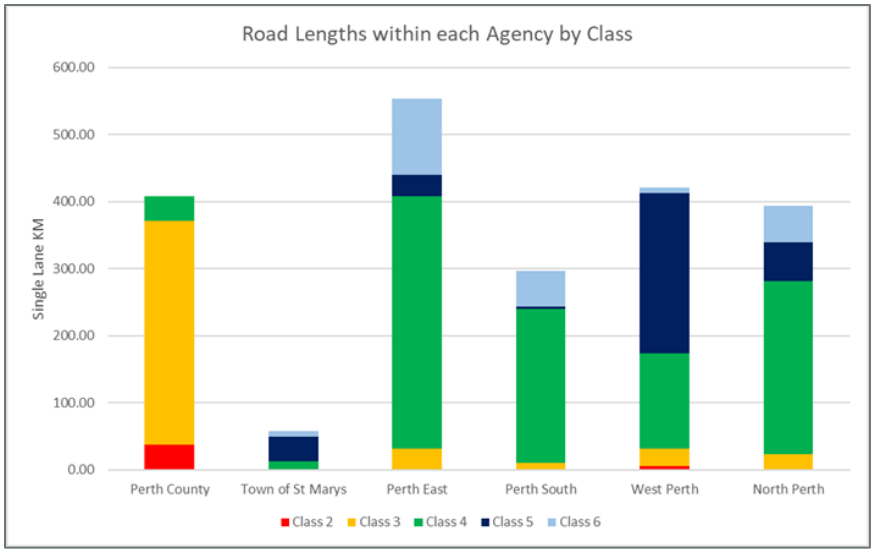



**Figure 6: MMS Road Class Distribution**

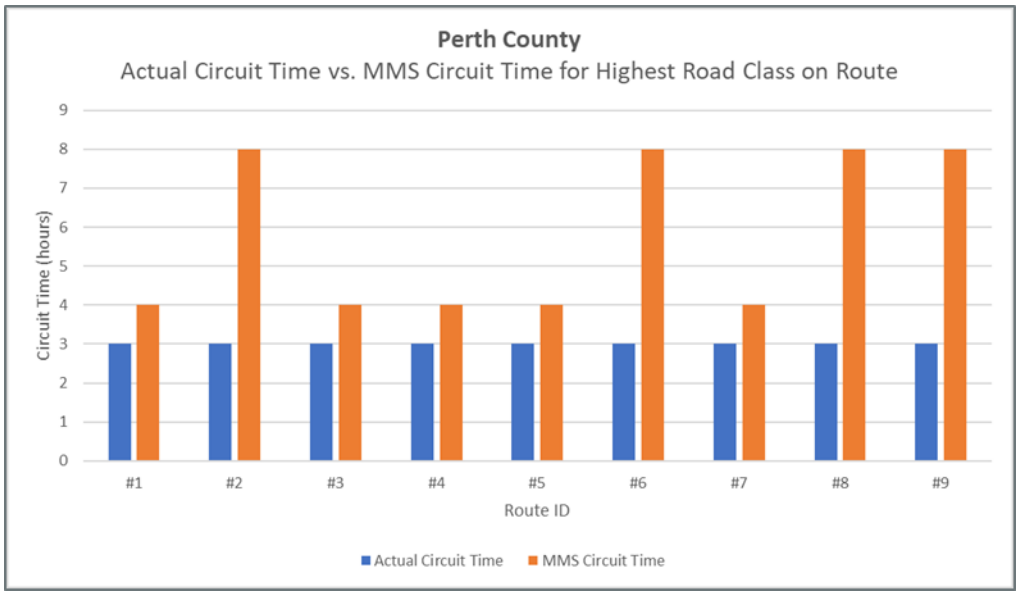



**Figure 7: Route Service Time Example**

Maintenance route length varies from less than 10 km to more than 150 km, excluding one listed route that services parking lots and sidewalks, and patrols roadways (M11) (**Figure 8**). Most County routes compare well with the benchmark MTO route lengths, and the Town of St. Marys and some routes in North Perth compare well with the urban benchmark. Route lengths are well balanced in Perth County, Perth East (excluding M11 which is used for parking lots and patrolling) and Perth South. Routes in other agencies are less well balanced.

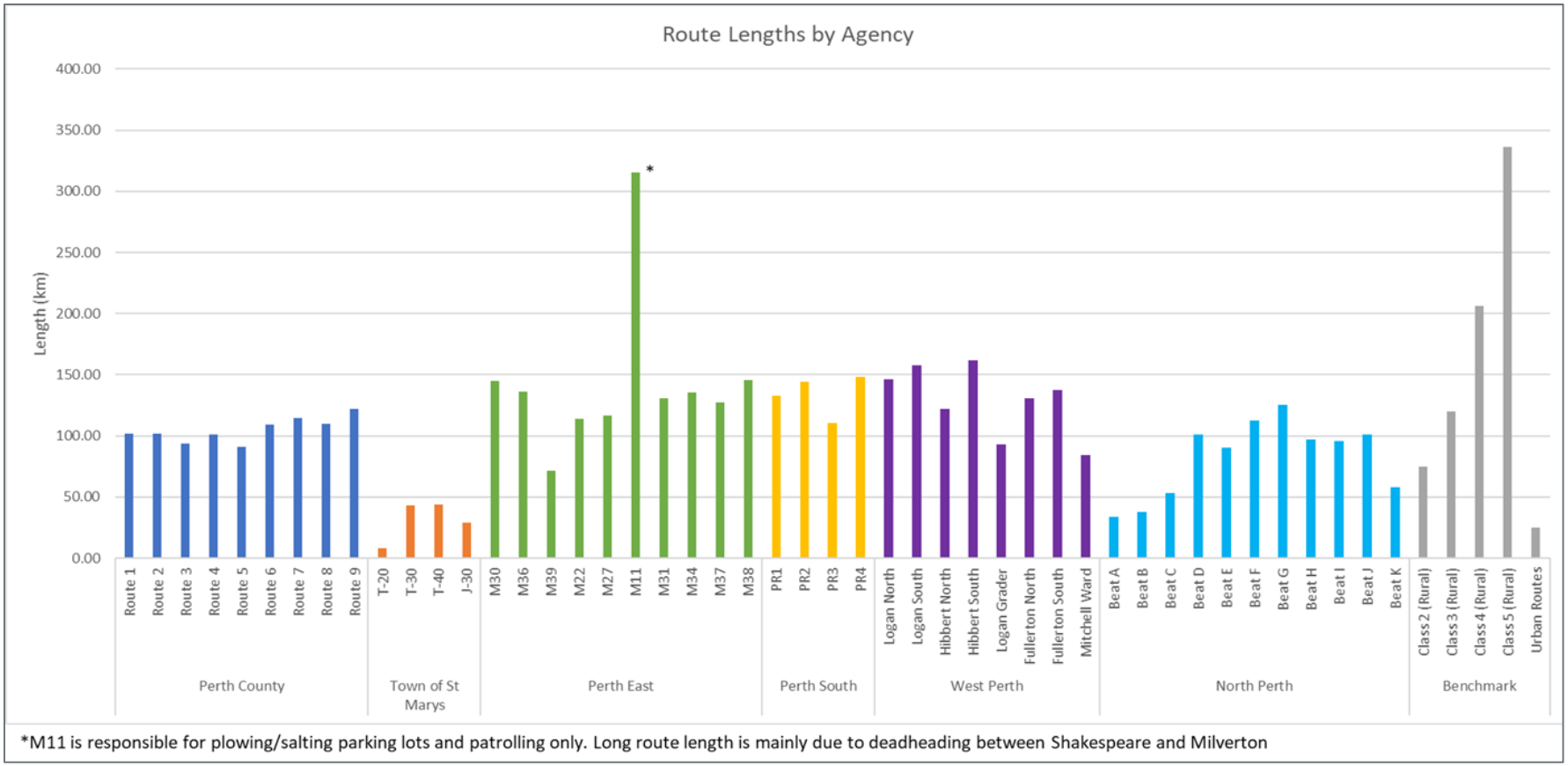



**Figure 8: Maintenance Route Lengths**

The roads are serviced from thirteen maintenance yards with material storage, plus one contractor yard with no material storage. The geographic distribution of the yard network is irregular, with yards belonging to different agencies in close proximity at Listowel, Milverton, and St Marys. Agencies reported sharing of material among yards, as illustrated in **Figure 9,** and comparison of route lengths (**Figure 10**) with material storage capacity (**Figure 11**) suggests that storage facilities are not always aligned with storage requirements to service the routes. Future network efficiency could be improved by reducing redundancy in location and by matching storage capacity with requirements to service routes based at that yard.

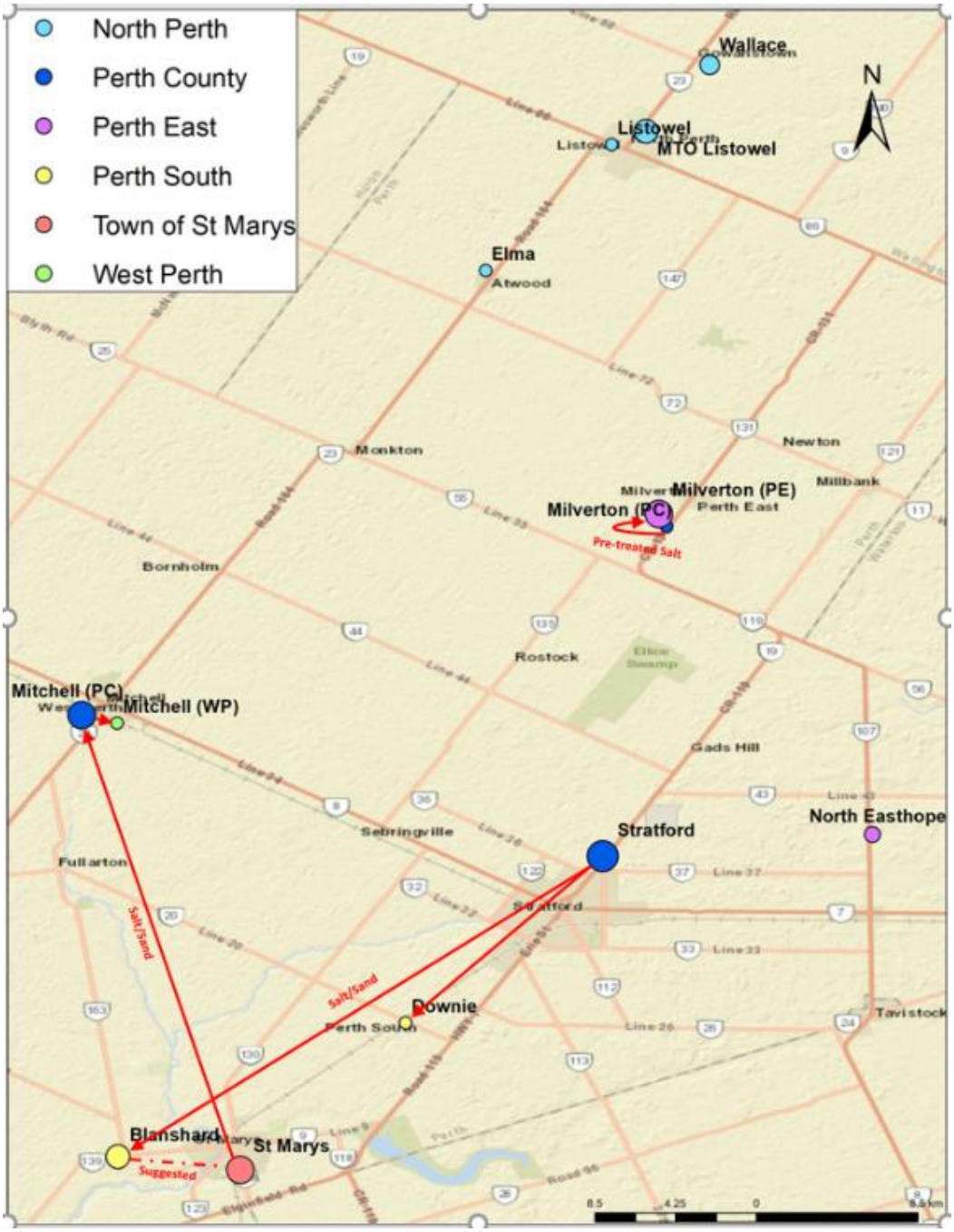



**Figure 9: Maintenance Yard Locations and Sharing of Winter Material**

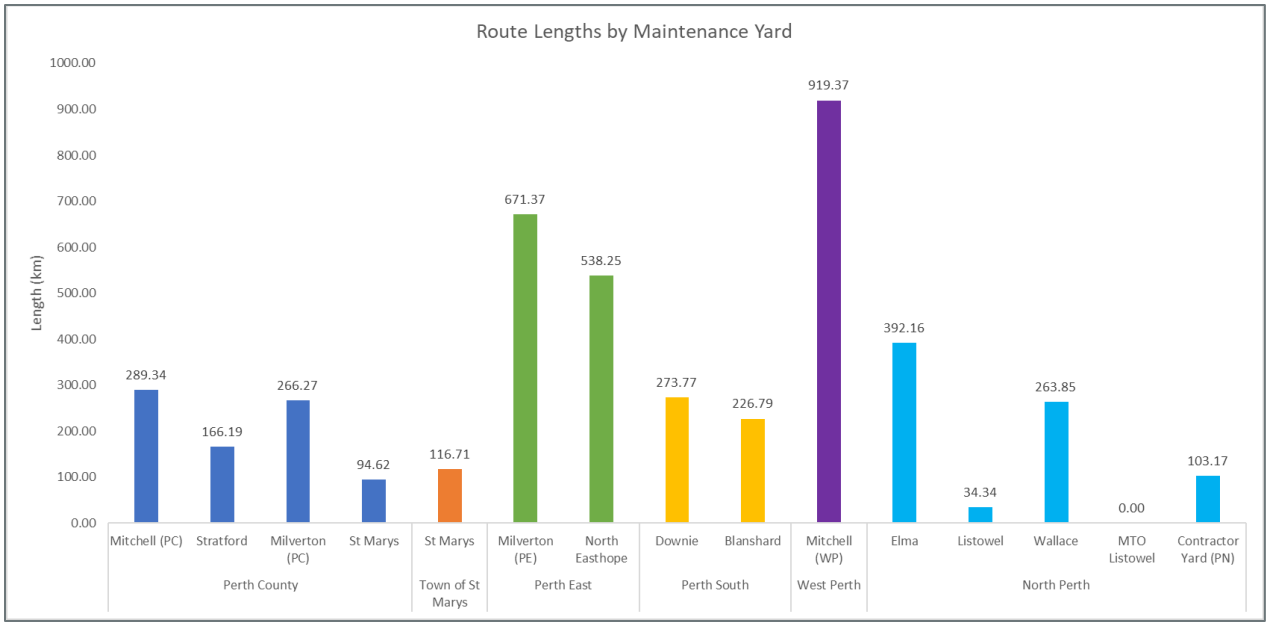



**Figure 10: Route Length Serviced Per Yard**

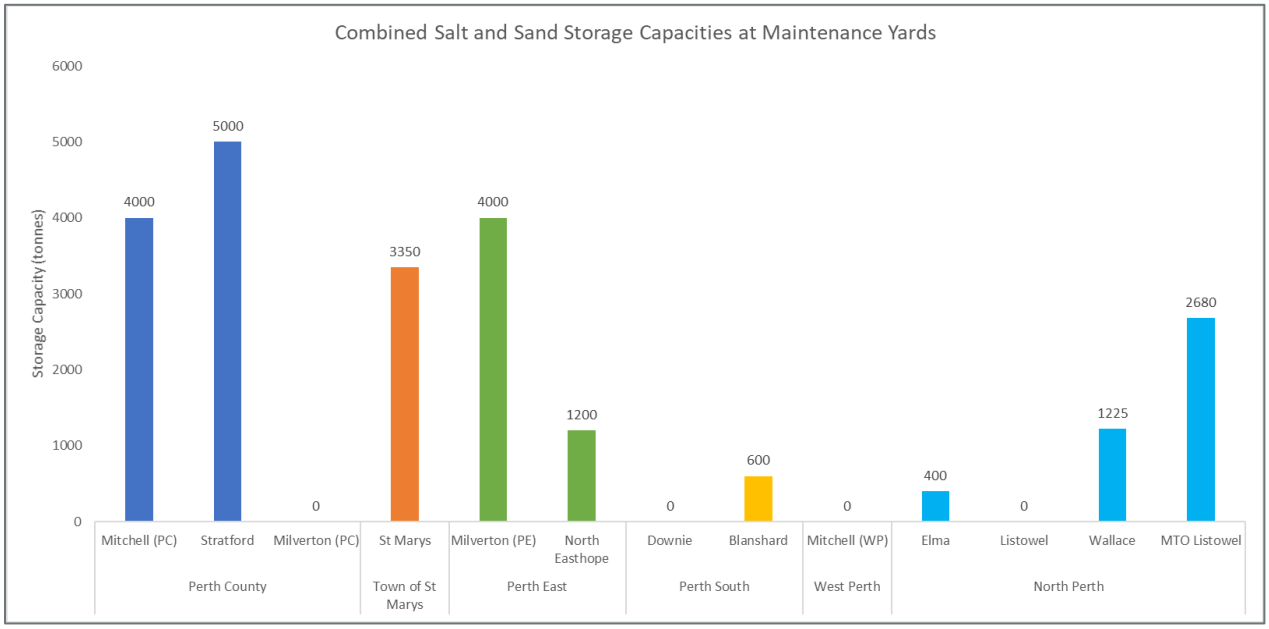



**Figure 11: Material Storage by Maintenance Yard**

### 4.3.2. Optimization of Existing Routes Using MMS Priority System

Optimization of existing routes within municipal boundaries and using the MMS class system priorities resulted in combination spreader route distance reductions averaging 3.2% (**Figure 12**) and grader route reductions of 2.1% (**Figure 13**). **Appendix E** presents detailed results for all routes. It is noted that a 10 km segment of a West Perth route may be misclassified as deadheading when plowing and its optimization may be overestimated. The distance reductions of the optimized routes within current municipal boundaries are within the limits of precision identified in the geocoded route data and the route optimization process and therefore considered not significant. It may be concluded that the current route network is very efficient.

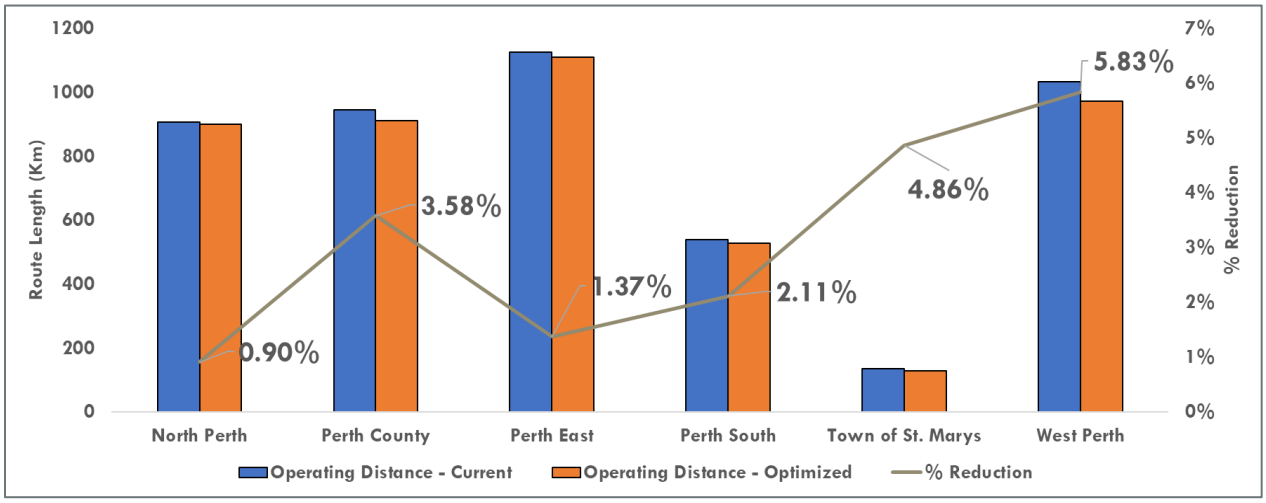



**Figure 12: Spreader Route Optimization within Existing Municipal Boundaries**

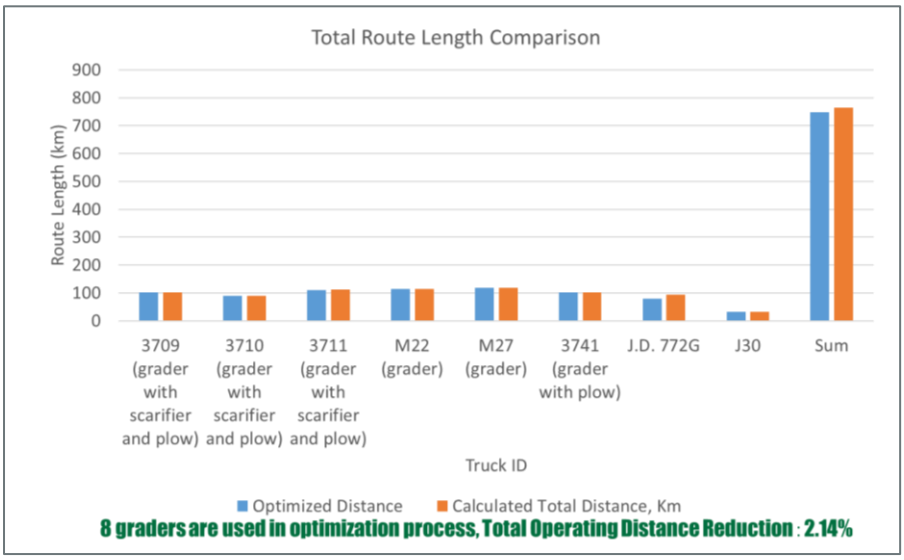



**Figure 13: Grader Route Optimization Within Existing Boundaries**

### 4.3.3. Network Optimizations Using Two-Level Priority System

In the following optimization analyses a two-level priority system was used to more closely resemble practical routing considerations.

The removal of municipal boundaries scenario used the current maintenance yard network and fleet characteristics. Routes were optimized without regard to municipal boundaries and resulted in 2% cost savings compared with the optimized within-municipal-boundaries routes (**Figure 20**), and a likewise marginal improvement in service time (**Figure 19**).

The maintenance yard removal scenario retired yards from service according to the yard's weighted function rank (**Table 3**). The MTO Listowel and Contractor's yards were eliminated prior to beginning the analysis, although the Contractor's service vehicles were retained. Each time a maintenance yard was removed from service, its associated spreaders or plows were also removed, and its routes were assigned to the nearest remaining yards. The process was repeated until the optimized routes no longer met the constraints of MMS service time or spreader capacity to complete the route. Since the remaining routes could consist of different route segments than the current routes, material spreading rates previously associated with each route segment were retained for that segment.

**Table 3: Yard Removal Process**

| Yard Removed | Vehicles Removed (total) | Change in Total Route Distance |
|---|---|---|
| **Blanshard** | 2 | 5% |
| **Milverton (PC)** | 3 (5) | 12% |
| **Downie** | 3 (8) | 18% |

The removal process proceeded for four steps until the spreader capacity requirement was no longer met by the optimized routes (**Figure 14**, **Figure 15**) predicting that ten yards with 37 vehicles is the lowest viable number. Detailed results for each scenario are provided in **Appendix E**. The analysis demonstrates the feasibility of retiring up to three maintenance yards and eight combination spreaders from the network while meeting basic service time and spreader capacity requirements. The removals result in an estimated increase of 18% in total route length. **Figure 14** and **Figure 15** also illustrate that the buffer in spreader capacity is reduced as fleet vehicles are removed and routes become longer with fewer depots, indicating that service standards are reduced with fewer depots and service vehicles.

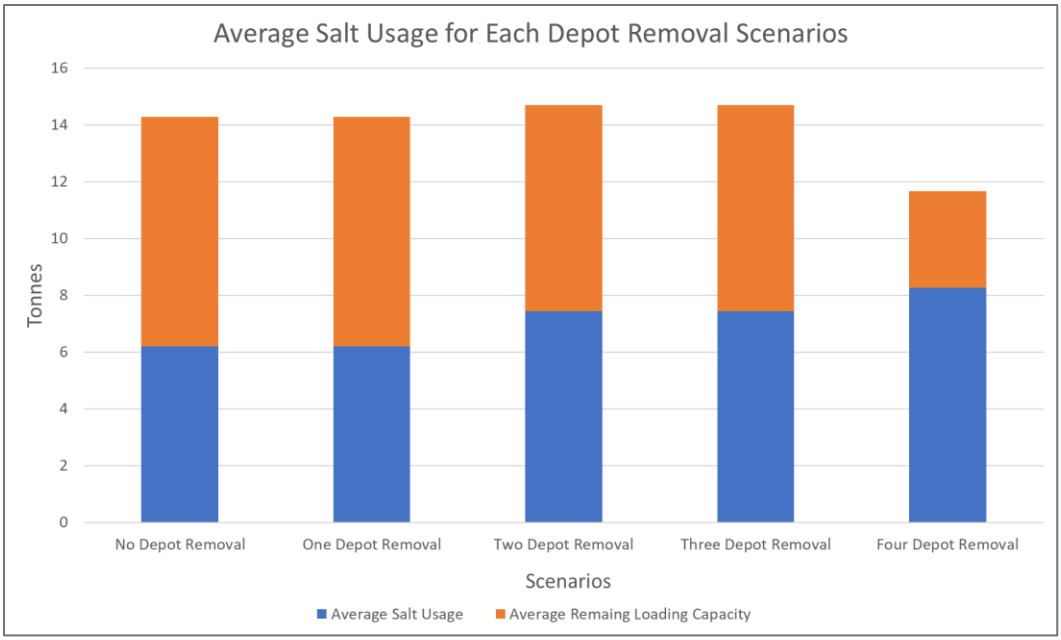



**Figure 14: Summary Salt Spreading Capacity with Yard Removal**

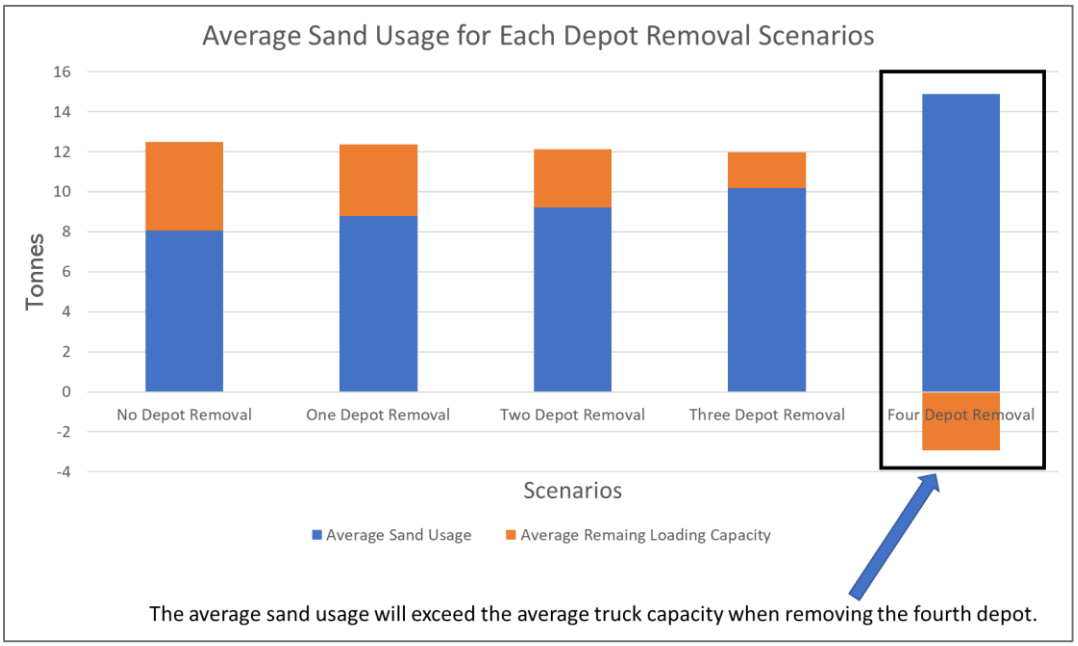
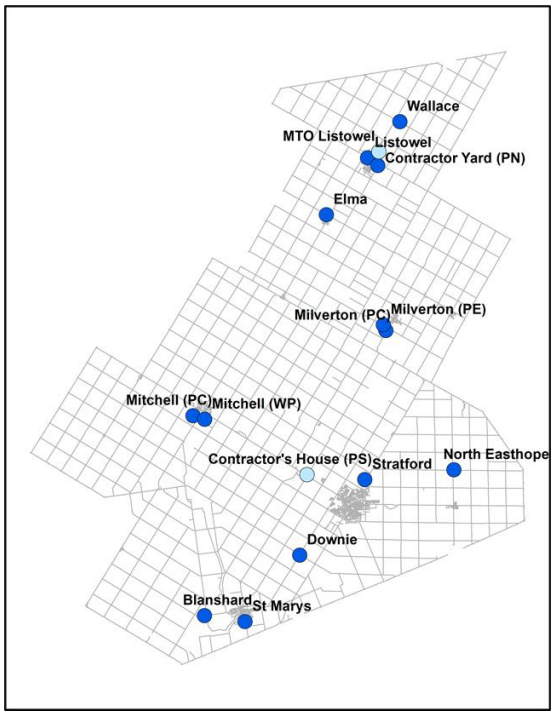


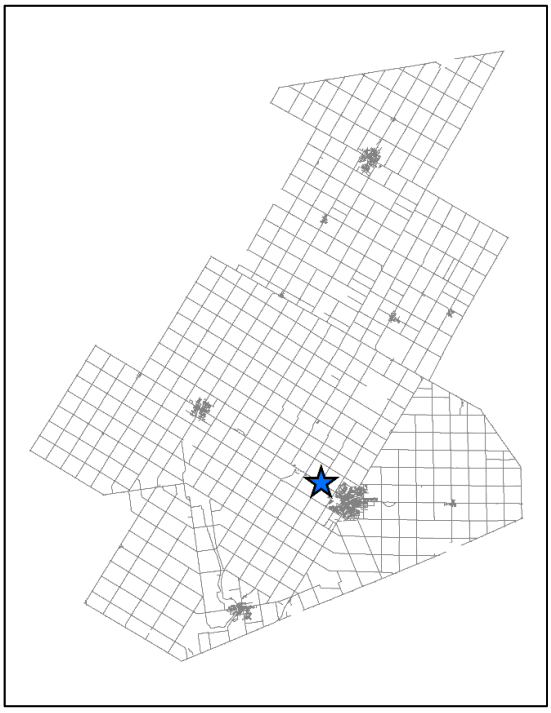

**Figure 15 Summary Sand Spreading Capacity with Yard Removal**

The clean slate approach used an initial analysis to locate maintenance yards such that they provide maximum coverage of the integrated road network without regard to road class or operating routes. This process was repeated for cases from one yard up to thirteen yards. A statistic was calculated, normalized travel cost, that represents the total travel distance to cover the road network based on the predicted yard locations (**Appendix E**). The current yard locations and examples of the optimum locations for a one, six, and thirteen yard network are illustrated in **Figure 16**, and marginal benefits associated with all cases from one to thirteen yards is illustrated in **Figure 17**. The curve predicts that

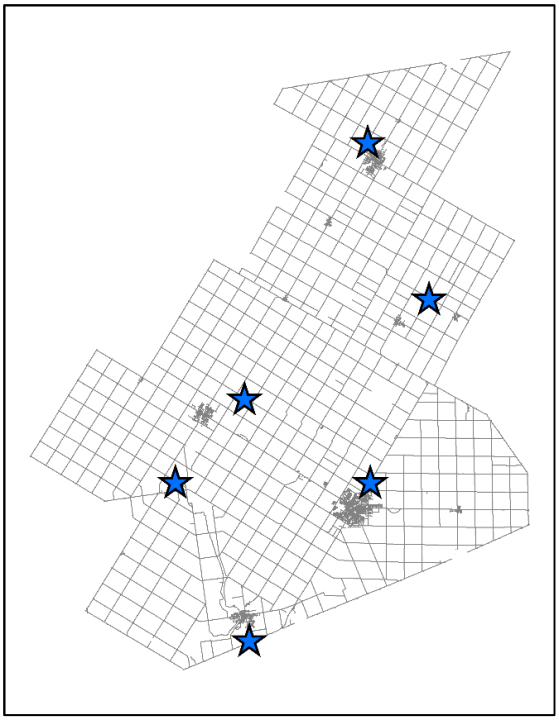
the benefit in adding more depots to reduce individual route lengths will level out as the number of depots exceeds eight.



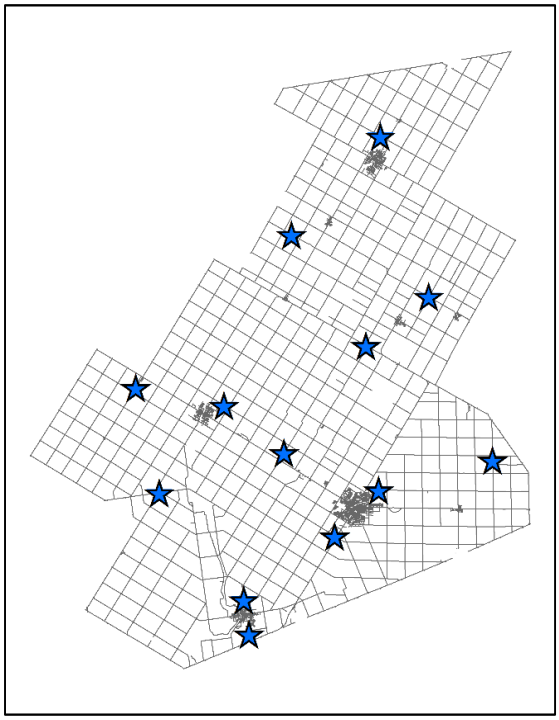

(a) Existing 13 depots



(b) Optimal 1 depot



(c) Optimal 6 depots



(d) Optimal 13 depots

**Figure 16: Existing Maintenance Yards and Optimized Location Examples**

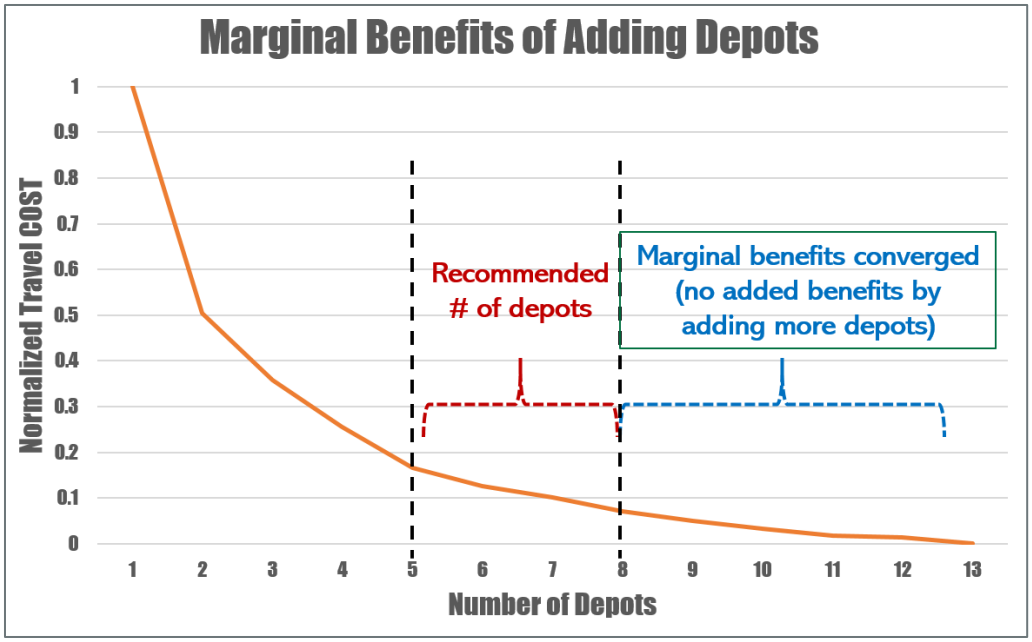



**Figure 17: Change in Route Servicing Cost with Increasing Number of Optimized Yards**

The total number of service vehicles was determined from the yard removal analysis, which showed that 37 vehicles is the minimum viable number to be able to service the ten-yard network without refilling. This number was adopted for the Clean Slate analysis. In addition, it was assumed in the Clean Slate analysis that all trucks are single axle capacity to ensure that both rural and urban routes can be serviced since the previous analysis including single, double and tri-axle trucks showed that many routes have excess capacity. This assumption assures a conservative result since double or tri-axle trucks would be assigned in practice to many routes. Trucks were assigned to each depot in proportion to the distance of road network assigned to that depot by the location model. Route optimization was predicted for each yard network scenario and the average route distance and service time were calculated. With reference to the marginal benefits curve (**Figure 17)**, six optimally located yards were selected for route optimization. The distribution of yards and vehicles for the optimal yard removal and clean slate analysis are compared in **Figure 18**. It is noted that at least four of the six clean slate yards are near an existing yard, suggesting the possibility of using them in a clean slate network.

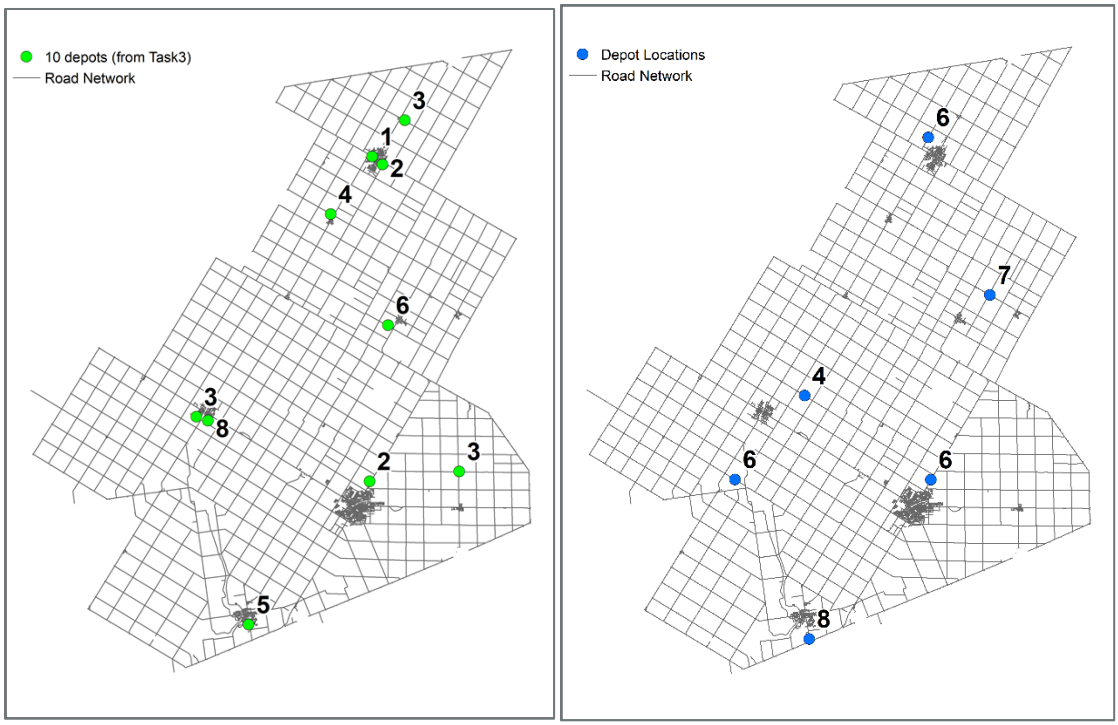



**Figure 18: Distribution of Optimal Yards and Fleet for Yard Removal and Clean Slate**

**Figure 18** above illustrates that geographically ideal locations are situated relatively nearby existing maintenance yards. For practical considerations it is suggested that network optimization could proceed on the basis of upgrading existing yards rather than construction of new ones.

Service level indicators for all scenarios are compared in **Figure 19** in relation to the base case of current routes in the existing network. An increase in either statistic, material volume to capacity ratio or service time ratio, indicates a reduction in level of service. An increase in material volume to capacity ratio means that the buffer in spreader capacity to complete the route is reduced. Both service level indicators increase with each step of yard removal. The service time ratio increases from 17% to 25% between the ten-yard removal scenario and the six-yard clean slate scenario, indicating that the clean slate scenario has a lower predicted level of service than the yard-removal scenario.

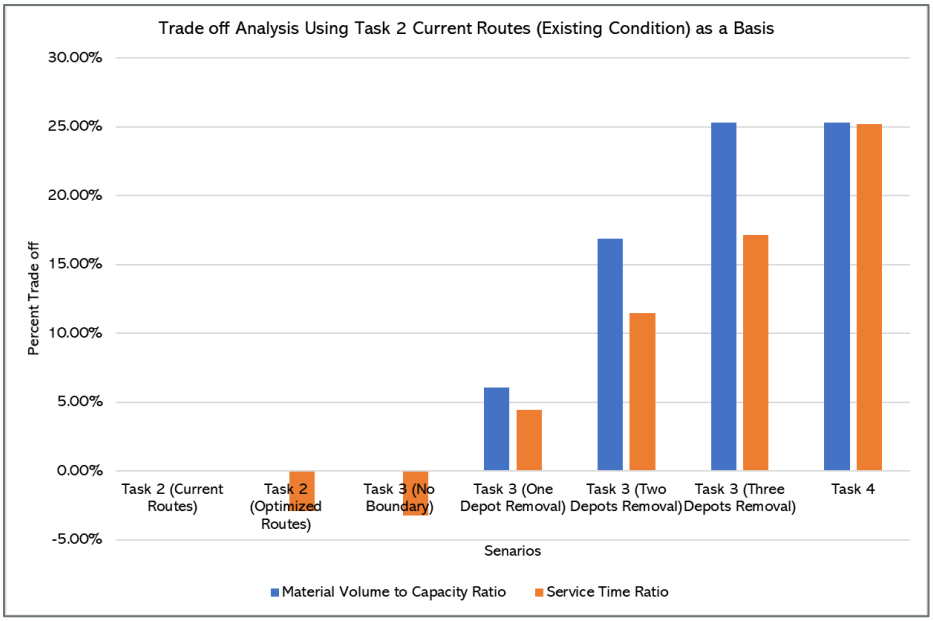



**Figure 19: Service Level Indicators**

The predicted cost of each scenario is compared in **Figure 20**. Predicted costs are shown separately for the total estimated annual yard rental and the total estimated annual fleet (including equipment rental and labour for plowing/spreading operations). Savings are predicted when the total cost of a scenario is lower than the current condition scenario. The ten-yard scenario provides the greatest predicted cost savings, estimated at $310,000 annually, or 14% of the estimated current cost for combined yard and fleet rental.

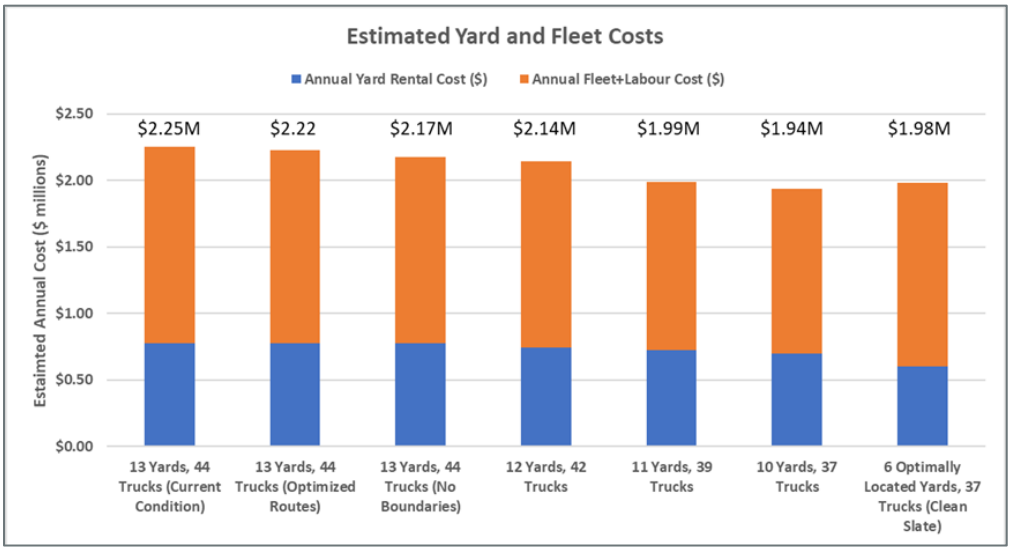



**Figure 20: Network Integration Cost Analysis**

The analysis demonstrates that with a reduced number of depots and reduced number of service vehicles, the predicted service time will increase and thus the level of service decreases (**Figure 19)**. The service time ratio is reduced (level of service improved) with removal of municipal boundaries and

current depots and service vehicles. But increased (reduced level of service) as depots and vehicles are removed.

While the service time ratio increases between the yard removal and clean slate scenario, the spreader capacity ratio remains constant. This implies that the six-yard ideally located scenario has increased deadheading compared with the ten-yard scenario. The number of service vehicles in the clean slate analysis was arbitrarily determined from the yard removal analysis, and analysis using other assumptions about fleet numbers or size could determine a fleet arrangement with different service levels.

### 4.3.4. Conclusion and Recommendations

Current maintenance routes are well matched to service areas and readily meet MMS requirements. Computer-based optimization of spreader and grader routes under existing agency boundary conditions showed that current routes operate very efficiently, and no significant savings are possible. Removal of municipal boundaries with current maintenance yards and fleet resulted in small cost savings and service improvements.

Optimization by retirement of lower functioning maintenance yards resulted in a minimum network of ten yards and substantial predicted cost savings but with attendant reduction in service level. Optimization using the clean slate approach with resulted in a minimum network of six yards with lower cost savings and lower predicted service levels than the ten-yard scenario. The reduction in service levels increases the risk that service times will not be met and that spreader capacities will not be enough to complete service routes under extreme weather conditions that require more material to be spread.

The overall conclusion of the network integration and route optimization analysis is that the removal of maintenance yards and their corresponding service vehicles reduces operating costs but results in an undesirable reduction in service levels compared with the current levels.

This study focused on the feasibility of yard network reduction while maintaining or simplifying the current fleet characteristics and predicting the associated annual operating costs of the maintenance yards and the fleet. It did not predict impacts of different numbers or types of service vehicles nor did it analyse capital costs associated with maintenance yard repurposing, whether expanding to accommodate a larger fleet or decommissioning from winter maintenance operations. The following additional planning studies are recommended to further investigate the feasibility of a reduced-yard network:

- Estimate service levels of optimization scenarios with the reduced yard network but different numbers of service vehicles and loading capacity characteristics as a **Priority 1 Action** .
- Review maintenance yard facilities in more detail to prioritize those which would be part of a future network and those which would be retired, and to analyze changes or upgrades to accommodate the different fleet and personnel distribution of a new yard network, as a **Priority 2 Action**.
- To review staffing implications of a new maintenance network based on the predicted numbers of trucks to be stationed at each yard, including personnel issues in scheduling the roll-out of a new network configuration, as a **Priority 3 Action**.

## 4.4. Weather Information

### 4.4.1. Background and Benchmarks

Road maintenance supervisors require timely weather forecasts specific to snow and ice accumulation on road surfaces, in order to plan and schedule winter patrolling and operations. Section 3.1 of MMS requires monitoring of current conditions and 24-hour weather forecast, at least 3 times per day from October through April or once per day from May 1-September 30. Details as to the method of weather monitoring are not specified in MMS but are addressed in OGRA Guidelines for patrolling. They include access to a local weather forecast that includes air temperature, wind direction, speed and dew point, and to a Road Weather Information System (RWIS) or a patrol truck equipped to monitor pavement and air temperature, and to communicate the observed data to operations staff.

Weather information is also a key component used in defense of road liability for winter accidents and it is therefore critical to retain a chain of custody: documentation of when weather information was consulted, the content of the information and how it was used in decision making.

These factors are adopted as benchmarks for weather forecast information in this study.

Sources of weather information available to road agencies in Ontario are listed in **Table 4**.

**Table 4: Sources of Weather Information in Ontario**

| Source | Measurement sites | Forecast sites | Key features and sensors | $ Operating | $ Capital |
|---|---|---|---|---|---|
| **Environment Canada** | ~15 | ~ 200 | Atmospheric only | 0 | 0 |
| **MTO RWIS** | ~150 stations<br>~300 cameras | ~150 | Road sensors, visibility, icing, cameras | ~$10,000/site/yr | $500,000 |
| **OGRA Winter Weather App (MESH)** | 0 | 1 to 7 | Atmospheric only | $259-999/month | 0 |
| **Private RWIS** | yes | yes | Road temp., visibility, icing | ~$1000/site/month | $500,000 |
| **Mini-RWIS** | yes | no | Icing, visibility, weather | $500/site/month | $20,000+ |
| **TV/Web weather channel** | 0 | yes | Atmospheric only | 0 | 0 |
| **Mobile RWIS with Spectral Camera** | Yes. Agency vehicles | no | Road temp, icing | $100/month/vehicle | $20,000 Per vehicle |
| **Infra-red thermometer (IRT)** | Yes. Agency vehicles | no | Road temp. | Agency vehicle | $2,000 per vehicle |
| **Road patrol** | See mobile RWIS | no | Snow cover, icing, drifting | Agency vehicle | 0 |

The implementation of different weather sources by road agencies typically follows a hierarchy, with MTO and several large and medium municipalities (i.e. Toronto, Ottawa, Waterloo, Chatham) using RWIS. These systems meet all requirements of MMS and can be configured to push a weather forecast to local sites or cell phones at defined times. They include in-pavement and roadside sensors that support the use of winter liquids such as Direct Liquid Application or selection of variable application rates for granular or pre-wet salt. Access to the MTO RWIS system (**Figure 21**) is available to any municipality at no charge. It is currently accessed by 20 Ontario municipalities.[10]

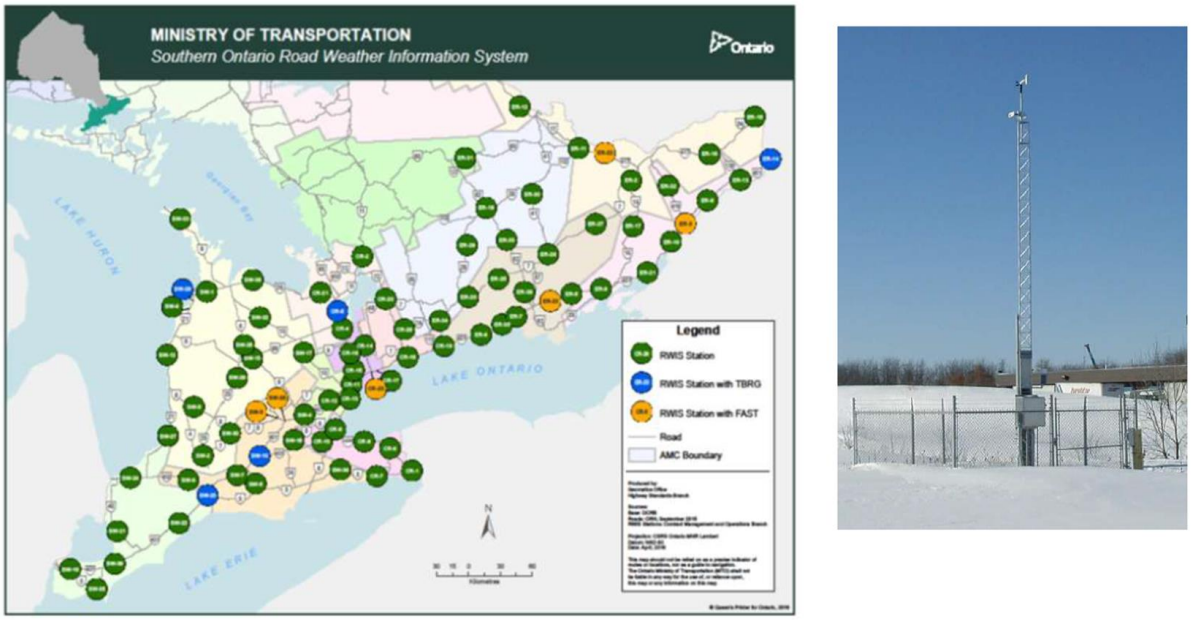



**Figure 21: MTO Southern Ontario RWIS Network and Typical Roadside Station**

**Figure 22: Mobile Spectral Camera and Map Data Display**

[10] personal communication, J. Boone, MTO

Key differences among the weather sources are:

- Sources with no measurement sites use global weather models obtained from forecast agencies to estimate conditions at a particular site. Global weather models are checked and calibrated against atmospheric weather station data, but not against roadside data. Sources with no measurement sites do not measure nor accurately forecast road surface conditions. They can estimate the occurrence of falling or drifting snow or freezing rain. The OGRA Enterprise Weather App and MESH, a commercial service, meet all requirements of MMS. A single Enterprise App subscription provides atmospheric forecast at up to seven sites.
- RWIS-based road sensors measure pavement surface and subsurface temperature, presence of road salt, likelihood of frost or snow film, and estimated freezing point of road surface at the sensor location. They are typically coupled with a forecast service. Road surface temperature and forecast are very important for the safe use of anti-icing liquid. A recent study on road weather information systems for U.S. state Departments of Transportation concluded a benefit:cost ratio of 4:1 for direct benefits in operational savings, and more than 200:1 considering indirect benefits such as reduced accident costs, reduced patrolling costs and reduced maintenance costs.
- Mobile RWIS uses remote sensing technology mounted on patrol vehicles (**Figure 22**), spreaders or other vehicles to measure road surface temperature, barometric temperature, and detect the presence of a snow or ice film (spectral camera). While they can help to extrapolate RWIS site forecasts along a roadway, systems currently available do not directly provide a forecast.
- Infra-red thermometer mounted on road vehicles provide a real-time reading of surface temperature (whether pavement or snow on the pavement). The information is useful for adjusting salt application rates and necessary for anti-icing with direct liquid application. It provides information only while the vehicle is traversing the road and so is limited in frequency.

Based on the above discussion, many agencies use the OGRA Weather App or similar commercial services, as they provide a weather information push at regular intervals as required by MMS, a record when the information is consulted, and the content of the information. The current status of weather information and record keeping of the Perth agencies is summarized in **Table 5**.

**Table 5: Current Status of Weather Information and Record Keeping**

| Agency / Criteria | Perth County | Perth East | North Perth | Perth South | St Marys | West Perth |
|---|---|---|---|---|---|---|
| **Source of Weather Forecast** | RWIS for Foreman, OGRA, IRT | EC Stratford Station for Public Works Manager or Delegate, IRT | Unknown (IRT present on patrol trucks) | RWIS for Director and Foreman, OGRA, IRT | RWIS, OGRA, IRT | OGRA, IRT |
| **Frequency** | 3 | 3 | Unknown | 3 | 3 | 3 |
| **Actioner** | Foreman | Public Works Manager or Delegate | Patroller and Supervisor | Director and Foreman | Supervisor and On-Call Operator | Operations Manager and Foreman |

| Agency / Criteria | Perth County | Perth East | North Perth | Perth South | St Marys | West Perth |
|---|---|---|---|---|---|---|
| **Archiving** | MESH, Paper | MESH | Paper | OGRA Winter Web App, Paper (expecting to switch to MESH) | OGRA Winter Web App | OGRA Winter Web App, Paper |

### 4.4.2. Conclusions and Recommendations

All agencies document weather forecast information to provide a legal record if required. Five subscribe to a benchmark weather forecast system that provides required information and documentation with frequency required by MMS, of three times a day. The lack of documented monitoring of a weather forecast imposes a liability risk should an incident occur due to a delayed response in deploying equipment.

Three agencies have access to data from a nearby MTO RWIS station and all agencies employ their own mobile infra-red thermometers to track pavement temperatures, as recommended by OGRA weather monitoring guidelines. This assists in selecting winter materials and application rates that are effective at the current or forecast pavement temperature. Agencies that do not use those technologies are more susceptible to using winter materials less efficiently and to challenge in court. Finally, the chain of custody of weather information is not clearly documented in all cases, opening the possibility of challenge in court.

The identified gaps can be addressed through the following recommended actions:

- **Priority 1 Actions** to reduce to reduce liability risk and to assist in using winter materials effectively:
  - Extend the OGRA Winter Weather App subscription to all agencies to ensure a regular and archived forecast that is communicated to key staff. A single subscription such as that held by Perth County and others, can service up to seven clients,[11] and the extended implementation can be obtained with a single subscription at the Enterprise level. Use of the App will serve to reduce the risk of road liability by documenting the use of best practices for weather information.
  - All agencies update their processes to access weather information at least three times daily.
  - Extend the existing MTO RWIS sharing agreement[10] (**Appendix G**) to all agencies to promote more effective use of winter materials and especially of winter liquids, in which the benefits of use vary with pavement temperature and air humidity levels. Implement a training and demonstration session to promote the benefits of a future RWIS station or mini-RWIS within Perth County.
- **Priority 2 Actions** that support the effective use of winter materials:
  - Develop a plan to evaluate the benefits of a county-owned RWIS in selecting currently used winter materials (pre-wet or pre-treated salt) and in future adoption of direct liquid application technology. Safe and effective use of direct liquid application requires access to a local road temperature forecast.
- **Priority 3 Action** can be the implementation of a future RWIS station or mini-RWIS within Perth County.

[11] Personal communication, F. Suja, OGRA

## 4.5. Patrolling

### 4.5.1. Background

Patrolling is the regular, direct observation of road conditions on a representative part of the road network in advance of and during winter events to help make informed, logical, and forward-looking decisions about plowing, salting, and sanding operations as a storm evolves. In addition to the observation of conditions, it includes documentation and communication; providing a written record with a chain of custody of what was seen, where and when, in case of future legal action. It normally involves a recording template with standard terminology. This can be in the form a written diary or an electronic diary. Electronic diaries may include real-time or after the fact link to a communications and archive system.

Patrolling leads to deployment call-outs during the winter season, which involves providing instructions to equipment operators as to when to prepare, load equipment, and deploy for winter services, including operational details about where, when and how, and material application rates. Deployment may occur multiple times during a long storm. Deployment decisions normally use operating guidelines or rules of practice to help make consistent decisions, such as a table that relates current and forecast temperature and snow conditions to the recommended type of operation for those conditions. To provide reliable defense of claims the chain of custody should flow from the observer to the person managing deployment (such as the shift supervisor or foreman) or directly to the equipment operator. If it goes to the shift supervisor/foreman, then a separate record should show what operations were ordered, by whom, where, when, and what.

### 4.5.2. Benchmarks

MMS does not specify a frequency of patrolling for winter conditions beyond that specified for other conditions, but to patrol representative sections of highway at intervals deemed necessary to check for accumulation of ice or snow. The onus is on the municipality to establish a suitable frequency.

However, benchmarks for patrolling guidelines (A Guideline for Patrolling Representative Roads in Winter)[12] are provided by the OGRA and indicates that any patroller must be equipped with the following:

- Training as to what is a winter event and winter event response, what is the route of representative roads to be patrolled between winter events, their duties during a winter event, record keeping requirements and callout procedures, plus any and all other policy and procedures for winter highway operations. Training on the interpretation of the weather information and the de-icing chemicals to be applied for the forecasted weather conditions is also required;
- A vehicle equipped with a pavement thermometer, and ambient air temperature thermometer and two-way communications;
- Access to local weather forecasts (local radio station, computer at office with internet access, etc.) that includes information on air temperature, wind direction and speed and dew point;
- A map of the entire road system showing all plow routes and a map (or text document) of the representative roads and susceptible areas to be patrolled; and
- A method of recording weather and road conditions observed.

[12]https://www.ogra.org/files/Winter/A%20Guideline%20for%20Patrolling%20Representative%20Roads%20in%20Winter.pdf

If electronic surveillance equipment is to be utilized, OGRA states that any person monitoring a road system electronically must be equipped with the following:

- Training as to what is a winter event and winter event response. Training on the interpretation of weather forecasts and Road Weather Information Systems (RWIS) information. Training on record keeping requirements and callout procedures plus any and all other policy and procedures for winter highway operations;
- A computer with access to high speed internet;
- Access to RWIS station or stations;
- If available, access to GPS/AVL data; and
- Access to local weather forecasts that includes information on ambient air temperature, wind direction, wind speed and dew point.

Additionally, the OGRA Guideline for Patrolling Representative Roads in Winter provides a benchmark regarding the minimum percentage of the route length to be patrolled based on the road class, as summarized in **Table 6**.

**Table 6: OGRA Length of Patrol Route Benchmark**

| Maintenance Class | Minimum % of Road Class to be Patrolled to Check for Conditions as Described in Sections 4 and 5 of MMS |
|---|---|
| **Class 1** | 25% |
| **Class 2** | 25% |
| **Class 3** | 25% |
| **Class 4** | 10% |
| **Class 5** | 0% |
| **Class 6** | 0% |

OGRA also provides benchmarks for level of service guidelines for patrollers (A Guideline for Developing a Level of Service Policy)[13] and recommends that patrollers should keep records of the following winter operations documents:

- Winter Patrol Record – Route of Representative Roads;
- Winter Operations – Service Update Report;
- Call Out Diary;
- Weather and/or RWIS Information Received;
- Equipment Mobilization Records;
- Ambient and Pavement Temperatures; and
- Pavement Condition.

[13]https://www.ogra.org/files/Winter/A%20Guideline%20for%20Developing%20a%20Level%20of%20Service%20Policy.pdf

### 4.5.3. Current Status and Gaps

**Figure 23** summarizes each Perth agency's total patrol route length as a percentage of total maintenance route length and compares it to the OGRA patrolling guideline benchmark (**Table 6**) indicated by a grey bar.

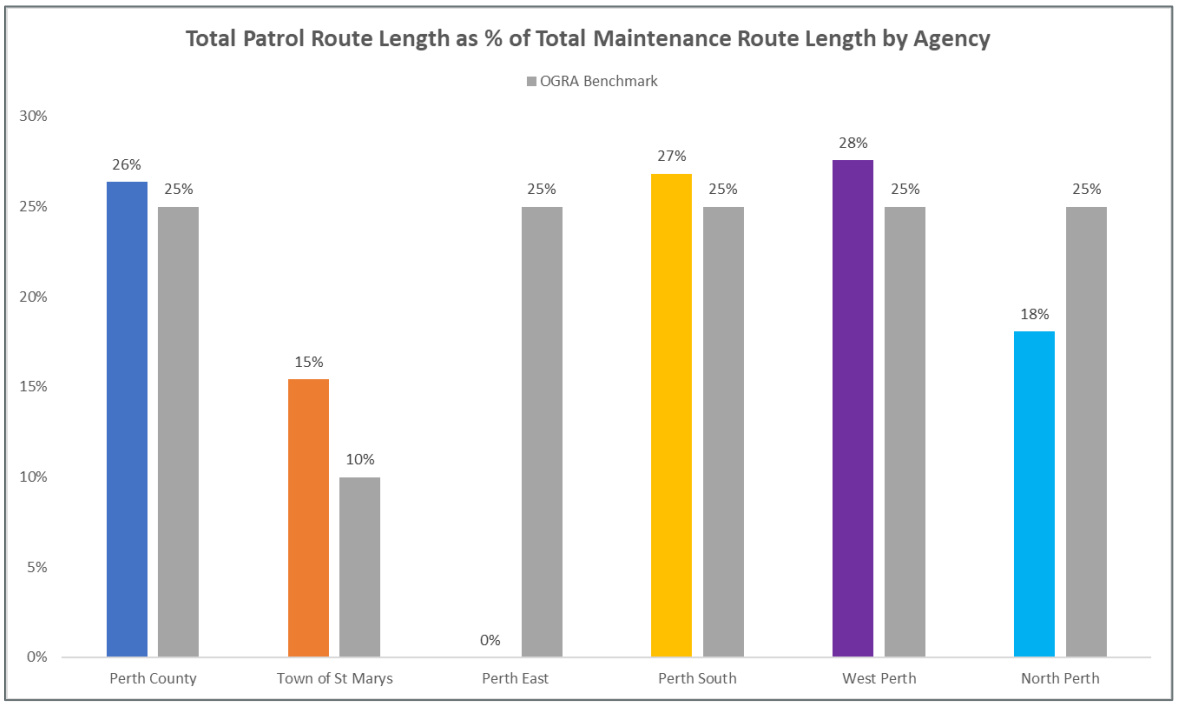



**Figure 23: Total Patrol Route Length as % of Total Maintenance Route Length by Agency**

Four agencies meet the OGRA recommended patrolling route length guidelines, based on the highest road class for each agency. Other agencies do not meet the recommended OGRA patrolling guidelines or do not have a defined patrol route (i.e. it varies due to storm conditions).

MMS allows the use of technology to enhance patrolling. One way this could be implemented would be through a webcam network that would allow observation of road conditions from a remote location, both extending the range and timeliness of patrolling information. It is also noted that municipalities in Perth County have many intersecting roads and additional efficiency could be obtained through an integrated patrolling network.

**Table 7** summarizes the existing status of patrolling and deployment for the Perth agencies.

**Table 7: Status of Patrolling and Deployment**

| Agency / Criteria | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|
| **Staffing/Patrolling Method** | Patroller + Operator | Patroller + Operator | Dedicated Patroller | Patroller + Operator | Patroller + Operator | Patroller + Operator |
| **Reporting Method (1=written log or** | 1 (paper documents | 1, 2 | 2, 5 (uploaded | 1 (Mr. Compliance + | 1, 2 | 1, 2 |

| Agency / Criteria | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|
| **diary, 2=radio, 3=tablet on return, 4=tablet download at patrol yard, 5=tablet download through server)** | kept on file), 2 | | over the air to server once a week to municipal office) | paper log), 2, 4 (Wi-Fi download at patrol yard with live GPS/AVL) | | |
| **Infrared Thermometer Available on Patrol Trucks?** | Yes | Yes | Yes | Yes | Yes | Yes |
| **RWIS Available?** | Yes | Yes | No | Yes | No | No |
| **Patroller Training Provided?** | Yes | Yes | Not Specified | Yes | Yes | Not Specified |
| **Written Material Application Guidelines or Rules of Practice Available?** | Yes | No | No | No | Yes | No |

All agencies use appropriate patrolling documentation. Perth East and Perth South utilize modern tablet technology to record/archive road conditions, while others use standard paper records and radios. All agencies also use infrared thermometers on patrol vehicles to measure current pavement temperatures, assisting in decision making regarding winter material application. However, only Perth County, Perth South, and the Town of St Marys have access to MTO's RWIS records, which provides, for nearby Provincial Highways, current/forecasted pavement temperatures, detection of salt on pavement, forecasts of when water/slush on pavement will freeze, and a webcam for remote patrolling, further enhancing decision making regarding winter material application.

Training for patrollers is provided by Perth County, Perth South, West Perth, and the Town of St Marys. However, information regarding patroller training was not obtained for Perth East and North Perth. Additionally, written material application guidelines or rules of practice that the patroller can refer to when advising equipment operators on actions to be taken during material application based on roadway conditions were not provided.

### 4.5.4. Conclusions and Recommendations

All Perth agencies employ a winter patrol to assist in planning winter operations under inclement conditions, meeting the basic requirement of MMS. However, some gaps exist in comparison with OGRA guidelines that were used as benchmarks in this study and can be addressed by the following recommended actions:

- **Priority 1 Actions** are to reduce liability risk by ensuring accurate knowledge about road surface conditions and the appropriate selection of operating procedures to address them:
  - Patrol routes in Perth East and North Perth should be reviewed to ensure that OGRA guidelines for patrol route length are met, and at the same time to review the potential for integrating patrolling operations with other municipalities.
  - All agencies should ensure that patrollers and patrollers/operators receive annual training appropriate to the patrolling equipment/technology available, such as the

'Supervisor/Patroller Workshop'[14] offered by the OGRA or the 'Winter Patroller'[15] course offered by the AORS to ensure that patrollers are aware of policies, weather information operating guidelines and decision making strategies;

- The Town of St Marys, Perth East, Perth South, and North Perth should provide written material application guidelines or rules of practice that the patroller can refer to when advising equipment operators on actions to be taken during material application based on roadway conditions. This is crucial if the Perth agencies need to defend any claims of negligence related to winter road conditions because written guidelines/rules of practice can be referred to when justifying any decisions that the patroller/operator made on the road; and

- **Priority 2 Action** to improve the timeliness of documentation and to reduce any potential clerical errors and use standardized road condition descriptors for Perth County, West Perth, St Marys, and North Perth to adopt tablet or other mobile technology to record road condition information during winter events.

The recommended actions also promote harmonization of operations with the benefits to providing similar levels of service and strengthening defense of claims.

## 4.6. Winter Materials

### 4.6.1. Background

Winter materials are applied along with plowing to help restore bare pavement after a snow event or to provide an immediate albeit small increase in traction on packed snow. The most widely used material for restoring bare pavement is rock salt.[16] In modern practice, liquid chemicals are mixed with rock salt in the stockpile (**Figure 24**), or during spreading operations to improve its retention on the road and performance in melting dry or packed snow. Salt application rates may be reduced by up to 30% with no loss in effectiveness.[17, 18, 19]

In addition to the benefit in salt reduction, the lower application rates mean that spreading routes can be extended to reduce spreading costs. Liquid chemicals can also be applied directly to the pavement in advance of snow accumulation (anti-icing or direct liquid application) to prevent frost or to delay the need for salt application, and may reduce the number of conventional salt applications needed in a long storm.[20] DLA is used in advance of snow accumulation on most Class 1 Provincial highways in Ontario and in large urban areas[20] (**Figure 25**).

[14]https://www.ogra.org/courses-and-events/Events/winter-maintenance-operations-training.html
[15]https://aors.on.ca/wp-content/uploads/2020-AORS-Winter-Patroller.pdf
[16] Perchanok, 1991, Report MAT-91-02. Highway Deicers-Standards and Practice in the Province of Ontario., Research and Development Branch, MTO
[17] https://clearroads.org/project/15-01/
[18] https://aurora-program.org/research/completed/expert-system-for-maintenance-decision-support/
[19] http://conf.tac-atc.ca/english/resourcecentre/readingroom/conference/conf2006/docs/s003/sooklall.pdf
[20] http://www.mto.gov.on.ca/english/ontario-511/winter-highway-maintenance.shtml

**Figure 24: Pre-Treated Salt and Dry Rock Salt (MTO)**


**Figure 25: DLA (MTO)**

Winter sand is used to improve traction when temperatures fall below the effective range of rock salt or on low volume roads where traffic is insufficient to activate salt, or where traffic volumes do not warrant expenditure on salt, and on unpaved roads. A small quantity of salt (<15% of sand mass) is normally mixed with sand to prevent stockpile freezing, and heavier mixtures of salt (>15%) with sand may be used to aid in slowly restoring bare pavement or in immediately increasing traction on packed snow (i.e. >15% salt in mix). While high ratios of salt are sometimes used with the intention of melting snow, experimental research has not proven out a benefit over simply applying the same mass of salt without sand.[21] In addition, road safety studies show a much greater safety and mobility benefit to baring pavement soon after a winter storm than to maintaining a sanded, snowpacked surface.[22]

[21] Comfort, G. and A. Dinovitzer, 1996. Field Tests of Winter Sand on Packed Snow and Bare Ice Surfaces. MTO R&D Branch Report MAT-96-01

[22] https://itsslab.com/perchanok-m-mcclinktock-h-fu-l-thakali-l-huid-h-t-2014-a-benefit-cost-approach-to-level-of-service-standards-for-winter-road-maintenance-proceedings-of-the-14th-international/

Considering the cost differences and increased effectiveness of pre-treated or pre-wet salt vs. dry rock salt, 10% net savings in material costs can be achieved using pre-treated salt and 20% net savings using pre-wet salt (**Appendix H**). Additionally, these savings do not include potential cost reductions due to the ability to increase route length as a result of the reduced application rates nor the environmental aspect of salt reduction.

Winter materials comprise a total of approximately $1.9M by the Perth County agencies, with road salt being the largest single factor (**Figure 26**). The direct cost of materials is closely associated with fleet costs and with the material storage component of maintenance yard costs. Material use is also related to the  much higher higher indirect costs of environmental contamination from road salt and indirect benefits of road user costs arising from avoided travel delays and collisions on icy roads. Effective use of winter materials is therefore a key factor in a cost-effective winter maintenance program.

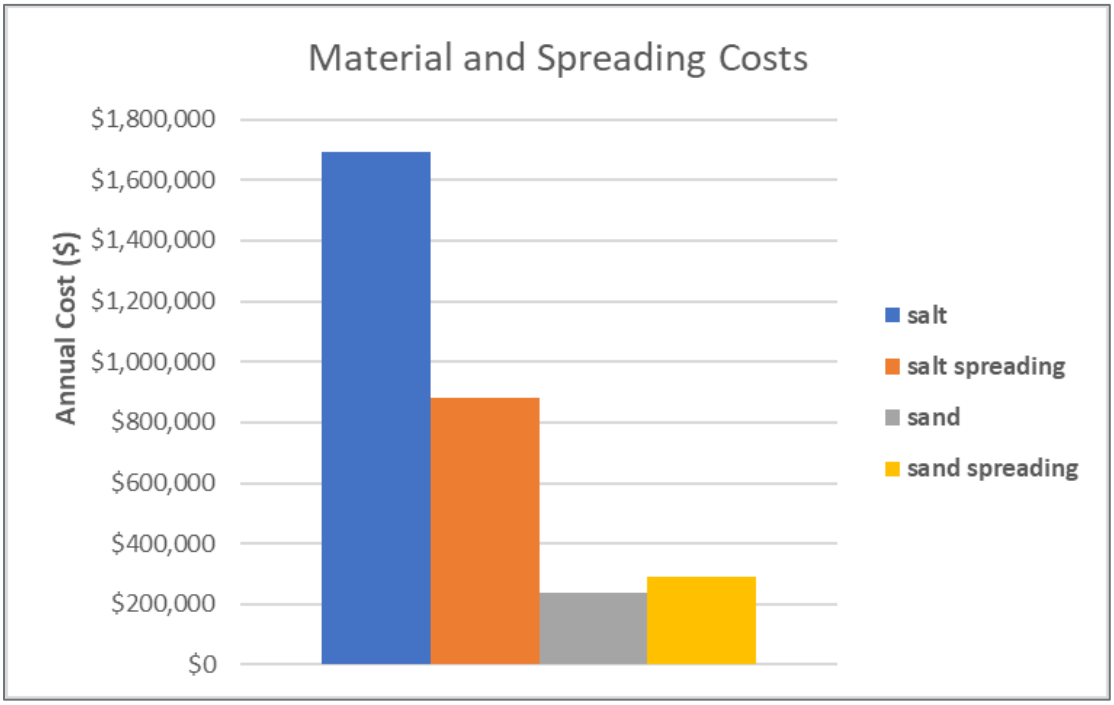



**Figure 26: Winter Materials Costs – Perth County Agencies**

### 4.6.2. Benchmarks and Comparison

Neither the selection of winter materials nor their application rates are prescribed in MMS and practices used by agencies are known to vary dramatically, especially in lower tier agencies between urban areas with higher traffic volumes and rural areas with low volumes. While there is extensive research literature that recommends pre-wetting[23] and relating application rates to weather conditions,[24] none was found to provide guidance about material applications on different classes of roadway or surface

[23] https://www.canada.ca/content/dam/eccc/documents/pdf/pollution-waste/road-salts/6136_Annual%20Overview%20Road%20Salts%20Report_full%20document_EN.pdf#:~:text=Code%20of%20Practice%20for%20the%20Environmental%20Management%20of,harm%20to%20the%20environment%20while%20maintaining%20roadway%20safety.

[24] http://clearroads.org/wp-content/uploads/dlm_uploads/Summary-Report-of-Task-2-Findings.pdf

types. Nearby road agencies were therefore surveyed to provide comparators for Perth County (**Table 8**).

Material type was found to vary from upper tier agencies to lower tier agencies (i.e. MTO > County > Town/Township). Upper tier agencies such as the MTO, Wellington County, and Grey County use pre-treated/wet salt and/or DLA on paved roads while lower tier agencies use sand mix or straight sand. Only straight sand or sand mix is used on gravel roads of both upper and lower tier agencies.

Material application rates are illustrated in **Figure 27** for comparator agencies and in **Figure 28** for Perth County agencies. (A rate of 0 is shown in **Figure 27** where an application rate could not be determined but the material is used, and in **Figure 28** where no material is applied on grader routes.

Material application practices in Perth County are similar to those of Wellington and Grey Counties. Perth County uses pre-treated/wet salt on all routes at a typical application rate of 65 kg/lane km. Wellington County uses pre-treated salt at an application rate between 45 and 70 kg/lane km and DLA is also used on bridges or roads with higher traffic volumes. Grey County does not use pre-treated or pre-wet salt but uses DLA prior to any solid material application.

The Town of St Marys uses practices comparable with the Town of Caledon, primarily using sand/salt mix on all routes at a typical application rate of 115 kg/lane km. Caledon uses a mix of sand and pre-treated salt is at an application rate of 100 kg/lane km.

The Township of Wellington North uses only winter sand, at an application rate from 150 to 375 kg/lane km. Perth South uses similar practices while other townships in Perth use sand/salt mix at lower rates, from 120 to 150 kg/lane km.

Pre-treated or pre-wet salt is used only by Perth County and some roads in Perth East. West Perth and Perth East only use salt in urban areas, whereas North Perth, Perth South, and the Town of St Marys use winter sand. Material usage exhibits a trend to more use of salt with increasing proportion of Class 2 and 3 roadways ( **Figure 29).**

Sand application by all agencies is at operator's discretion using criterion such as weather conditions (i.e. wind conditions, temperatures below -14C) and 'danger spots' (i.e. hills, curves, intersections) to apply sand. Perth County, Perth East, Perth South, and West Perth use written rules of practice for application rates. None of the agencies use any material on gravel roads.

**Table 8: Winter Materials Used by Comparator Agencies**

| Benchmark | Agency | | | | |
|---|---|---|---|---|---|
| | **Wellington County** | **Grey County** | **Town of Caledon** | **Township of Wellington North** | **MTO** |
| **Paved Roads** | | | | | |
| **Material(s) Used** | Pre-Treated Salt, Pre-Wet Sand** (pre-wet on trucks), 50:50 Sand/Pre-Treated Salt Mix, DLA (typically applied on bridges, where no salt or sand is applied, and on roads with higher traffic volumes) | Dry Salt, Winter Sand**, DLA (applied on road prior to material application) | 75:25 Sand/Pre-Treated Salt Mix | Winter Sand** | Dry Salt, Pre-Treated Salt, Pre-Wet Salt, Winter Sand**, DLA (applied on Class 1 highways only) |
| **Application Rate(s)** | Pre-Treated Salt: 45 to 70 kg/lane km<br>Pre-Wet Sand: Up to 200 kg/lane km<br>Sand/Pre-Treated Salt Mix: 105 to 110 kg/lane km<br>DLA: Not Provided | Dry Salt: 65 kg/lane km<br>Winter Sand: Not Provided<br>DLA: Not Provided | Sand/Pre-Treated Salt Mix: 100 kg/lane km | Winter Sand: 150 to 375 kg/lane km | Dry Salt: 50 to 85 kg/lane km<br>Pre-Treated Salt: 30 to 100 kg/lane km*<br>Pre-Wet Salt: 25 to 85 kg/lane km<br>Winter Sand: 285 kg/lane km<br>DLA: 70 to 90 L/lane km |
| **Gravel Roads** | | | | | |
| **Material(s) Used** | Pre-Wet Sand** (pre-wet on trucks) | Winter Sand** | 75:25 Sand/Pre-Treated Salt Mix | Winter Sand** | Winter Sand** |
| **Application Rate(s)** | Pre-Wet Sand: Up to 200 kg/lane km | Winter Sand: Not Provided | Sand/Pre-Treated Salt Mix: 100 kg/lane km | Winter Sand: 150 to 375 kg/lane km | Winter Sand: 285 kg/lane km |

*Estimated based on a 15% higher application rate than pre-wet salt
**Includes sand mix with <=15% salt

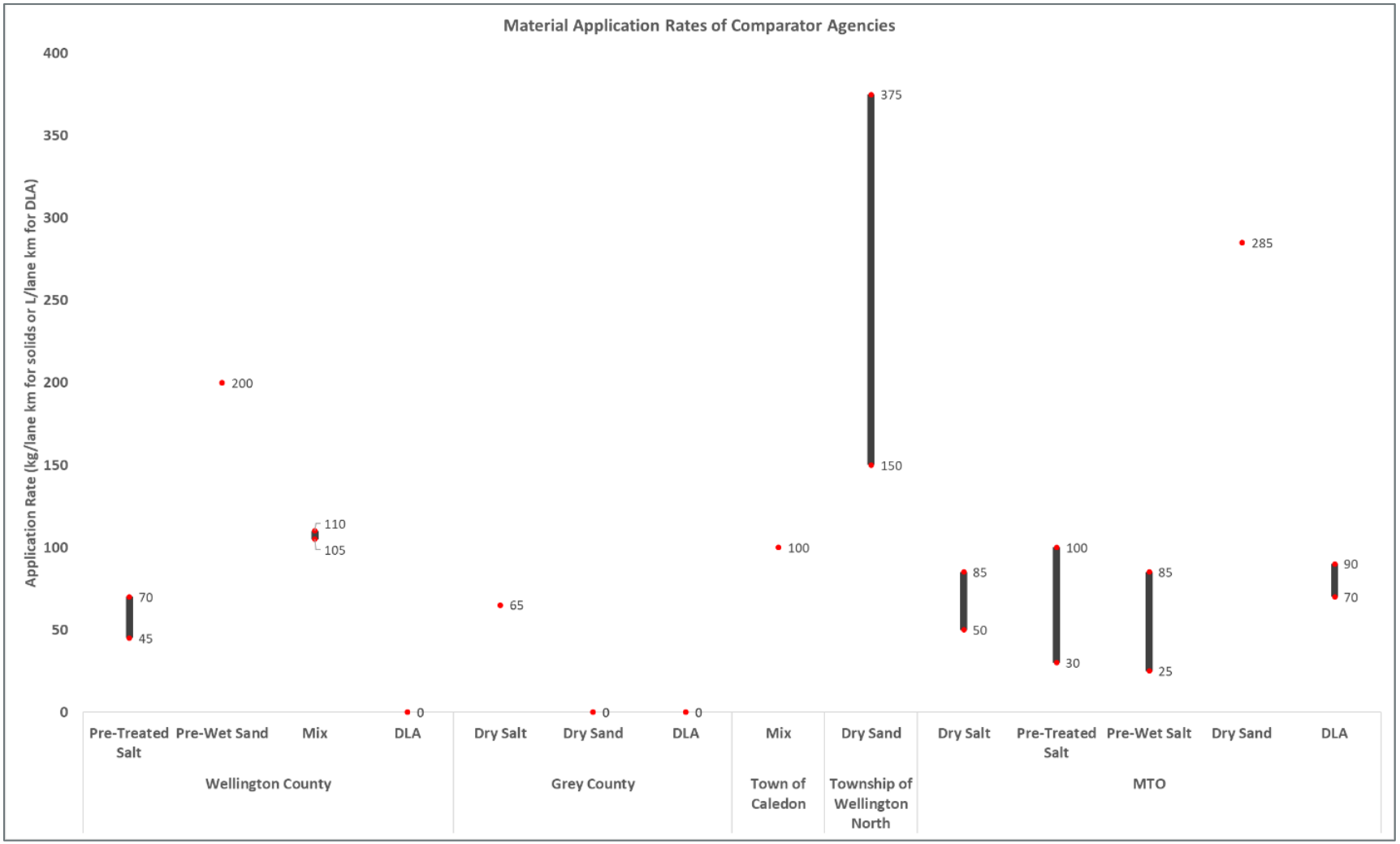



**Figure 27: Material Application Rates of Comparator Agencies**

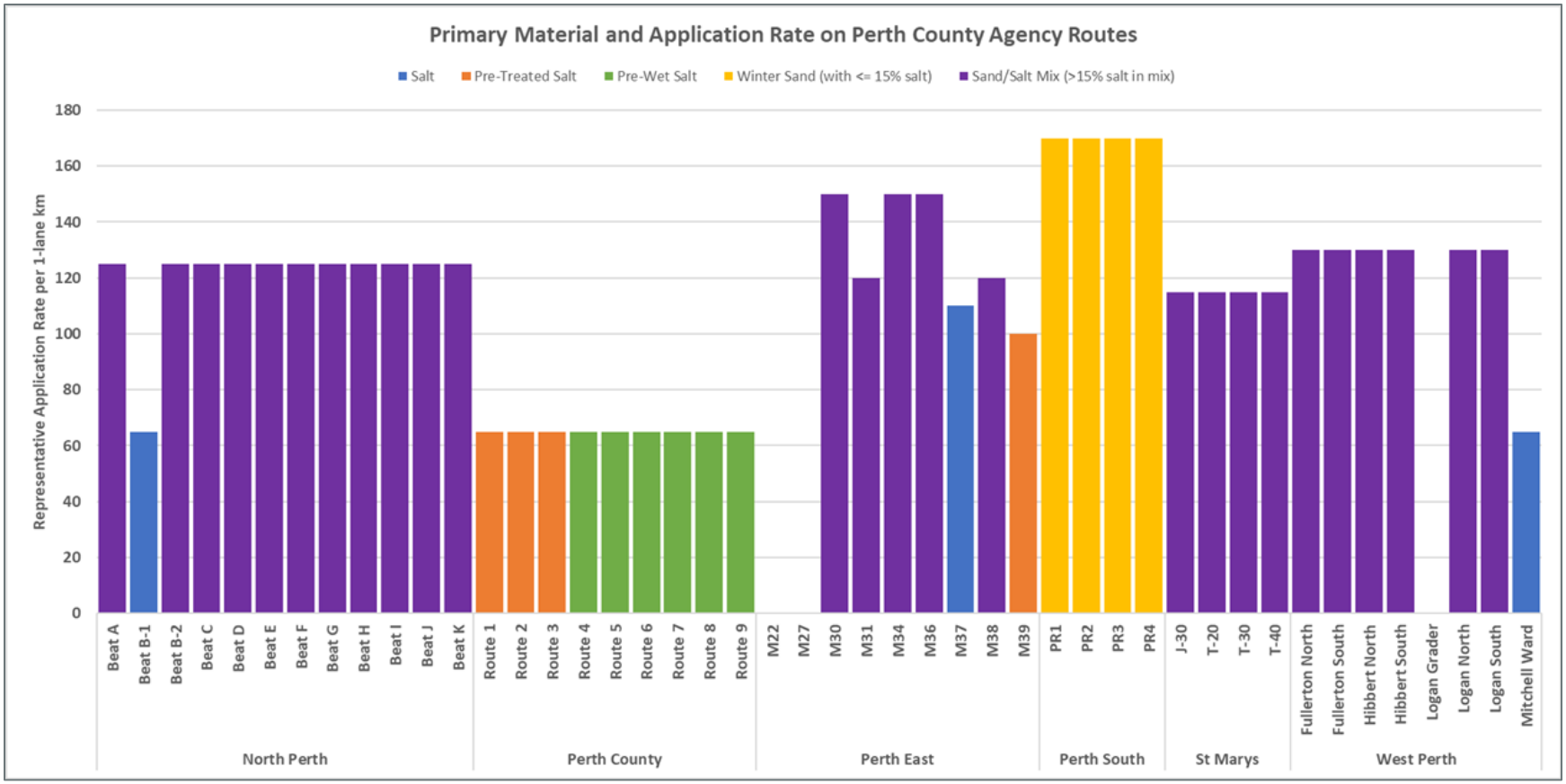



**Figure 28: Primary Material and Application Rate on Perth County Agency Routes**

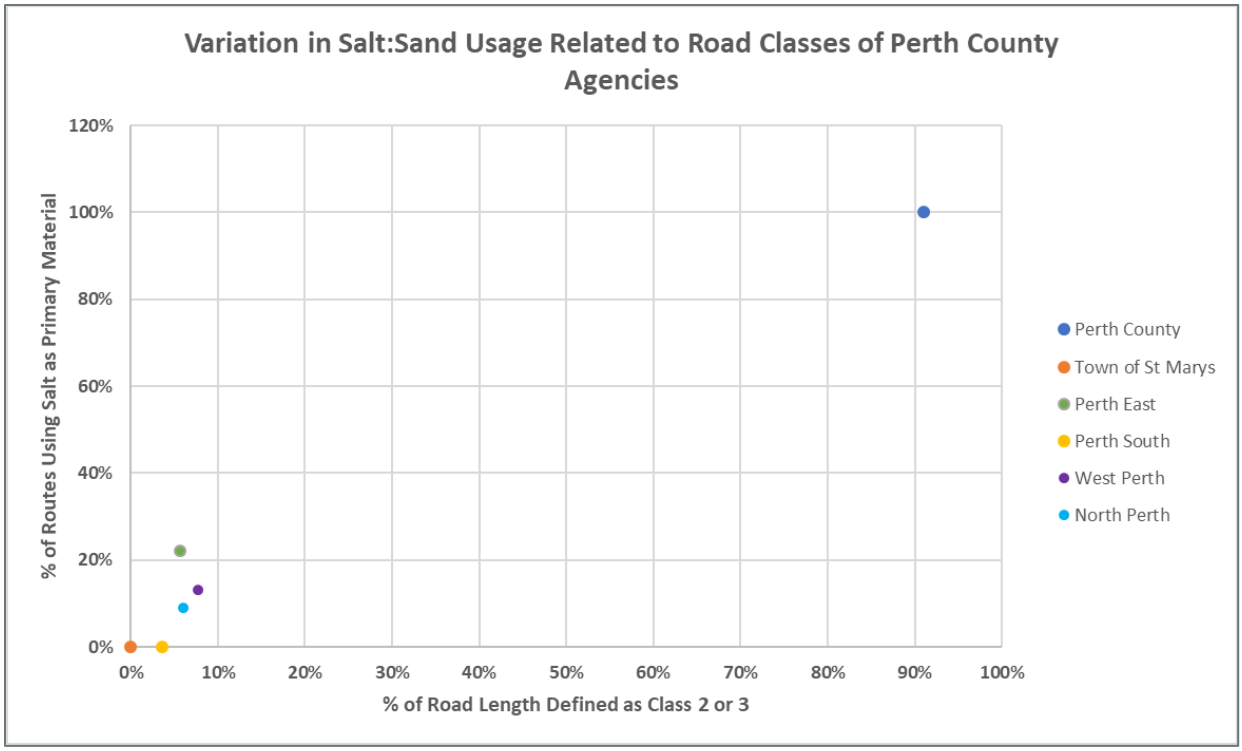



**Figure 29: Variation in Salt:Sand Usage Related to Road Classes of Perth County Agencies**

**Table 9** further compares material usage guidelines on paved and gravel roads for agencies within Perth County.

**Table 9: Perth County Material Use**

| Guideline | Agency | | | | | |
|---|---|---|---|---|---|---|
| | North Perth | Perth County | Perth East | Perth South | Town of St Marys | West Perth |
| **Salt** | No pre-wet/treated salt used<br>Straight salt is typically not applied directly to roads | Pre-treated or pre-wet salt used | Pre-treated salt is used only on the three routes originating from the Milverton yard. Dry salt is used otherwise.<br>100% salt is used in Towns | No pre-wet/treated salt used<br>Straight salt is typically not applied directly to roads | No pre-wet/treated salt used<br>Straight salt is typically not applied directly to roads | No pre-wet/treated salt used<br>100% salt is used in Towns |
| **Sand** | Typically used in very | If sand is applied | Applied at operator's | Sand application | Sand is only applied if it's | Sand application at |

| Guideline | Agency | | | | | |
|---|---|---|---|---|---|---|
| | North Perth | Perth County | Perth East | Perth South | Town of St Marys | West Perth |
| | cold conditions<br>Spot sanding in specific areas is conducted based on conditions as well | (operator's discretion), it is applied continuously | discretion at 'danger spots' | at operator's discretion depends upon weather, wind conditions, road surface type | below -14C.<br>When necessary, more sand will be applied on hills, curves and danger spots | operator's discretion but more material generally used on Class 3 roads and at intersections |
| **Gravel Roads** | No material applied on gravel roads | No gravel roads are present at the County level | No material applied on gravel roads | Generally, try not to apply material on gravel surfaces and aim to scarify as much as possible | No material applied on gravel roads | No material applied on gravel roads |
| **Defined Rules of Practice for Application Rates?** | No | Yes | Yes | Yes | No | Yes |
| **Other** | - | Material type is based on operator's discretion | - | - | - | - |

### 4.6.3. Conclusions and Recommendations

Perth County aligns with other upper tier agencies in the use of pre-treated salt but lags in not using DLA in advance of snow accumulation. DLA has the potential to reduce overall demand for road salt through a winter event, to aid in restoring bare pavement faster, and to allow anti-icing operations in advance of forecast snow or frost. The use of winter sand on lower tier roads is consistent with peer agencies but may result in a lower overall benefit than salt at higher traffic locations where safety can be improved by baring pavement, especially if pre-wet or pre-treated salt is used.

The following actions are recommended to maximize effectiveness of winter materials:

As a **Priority 1 Action**, develop written rules of practice for winter materials, for agencies that do not currently have them. The objective of written rules is to provide more consistent levels of service and to support defense of claims beyond an individual's practical experience.

As a **Priority 1 Action**, expand the use of stockpile-treated salt for salting routes of agencies that do not have on-board pre-wetting equipment. Where on-board pre-wetting is available, expand pre-wetting to

additional salting routes. The expanded implementations will help to reduce salt usage with the added benefits of reducing spreading costs and reducing salt loadings to the roadside environment.

As a **Priority 2 Action** review the criterion distinguishing sanding routes from salting routes and consider converting sanding route to salting routes to improve road safety on roads with higher MMS class or traffic congestion. Additionally, the development of harmonized rules of practice is recommended for all winter materials, including the conditions and application rates of use, which can become part of a future harmonized Road Salt Management Plan. Include information on Sourcewater Protection Areas in harmonizing rules of practice across the project area.

It should be noted that this analysis is focused at the agency and maintenance route level. Local conditions along a maintenance route, such as hills, curves, intersections, environmentally sensitive areas or drift areas may require local adjustment of materials or application rates that are beyond the scope of this analysis and require further analysis prior to implementation.

## 4.7. Fleet

The truck fleet is the heart of a winter maintenance operation, supporting distinct roles of patrolling, plowing, scarifying and applying salt, sand, liquids and mixtures on a varied road network consisting of arterial, collector and local roadways and parking lots. Managing the fleet means understanding the functional requirements, planning, procuring and maintaining the trucks and supporting equipment, and keeping accurate records for financial, maintenance and operational purposes. Efficient use of winter equipment is an important concern with annual expenditure on equipment estimated to exceed $800,000 (**Appendix I**).

This study focusses on key aspects of fleet operations that help road maintenance agencies meet benchmarks or legislative requirements specific to winter maintenance: right-sizing the fleet to the road network, right-sizing spreader capacity to route length, life-cycle planning, and equipment outfit.

The number of service vehicles appropriate to a service area can vary widely with the level of service required, traffic conditions, travel speeds, winter material types and application rates, and requirement for spares. A benchmark for appropriate overall fleet size was provided through a survey comparable agencies with respect to maintenance route length and total numbers and types of combination plow/spreaders assigned. A benchmark for number of spares was adopted from MTO practice, where a 10% spares ratio is typical. MTO also provides a benchmark for equipment age, where maximum age of trucks in new contracts is 5 years, and contracts may be renewed for an additional 5 years. The suitability of equipment to the assigned task was established by estimating the material usage on assigned routes in comparison with the capacity of assigned spreaders, and the suitability of truck-mounted spreading equipment as recommended in Environment Canada's Code of Practice for Environmental Management of Road Salt [25] and the Transportation Association of Canada Synthesis of Practice for Road Salt Management.[26]

The road maintenance fleet of the client agencies in Perth County linked with snowplow routes or parking lot maintenance totals 65 vehicles including spares, and comprises single, dual, and tri-axle combination units, plows, spreaders, parking lot type vehicles (i.e. loaders), and graders (**Appendix J**).

[25] https://www.canada.ca/content/dam/eccc/documents/pdf/pollution-waste/road-salts/6136_Annual%20Overview%20Road%20Salts%20Report_full%20document_EN.pdf#:~:text=Code%20of%20Practice%20for%20the%20Environmental%20Management%20of,harm%20to%20the%20environment%20while%20maintaining%20roadway%20safety.
[26] https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-1.pdf

The average road length assigned to each combination plow/spreader for the Perth agencies is 153 km (**Figure 30**). The road length assigned to comparable agencies surveyed ranges from 38 to 176 km, averaging 151 km/combo. This comparison suggests that the overall complement of spreaders operating in Perth County meets industry norms and the average number of spares exceeds values for MTO contractors (**Table 10**).

The age of the fleet, of which 42% is 5 years old or less and 74% 10 years old or less (**Figure 31**), compares well with MTO maintenance contract requirements and represents good life-cycle management.

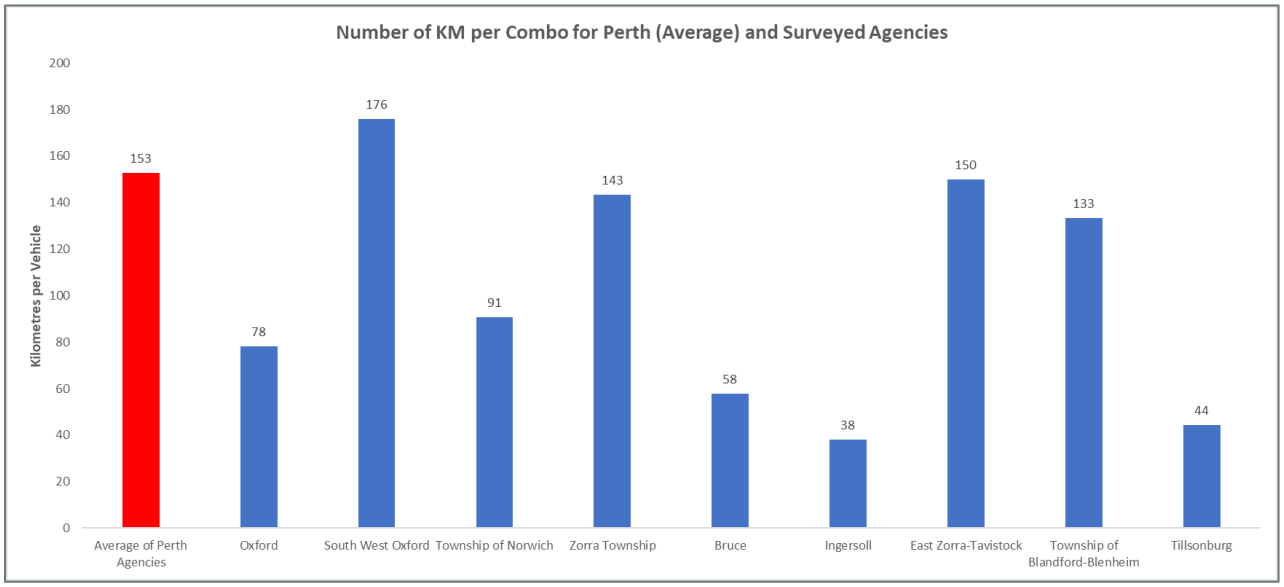



**Figure 30 Average Road Length Serviced**

**Table 10: Percentage of Spare Road Equipment by Agency**

| Agency | Total Road Equipment (tied to routes or responsible for parking lots) | Spare Road Equipment (tied to routes or responsible for parking lots) | Percentage of Spare Road Equipment |
|---|---|---|---|
| **Perth County** | 11 | 2 | 18% |
| **Town of St Marys** | 6 | 1 | 17% |
| **Perth East** | 14 | 3 | 21% |
| **Perth South** | 9 | 0 | 0% |
| **West Perth** | 12 | 2 | 17% |
| **North Perth** | 13 | 2 | 15% |

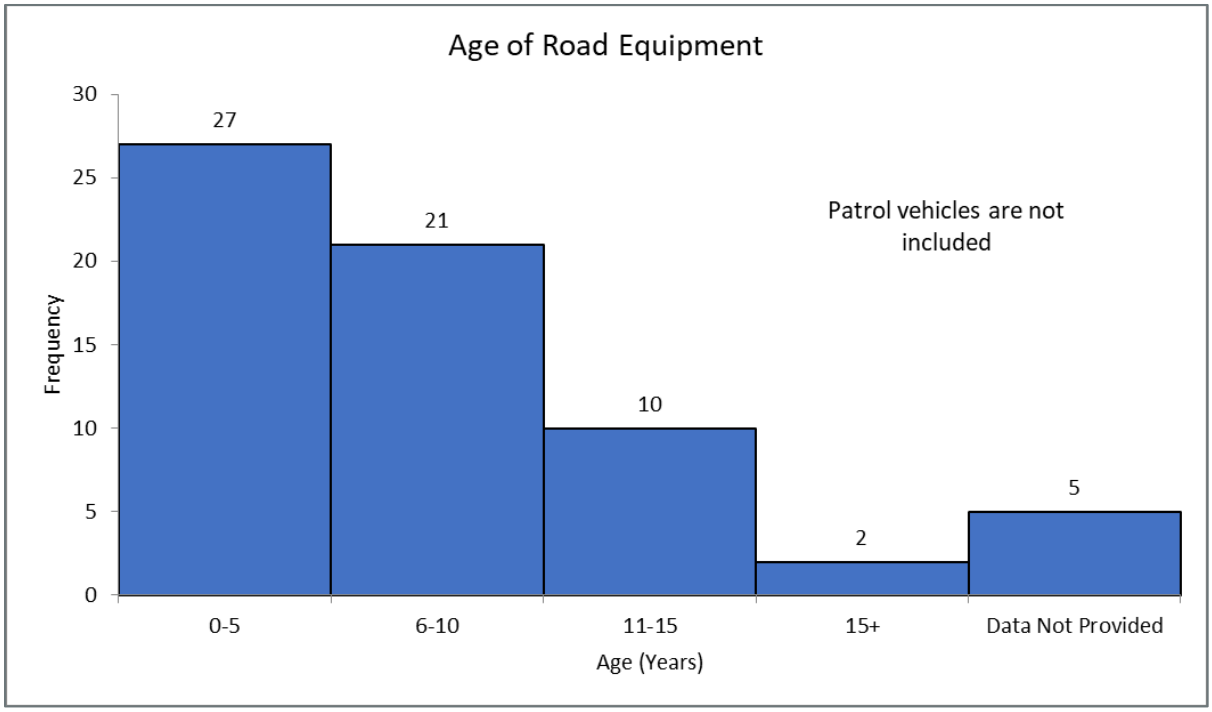



**Figure 31: Age of Road Equipment**

### 4.7.1. Spreader Capacity

Equipment load capacity for spreading salt or sand ranges from 1.5 to 18.9 tonnes (**Appendix J**). The analysis of spreader capacity in relation to route lengths indicates that spreaders have excess capacity ranging from 20 to 80% in comparison with requirements for spreading salt on the current routes (**Figure 32** and **Appendix E**). The analysis does not consider the requirement for spreading winter sand which typically uses rates from 2 to 4 times salting rates over portions of the route. A back-calculation of sanding rates for Perth South indicated that the sand application rate averaged over a route length was approximately 100 kg/single-lane km (**Appendix E**), suggesting that material spreading capacity is satisfied by the equipment used for all current routes.

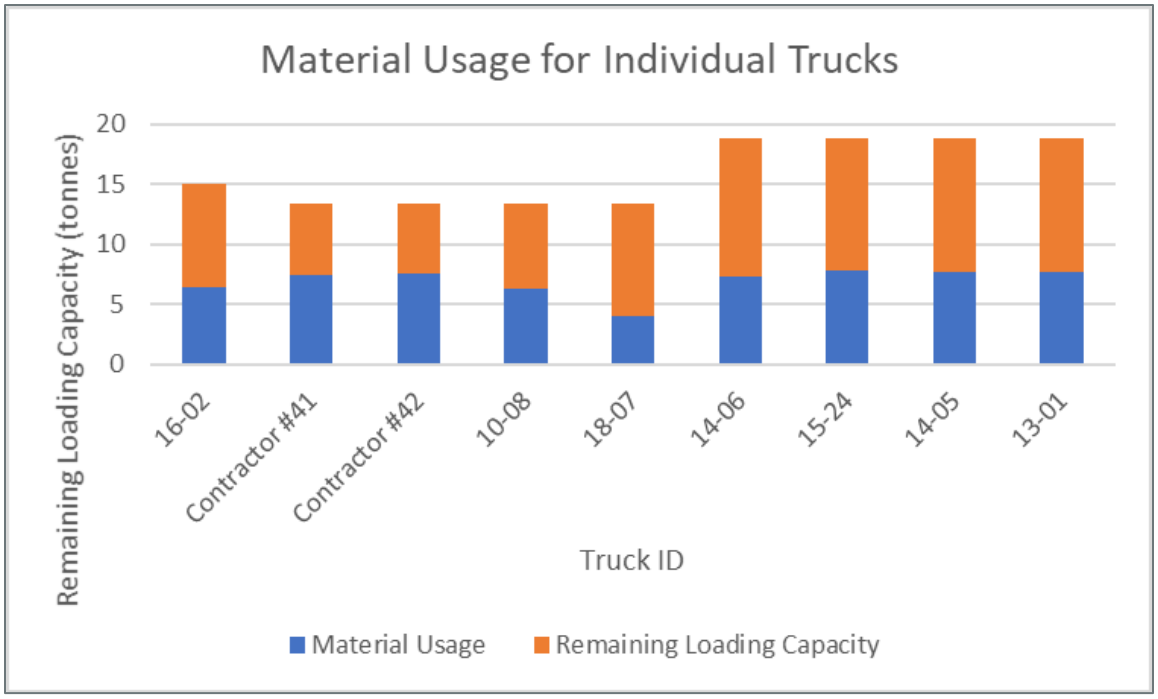



**Figure 32: Spreader Capacity Example for Perth County**

### 4.7.2. Truck-Mounted Equipment

Spreading equipment mounted on the truck controls the mass of salt spread and its position across the road, in addition to providing a legal record of the amount, times and locations. The type of truck-mounted spreading equipment is not governed by legislation but is referenced in the TAC Code of Practice and in contract requirements of MTO and other agencies, along with benchmarks for percentage of fleet equipped. The existing spreading equipment outfit compared with these benchmarks for the Perth agencies is summarized in **Table 11**.

Benchmarks include:

- Electronic Spreader Controllers (ESC)
  - Adjusts application rate to road speed, reduces salt loss from road surface, provides automatic record of material use and distance, travelled for legal, material management. Up to 30% impact on material use.
- Vehicles Equipped for Pre-wetting if rock salt
  - Allows reduced application rates, longer spreading routes. Up to 30% impact on material use and fleet requirement. May be substituted by pre-treating salt in stockpile
- Spreaders Calibrated Annually
  - Up to 30% reduction in material usage compared with non-calibrated equipment, more consistent winter road conditions. Additional detail on spreader calibration is provided in **Appendix K**[27, 28, 29]

[27] http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Calibration-Guide.pdf
[28] https://clearroads.org/project/calibration-accuracy-of-manual-and-ground-speed-control-spreaders/
[29] MTO Maintenance Management Office, 2001, internal report, Tolerance of Spreader Calibrations

- Electronically Recording Material Use.
  - Systems other than ESC can measure and record material application.
- Vehicles Equipped with AVL or GPS.
  - Automated recording and archiving of ESC data, truck location and other factors, automated retrieval, display, mapping and reporting of operations and material use, real-time tracking of operations. Reduced clerical time and error.
- Percentage of Combination Plow/spreaders.
  - More efficient service by combining plow and spreader operations. Up to 50% reduction in fleet requirement compared with separate plow and spreader units.

Perth County meets five out of the six recommended benchmarks for salt spreading equipment outfit. All six agencies are equipped with ESC and five with AVL/GPS. However, only two out of the five agencies equipped with AVL/GPS use this technology for automated recording of material application. Pre-wetting equipment is not available in most areas, especially on routes where sand is the primary material. The proportion of combination spreaders is lower than the benchmark but may be explained by the requirement to grade snowpacked conditions on unpaved roads where salt cannot be used or limitation of tight turning radius in urban areas. Incomplete calibration of the fleet is a concern for road salt management.

**Table 11: Spreading Equipment Outfit**

| Benchmark Criteria | Benchmark | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|---|
| **Vehicles Equipped with Electronic Spreader Controls (Code of Practice)** | **95%** | 100% | 60% | 100% | 80% | 100% | 67% (does not include 2 contractor single axle trucks that have unknown spreader types) |
| **Vehicles Equipped for Pre-Wetting (Code of Practice)** | **80%** | 73% (includes 2 contractor trucks not equipped for pre-wetting) | 0% | 0% | 0% | 0% | 0% |
| **Vehicle Spreaders Calibrated Annually (Code of Practice)** | **100%** | 100% | 100% | Unknown | 100% | 100% | Unknown |
| **Vehicles Electronically Recording Material Usage (Best Practice)** | **100%** | 100% | 0% | 100% | 0% | 0% | 0% |
| **Vehicles Equipped with AVL or GPS (Best Practice)** | **100%** | 100% (AVL) | 100% (just GPS, AVL logger available but not used) | 100% (AVL) | 100% (AVL) | 0% | 100% (GPS) |
| **Percentage of Combo Plow Spreaders (Best Practice)** | **100%** | 100% | 75% | 58% | 57% | 70% | 54% |
| **Number of benchmarks met** | | 5 | 2 | 3 | 2 | 2 | 1 |

### 4.7.3. Conclusions and Gaps

The number, size, and capacity of the spreader fleet is suitable to complete the work required safely and with a buffer for higher application rates, the fleet has a good lifecycle characteristic, and the distance serviced by each truck compares well with peer agencies. The existing fleet size is well suited to the job requirements.

The unmet benchmarks on implementation of ESC, AVL, pre-wet equipment, and annual calibration are all areas impacting the efficiency of material usage and of documenting operations. Expanded implementation of these technologies and practices is recommended as a **Priority 1 Action** where they are not currently used.

The use of combination units as opposed to separate plows and spreaders is an area for possible cost reduction but needs to be assessed against road classification and surface type, and turning abilities in urban areas. Further analysis of areas suitable for conversion to combination units is recommended as a **Priority 2 Action** in coordination with equipment replacement schedule.

## 4.8. Mobile Record Keeping; Patrolling and Material Spreading

Record keeping has many important functions in a modern winter maintenance organization. These include: materials and fleet management, contract management, annual reporting on salt use for the Code of Practice, tracking and reporting of business performance measures, to provide business analysis tools to plan future improvements, and to show due diligence and a logical process for defence of claims.

There is no legislative requirement on methods of record keeping, but OGRA[13] recommends 14 types of maintenance records including four of particular relevance to winter: patrol diary and road-weather condition report, winter operations record of equipment call-out and instructions, and material management reports.

Record keeping practices can be summarized in three tiers of sophistication:

- Paper-based records (patrol diary, winter operations record, road report);
- Tablet or other electronic inputs requiring operator actions; and
- Fully automated inputs (AVL, RWIS).

All types can be found in practice today, but with a trend to moving up-tier.

A review of automated maintenance data collection systems available from service providers in Ontario revealed the following key functions:

- In-vehicle tablet or cell-phone based patroller app (**Figure 33**) with operator-keyed input on road and weather conditions, dash-cam images or video, air and road temperature measurements, spectral camera estimate of frost and water depth (**Figure 22**). Each data element is tagged with time and GPS location and transmitted to a server where it is archived and can be used to generate automated or specialty reports Some systems automatically track compliance to MMS frequency of operations requirement.

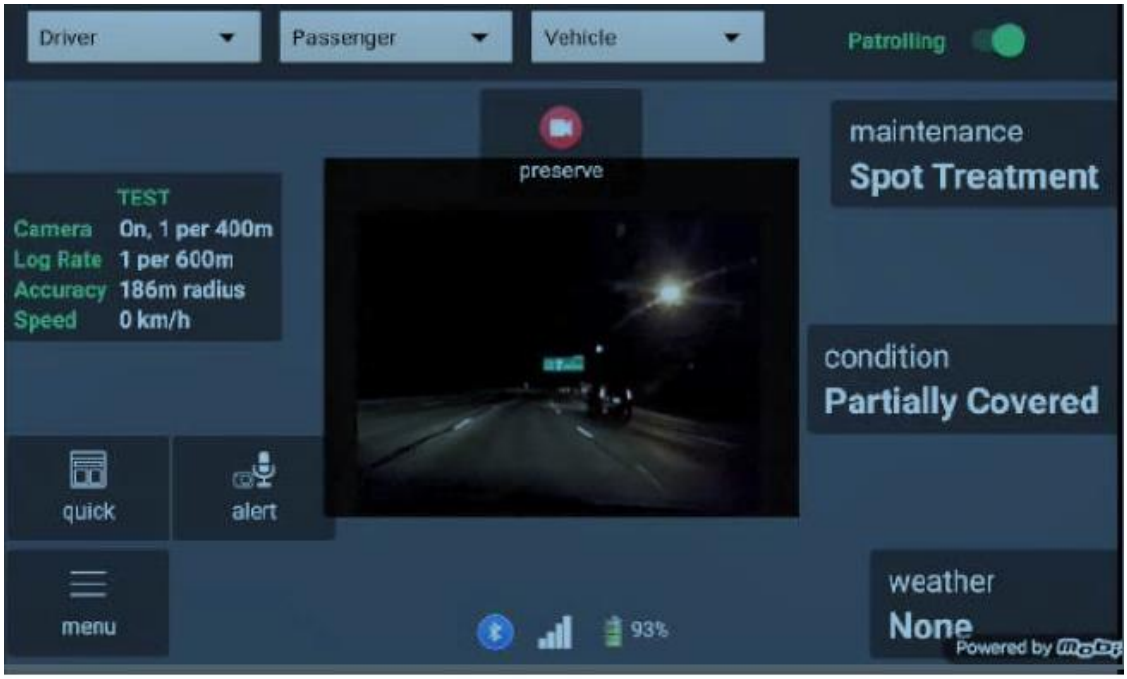



**Figure 33: Automated Patrol Diary Screen[31] (Viaesys.com)**

- Spreader-based Automated Vehicle Location (AVL) systems linked to Electronic Spreader Control (ESC) that tracks plow position, material setting and application rate, operating parameters such as road speed, air and road temperature, dash-cam images. Information is typically recorded at intervals of 10 seconds, geotagged and transmitted to a server where it can be displayed in real-time maps for monitoring operations or provided through a public web site (i.e. Track My Plow) and archived. The archived data can be used to generate automated, standard reports or dashboards for operations management, speciality ad-hoc reports to analyze business processes, or special reports for legal discoveries (**Figure 34**, **Figure 35**, **Figure 36**, and **Figure 37**).[30, 31]

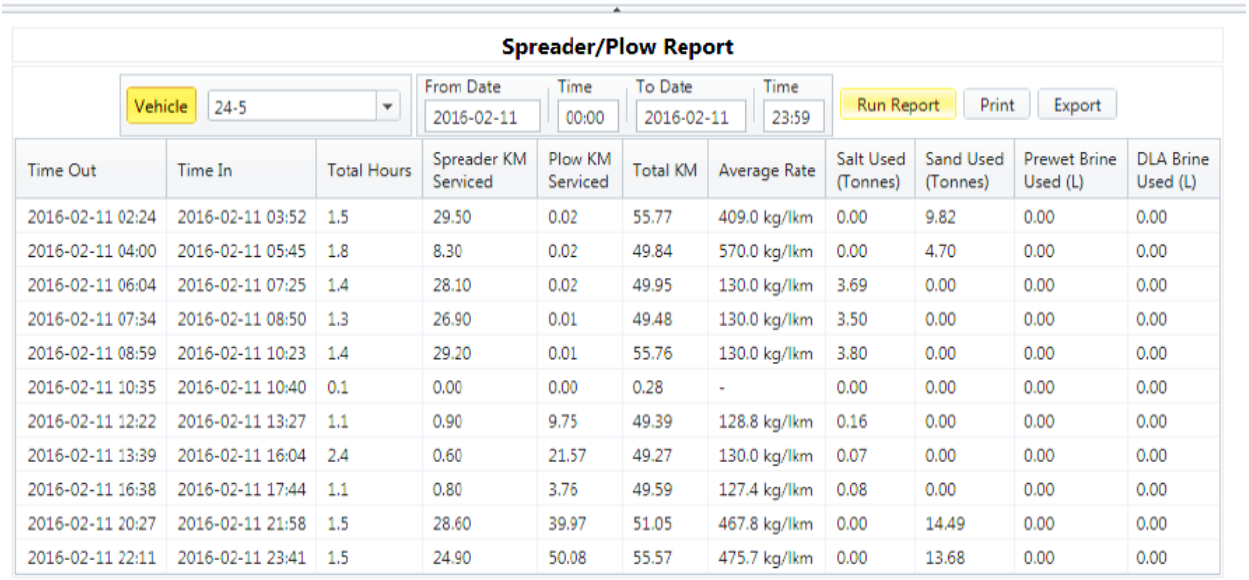
Such systems can be purchased and installed by agency staff and operated internally, purchased with a service agreement, or rented as a service. The service agreement approach has been the most successful.[32] System hardware for a typical AVL system for one vehicle is in the order of $2,000 per vehicle and monthly service fee including data charges is in the order of $50 including data archiving and standard outputs but not including instrumentation maintenance and repair.[32] A turn-key service approach with no hardware ownership is in the order of approximately $100 per month per vehicle.[31] These costs are in line with those reported in a U.S. synthesis on AVL systems.[3334]

The benefits of automated systems provide advantages over manual, paper-based systems in reducing or eliminating clerical time and errors, reducing or eliminating on-site records storage, in providing information at much higher resolution of time and location, and in the ability to automatically merge

[30] http://ahmct.ucdavis.edu/wp-content/uploads/wploads/max_perchanok_avl_on_provincial_highways_in_ontario.pd
[31] R. Omer, Viaesys.com, personal communication
[32] B.Crouse, IOT consultant, personal communication
[33] http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.14-01_Final.p
[34] https://rosap.ntl.bts.gov/view/dot/32513

records from different sources such as weather and material use or equipment and labour hours. Operations and material usage information can be provided automatically at the level of individual vehicles, aggregated to routes and summarized by geography and time periods, as well as access to ad hoc user queries.

Implementation of electronic patrolling technology and AVL spreader technology is limited to two agencies (**Table 12, Table 13)**.

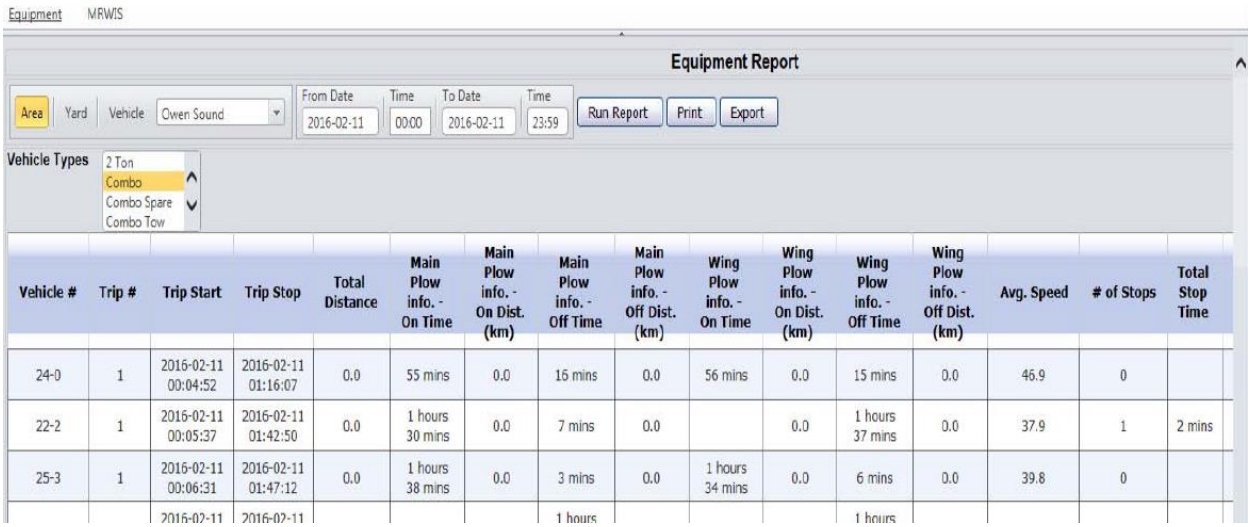


**Spreader/Plow Report**

Vehicle: 24-5 | From Date: 2016-02-11 | Time: 00:00 | To Date: 2016-02-11 | Time: 23:59 | Run Report | Print | Export

| Time Out | Time In | Total Hours | Spreader KM Serviced | Plow KM Serviced | Total KM | Average Rate | Salt Used (Tonnes) | Sand Used (Tonnes) | Prewet Brine Used (L) | DLA Brine Used (L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016-02-11 02:24 | 2016-02-11 03:52 | 1.5 | 29.50 | 0.02 | 55.77 | 409.0 kg/lkm | 0.00 | 9.82 | 0.00 | 0.00 |
| 2016-02-11 04:00 | 2016-02-11 05:45 | 1.8 | 8.30 | 0.02 | 49.84 | 570.0 kg/lkm | 0.00 | 4.70 | 0.00 | 0.00 |
| 2016-02-11 06:04 | 2016-02-11 07:25 | 1.4 | 28.10 | 0.02 | 49.95 | 130.0 kg/lkm | 3.69 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 07:34 | 2016-02-11 08:50 | 1.3 | 26.90 | 0.01 | 49.48 | 130.0 kg/lkm | 3.50 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 08:59 | 2016-02-11 10:23 | 1.4 | 29.20 | 0.01 | 55.76 | 130.0 kg/lkm | 3.80 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 10:35 | 2016-02-11 10:40 | 0.1 | 0.00 | 0.00 | 0.28 | - | 0.00 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 12:22 | 2016-02-11 13:27 | 1.1 | 0.90 | 9.75 | 49.39 | 128.8 kg/lkm | 0.16 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 13:39 | 2016-02-11 16:04 | 2.4 | 0.60 | 21.57 | 49.27 | 130.0 kg/lkm | 0.07 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 16:38 | 2016-02-11 17:44 | 1.1 | 0.80 | 3.76 | 49.59 | 127.4 kg/lkm | 0.08 | 0.00 | 0.00 | 0.00 |
| 2016-02-11 20:27 | 2016-02-11 21:58 | 1.5 | 28.60 | 39.97 | 51.05 | 467.8 kg/lkm | 0.00 | 14.49 | 0.00 | 0.00 |
| 2016-02-11 22:11 | 2016-02-11 23:41 | 1.5 | 24.90 | 50.08 | 55.57 | 475.7 kg/lkm | 0.00 | 13.68 | 0.00 | 0.00 |

**Figure 34: AVL Daily Vehicle Report (MTO Contractor)**



Equipment | MRWIS

**Equipment Report**

Area | Yard | Vehicle: Owen Sound | From Date: 2016-02-11 | Time: 00:00 | To Date: 2016-02-11 | Time: 23:59 | Run Report | Print | Export

Vehicle Types: 2 Ton, Combo, Combo Spare, Combo Tow

| Vehicle # | Trip # | Trip Start | Trip Stop | Total Distance | Main Plow info. - On Time | Main Plow info. - On Dist. (km) | Main Plow info. - Off Time | Main Plow info. - Off Dist. (km) | Wing Plow info. - On Time | Wing Plow info. - On Dist. (km) | Wing Plow info. - Off Time | Wing Plow info. - Off Dist. (km) | Avg. Speed | # of Stops | Total Stop Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24-0 | 1 | 2016-02-11 00:04:52 | 2016-02-11 01:16:07 | 0.0 | 55 mins | 0.0 | 16 mins | 0.0 | 56 mins | 0.0 | 15 mins | 0.0 | 46.9 | 0 | |
| 22-2 | 1 | 2016-02-11 00:05:37 | 2016-02-11 01:42:50 | 0.0 | 1 hours 30 mins | 0.0 | 7 mins | 0.0 | | 0.0 | 1 hours 37 mins | 0.0 | 37.9 | 1 | 2 mins |
| 25-3 | 1 | 2016-02-11 00:06:31 | 2016-02-11 01:47:12 | 0.0 | 1 hours 38 mins | 0.0 | 3 mins | 0.0 | 1 hours 34 mins | 0.0 | 6 mins | 0.0 | 39.8 | 0 | |
| | | 2016-02-11 | 2016-02-11 | | | | 1 hours | | | | 1 hours | | | | |

**Figure 35: AVL Daily Vehicle-Type Roll-Up**

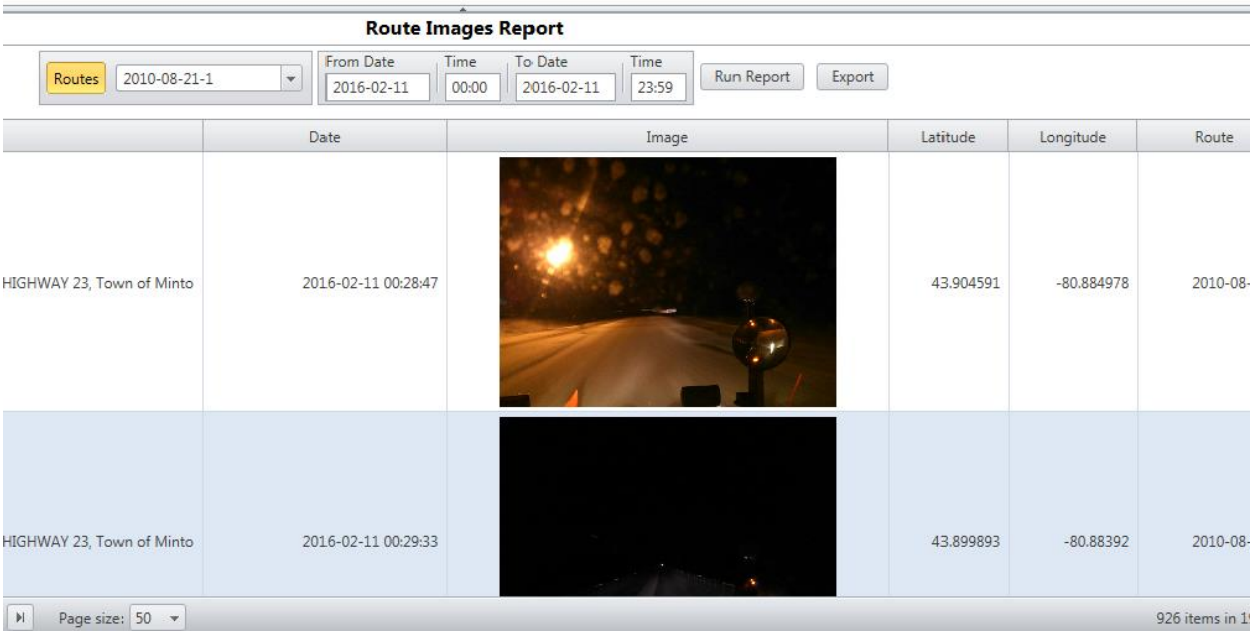



**Figure 36: AVL Dash-Cam Archive (MTO Contractor)**

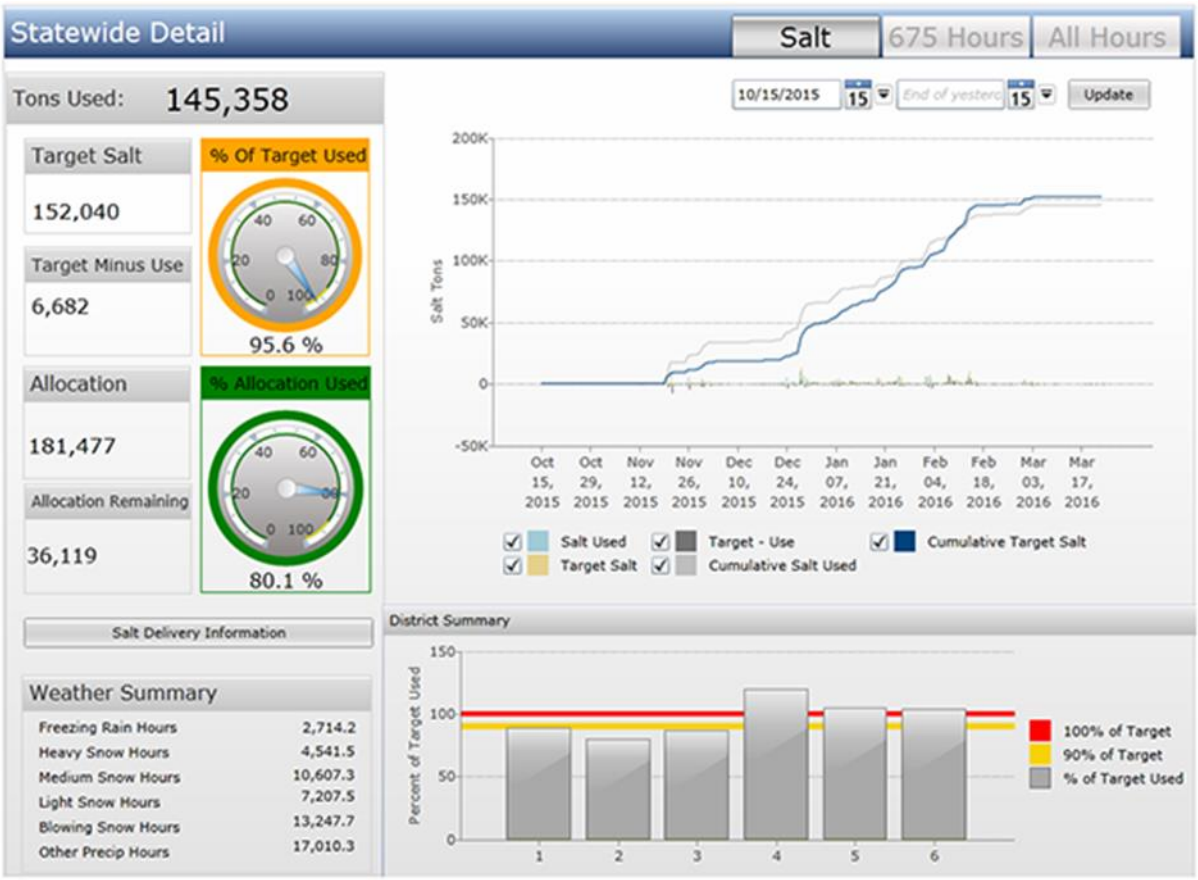



**Figure 37: Operations Management Dashboard Combining AVL and RWIS (Iowa DoT)**

**Table 12: Implementation of Technology for Weather, Patrolling and Salt Tracking**

| Municipality | Record Keeping (1=Paper Logs, 2=MR Compliance, 3=OGRA Winter Web, 4=MESH, 5=GPS Generated Reports) | How is the amount of material used recorded for each trip? 1=Paper Logs, 2=ESC 3=AVL |
|---|---|---|
| **Perth County** | 1, 3 (for weather), 4 (for weather), 5 (AVL is available to track plows live and the report shows sander on sander off, time, location, speed) | 3 |
| **Perth East** | 1, 2 (timestamped GPS log of only the patrol), 4, 5 (AVL shows spinner on/off, plow up/down, and material application rate - recorded digitally and in operator log) | 1, 3 |
| **North Perth** | 1, 5 (GPS on all winter equipment with live tracking and reporting capability) | Amount of material is not recorded. They have that capability on 3 of their Rexroth trucks but not doing that right now. |
| **Perth South** | 1, 2 (patroller only), 3 (weather report sent to foreman), 5 (AVL shows plow up plow down, sander on sander off but not application rate) | 1, 2 (2 units with newer sanders could record material usage in future) |
| **St Marys** | 1, 3 (weather report received 3 times a day), 5 (GPS tracks location, speed, and time of operations for each vehicle but not where material was applied) | 1 (AVL logger is available (i.e. the hardware) but they don't have access to the output. Trucks have a base, consumer-grade GPS) |
| **West Perth** | 1, 3 (weather report sent to foreman) | 1 (amounts not recorded on a daily usage basis, but County will bill them based on the amount of material used) (electronic spreaders CAN record but they don't right now) |

**Table 13: Implementation of ESC and AVL for Record Keeping**

| Technology | Benchmark | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|---|
| **Electronic Spreader Controllers Actively Used for Recording Material Usage (Best Practice)** | **100%** | 100% | 0% | 100% | 0% | 0% | 0% |
| **Vehicles Equipped with AVL Actively Used** | **100%** | 100% (AVL) | 0% | 100% (AVL) | 0% | 0% | 0% |

| Technology | Benchmark | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|---|
| **for Record Keeping (Best Practice)** | | | | | | | |

### 4.8.1. Conclusions and Recommendations

Two of the agencies meet the benchmark for automated collection of operations data using AVL and ESC to digitally record and use the information for business purposes (**Table 12** and **Table 13**).

Perth County agencies have made initial implementations of AVL technology to automate winter operations record keeping but implementation has not progressed to the point where benefits are fully realized. Progress toward realizing the benefits of AVL technology in managing operations, reducing administrative costs and improving information quality can be made through the following recommended actions:

As a **Priority 1 Action**, integrate AVL data from currently equipped vehicles to replace manual data inputs to normal business processes. Develop standardized reports that support fleet and material management and compliance reporting. This pilot demonstration will support and promote future network-wide implementation of AVL to achieve maximum cost-saving and efficiency benefits.

As a **Priority 2 Action**, investigate procurement options to provide AVL service on all maintenance vehicles, and plan future implementation of AVL to all vehicles not currently equipped.

As a **Priority 2 Action**, plan and implement a demonstration of automated patrol technology including a formal evaluation of its benefits compared with conventional methods.

## 4.9. Sidewalk Operations

### 4.9.1. Standards and Benchmarks

#### Minimum Maintenance Standards

The Ontario MMS specifies that accumulated snow on sidewalks be cleared to a maximum depth of 8 cm within 48 hours of accumulation and may be addressed by plowing and or application of materials, and to treat icy sidewalks with salt, sand or mix within 48 hours. MMS does not provide guidance on which sidewalks should be treated.

During significant weather events (e.g., snow storms), the standard for addressing snow accumulation or prevention of ice formation on sidewalks is to monitor the weather conditions and deploy resources to address snow accumulation or prevent ice formation on sidewalks, starting from the time that the municipality deems appropriate to do so. In this case, all sidewalks are deemed to be in a state of repair with respect to snow accumulation or ice formation until 48 hours after the declaration of the end of the significant weather event by the municipality.

In terms of sidewalk patrolling activities during winter season, MMS indicates that in cases where there is a substantial probability of snow accumulation on sidewalks in excess of 8 cm, ice formation on sidewalks or icy sidewalks, the standard would be for the municipality to select representative sidewalks and conduct patrolling activities at intervals deemed necessary by the municipality.

#### Peer Review and Jurisdictional Scan

A review of peer agencies showed that most employ a sidewalk clearing classification system with three or more service levels, designating the precedence and timing of treatment. For the City of Toronto, service levels also vary by month and by storm severity. For example, Toronto begins sidewalk plowing in mid-winter when depth equals 2 cm and completes sidewalk clearing on high volume pedestrian routes within 15 hours of the end of a normal storm, and within 48 hours on low volume routes, transit pads and crosswalks.

Town of Whitby also has three level of service classes related to the road class, with maximum accumulations of 2.5 cm for Class A (Downtown Whitby and Brooklin), 5 cm for Class B (arterials and major collectors), and 10 cm for Class C (minor collectors, certain local roads and sidewalks adjacent to Town property). The sidewalk maintenance is conducted every 8 hours for all classes if precipitation continues. In addition, Whitby provides sidewalk snow clearing services for senior residents and individuals with disabilities.

Town of Aurora maintains all town sidewalks beginning at 5 cm snow accumulation and completing all routes within 24 hours. Levels of service are commonly related to adjacent road classification, types of municipal services fronting the sidewalk, and designated business districts. In addition, bylaws may be enacted requiring property owners to clear sidewalks fronting their property or business within a defined time period, or volunteerism promoted to clear sidewalks for disabled individuals.

The detailed information on the sidewalk winter maintenance operation was found to be limited across the Province. **Table 14** summarizes the details of such operations from some of the municipalities.

**Table 14: Summary of Sidewalk Winter Maintenance Operations for Comparator Agencies**

| Agency / Criteria | Toronto | Newmarket | Wellington North | Peterborough | Whitby | Barrie | Aurora |
|---|---|---|---|---|---|---|---|
| **Total Length (km)** | 6400 | | 33 | 399 | | 603 | |
| **Number of Plows** | 300 | 9 | 3 | 9 | | 19 | |
| **Average km per Route** | 21 | 19 | 11 | 44 | | 32 | |
| **Number of Priority Levels** | 3 + storm severity | | Downtown only | | 3 | | 3 |
| **Material** | mix | | salt | | | | |
| **Rate (kg/km)** | 100 | | | | | | |

The peer survey showed sidewalk route lengths varying from 10 km to more than 40 km, with a median of 20 km. While salt, sand, mix or other chemicals are permitted by MMS, few agencies report details on their materials or application rates. The City of Toronto uses an application rate of 100 kg/sidewalk km, equaling 2 tonnes per typical 20 km sidewalk route per storm.

### 4.9.2. Current Practices

The Perth agencies all indicated that sidewalk winter maintenance and winter patrols are completed during the winter season as per MMS. Agencies all clear sidewalks within 48 hours (typically sooner) to reduce the snow to a depth of less than or equal to 8 cm. Sidewalk winter patrols involve a patroller who inspects sidewalk conditions while performing the roadway winter patrol. It is assumed that the sidewalk snow accumulation/ice formation is similar to roadway conditions.

**Table 15** provides an assessment of the agencies' current practices with respect to the criteria discussed above and compared with one another. Perth County does not conduct sidewalk clearing.

**Table 15: Sidewalk Policy Comparison**

| Agency / Criteria | St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|
| **Written and defined service levels related to adjacent road class** | ✓ | ✓ | Contracted | ✓ | ✓ |
| **Written and defined service levels related to type of municipal services fronting the sidewalk (observed in policy or route map)** | ✓ | ✓ | Contracted | ✓ | ✓ |
| **Written and defined service levels related to storm severity** | ✓ | No | Contracted | ✓ | No |
| **Type of material used** | Salt/sand mix | Salt | Salt | Salt | Salt |
| **Application rate** | 68 kg/km (9 kg/minute) OR varies | 49 kg/km (0.05 $yd^3$/km) | 49 kg/km (0.05 $yd^3$/km) | 49 kg/km (0.05 $yd^3$/km) | Operator's Discretion |
| **Typical circuit time** | Sidewalks: 12 to 16 hours (for one machine)<br><br>Trails: 5 to 6 hours | 5 hours (to plow sidewalks only)<br><br>7 hours total (including travel to move equipment from hamlet to hamlet) | Contracted | 5 to 7 hours | Listowel: 4 hours (plowing) or 12 hours (blowing)<br><br>Atwood/Monkton: 2 hours (plowing) or 3 hours (blowing) |

All Perth agencies have defined service levels related to the adjacent road class (i.e. arterial, collector, local) and to the type of municipal services fronting the sidewalk (observed in policy or route maps). However, defined service levels related to storm severity were not specified for Perth East and North Perth (i.e. specific actions taken when there is less than 8 cm of snow, greater than 8 cm of snow, heavy storm conditions, etc.). The materials used on sidewalks fit the requirements of MMS and salt is the most commonly reported material used on sidewalks by the Perth agencies

A review of any available public by-laws regarding landowner responsibilities for sidewalk clearing was also conducted for the Perth agencies. It was found that generally, residents and downtown business-owners are responsible for plowing sidewalks in front of driveways. However, the agencies will typically maintain predetermined sidewalks based on school routes, public facilities, business areas, and those adjacent to MTO and County maintained highways.

Characteristics of sidewalk snow clearing equipment used by the Perth agencies are shown in **Table 16**.

**Table 16: Sidewalk and Trail Equipment**

| Municipality | Sidewalk/Trail Vehicle ID | Vehicle Type | Vehicle Age | Spreader Capacity (tonnes) |
|---|---|---|---|---|
| **Town of St Marys** | J20 | Kubota Tractor | - | 0.3 |
| **Town of St Marys** | J50 | Trackless Sidewalk Tractor | 2 | 4.9 |
| **Town of St Marys** | J90 | Trackless Sidewalk Tractor | 2 | 0.5 |
| **Perth East** | M59 | Trackless Sidewalk Tractor | 6 | 0.5 |
| **West Perth** | MT6 Trackless #92 | Trackless Sidewalk Tractor | 0 | 0.5 |
| **North Perth** | CONTSWALK | Kubota Tractor | 3 | 0.5 |
| **North Perth** | 3728 | Trackless Sidewalk Tractor | 13 | 0.3 |
| **North Perth** | 3720 | Trackless Sidewalk Tractor | 4 | 1.5 |

Application rates estimated from client information range from approximately 50 to 70 kg/km, with an average of 60 kg/km, which falls within the range normally reported for sidewalk spreaders. Equipment load capacity for spreading material ranges from 0.3 to 4.9 tonnes. At an application rate of 60 kg/km, approximately 50% of the routes could be completed with a single fill and the remaining routes require reloading. Assuming an average travel speed of 10 km/h, all routes could be completed within 3 hours if reloading was not needed (**Appendix I**). However, most reported completion times are longer, and staff indicated that refills are needed on most routes. Additionally, application rates for North Perth were reported to vary at the operator's discretion depending on sidewalk conditions, which could result in longer circuit times and more refills. The majority of the sidewalk vehicles are under 5 years old, with only one vehicle that is greater than 10 years old, indicating good life cycle management.

A review of sidewalk equipment at peer agencies showed common use of both specialized sidewalk equipment and all-purpose equipment adapted to winter sidewalk work. Sidewalk-specific equipment includes the MT Trackless, the Bombardier SW4, and Holder Tractors. These units have special winter attachment such a blowers and sand-salt spreaders and are very effective for winter operations, although more expensive than small farm tractors. Farm tractors equipped with front mounted rotating brooms are effective for light snow or with V plows for heavy snow areas.

**Figure 38** shows the length of the sidewalk routes and deadheading distances for each of the Perth agencies.

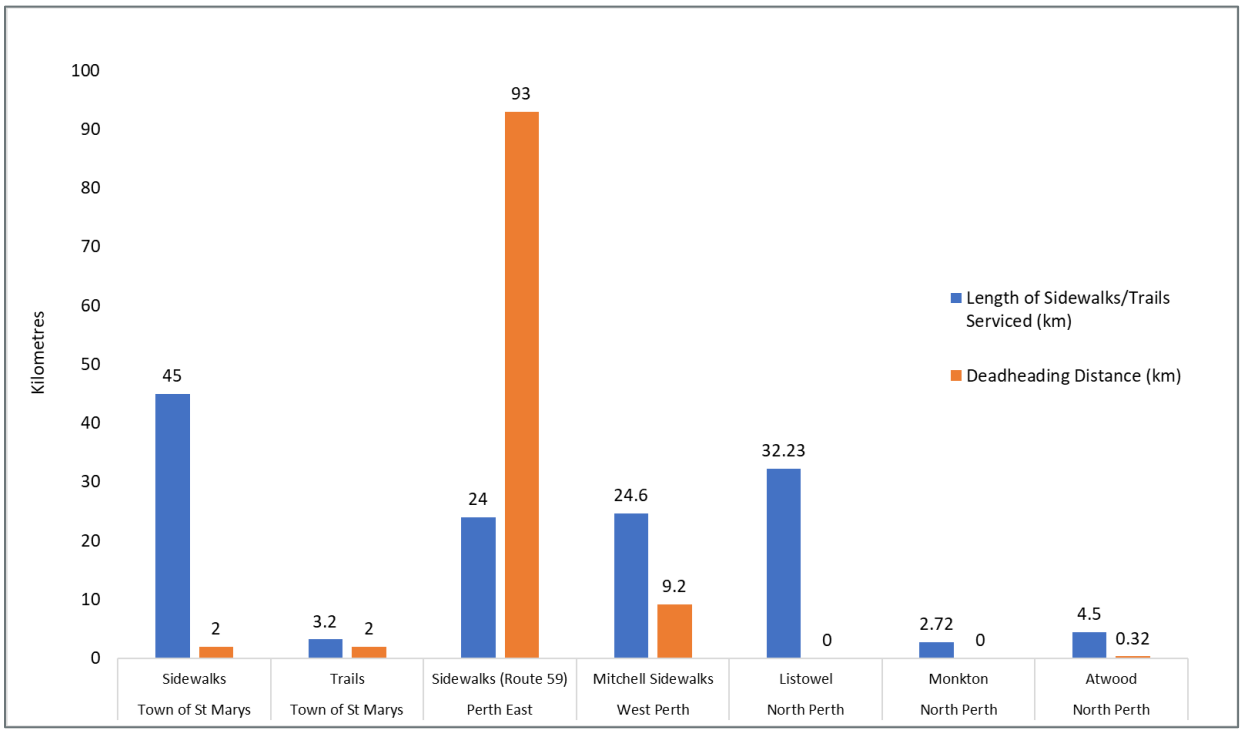



**Figure 38: Sidewalk Service Route Lengths and Deadheading**

As depicted in **Figure 38**, most sidewalks routes within Perth County are comparable in length with the comparator agencies (**Table 14**). It is noted that three routes are particularly short and could take significant equipment preparation and maintenance time in relation to the work performed. However, two of these shorter routes in North Perth are contracted out, which may help to alleviate these concerns. In addition, deadheading distance for Perth East, where the maintained sidewalks are far apart and equipment is transported by truck, could be considered for optimization.

While sidewalk routes in Perth South are contracted out, it was noted in general a lack of competition for winter maintenance services and difficulty in finding contractors due to the cost of insurance. The unavailability of contractors and range of route lengths suggests the advisability of integrating sidewalk services among County agencies.

### 4.9.3. Conclusions and Recommendations

Most sidewalk policies of the Perth agencies meet industry norms in terms of defined service levels. However, some agencies do not have defined service levels related to storm severity, which should be specified, should any claims arise regarding sidewalk conditions during the winter season.

The sidewalk equipment fleet is generally new and modern; however, it was found that some sidewalk vehicles require reloading in order to complete their route. This could result in deadheading and increased circuit times, lowering the overall level of service for sidewalks. Town of St Marys and North Perth have more than one sidewalk vehicle available (one with a larger spreader capacity and one with a smaller capacity), which allows two sidewalk vehicles to service a single route. The routes each vehicle is

responsible for was not provided, but ensuring that the higher capacity vehicles are assigned to the longest route segments can reduce reloading time and deadheading.

Sidewalk route locations are naturally grouped by agency and each group is distant from the others. Thus, optimization across the County would be difficult. However, the lengths of individual routes vary widely as do the deadhead distances in some cases for service equipment to reach the routes, which may be an inefficient use of equipment and labour.

The following actions are recommended to maximize the effectiveness and efficiency of sidewalk maintenance operations:

As a **Priority 1 Action**, develop and implement consistent, harmonized sidewalk maintenance policies (i.e. common criteria for clearly defined servicing and priority levels) between all Perth agencies. Two or three priority levels related to the adjacent road class and roadside facilities (i.e. schools, hospitals, municipal buildings, etc.) could be defined as part of these harmonized policies. Ensure that these policies are communicated clearly and are easily accessible to the public on each agency's respective website.

As a **Priority 1 Action**, the Perth agencies should consider implementing intermediate material storage facilities near priority sidewalks (i.e. educational, medical, and commercial areas) or have a dedicated service truck to refill sidewalk vehicles, carrying materials to transfer when needed. These recommendations have the potential to help reduce the number of material refills and deadheading distances.

As a **Priority 1 Action**, develop written rules of practice for winter materials, for agencies that do not currently have them. The objective of written rules is to provide more consistent levels of service and to support defense of claims beyond an individual's practical experience. Additionally, harmonize material usage on sidewalks to streamline the potential future integration of services.

As a **Priority 1 Action**, all agencies should expand the use of stockpile-treated salt for sidewalk maintenance. As discussed previously in **Section 4.6**, the expanded implementations will help to reduce salt usage with the added benefits of reducing spreading costs. Improving service and reducing salt loadings to the roadside environment.

As a **Priority 2 Action**, consideration should be given to expand sidewalk service in all urban/residential areas such as already implemented at St Marys, so that all sidewalks are maintained. There is currently a trend in winter maintenance operations to do so because it is not uncommon in urban/residential areas for sidewalks to not be maintained by the landowner (e.g. due to negligence, old-age, etc.) in a timely manner. Municipal by-law enforcement for winter sidewalk maintenance is costly and the by-laws, even when enforced, do not relieve the agency of the liability related to slip and fall accidents.

As a **Priority 2 Action**, harmonize sidewalk policies with a view to resourcing for future integration of sidewalk operations in-house.

## 4.10. Parking Lot Operations

### 4.10.1. Standards, Benchmarks, and Best Practices

Snow removal from parking lots is not included in the Ontario MMS requirements but is a recommended component of a Road Salt Management Plan, as requested by Environment Canada. However, there are few written policies that were found specific to the winter maintenance of parking lots. The following

section highlights some findings from a jurisdictional scan and peer review for parking lot winter maintenance standards, benchmarks, and best practices.

## Jurisdictional Scan and Peer Review

A jurisdictional scan revealed that two agencies, the Smart About Salt Council and the Sustainable Technologies Evaluation Program (STEP) have a common goal to bring standard practices and contracting language to the parking lot maintenance industry.

The STEP published a report in association with the Toronto and Region Conservation Authority titled 'Procurement Guidance for Parking Lot Snow and Ice Management'[35] that provides some recommended best practices for parking lot winter maintenance. The report specifies that an agency's policy detailing the winter maintenance of parking lots should include defined service levels related to the adjacent road's class, the type of municipal services utilizing the parking lot, and storm severity.

Additionally, both of these agencies provide programs/courses that certify contractors, agencies, and building owners to use sustainable salting practices. Certified agencies also ger preferred liability insurance rates.

Further, the University of Waterloo published a report titled 'Optimal Snow and Ice Control of Parking Lots and Sidewalks'[36] that includes a survey with over 55 respondents (cities and municipalities) in Canada and the United States regarding parking lot winter maintenance practices/guidelines. **Figure 39** illustrates the locations of the survey respondents and indicates that they are located across North America, suggesting that winter weather conditions and winter maintenance services between municipalities would vary.

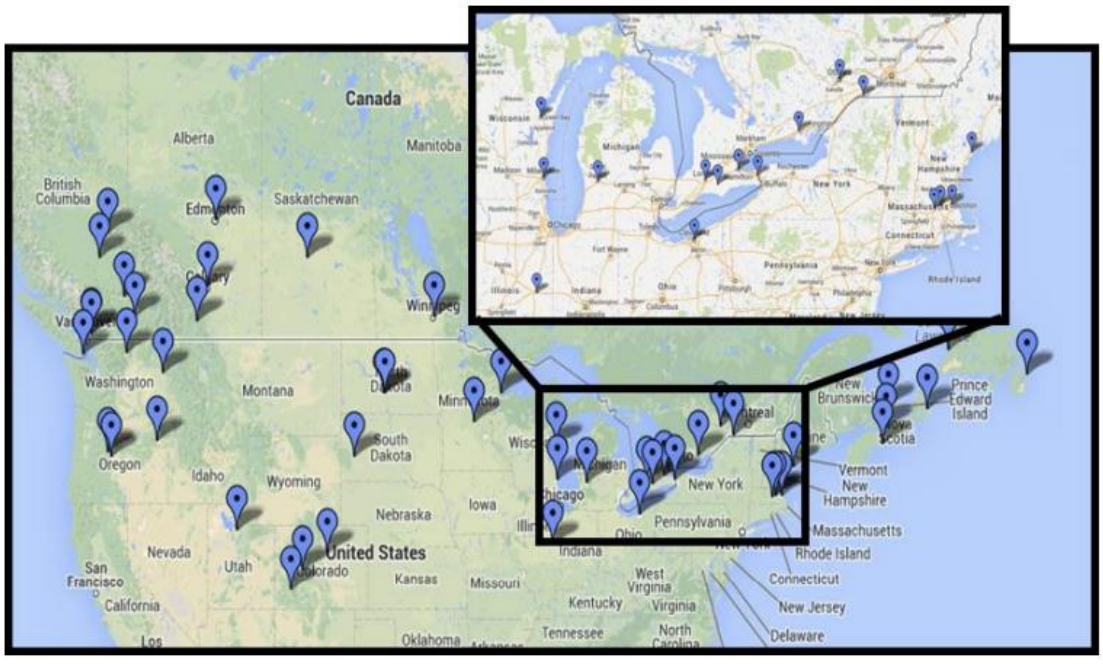



**Figure 39: Locations of Surveyed Cities from University of Waterloo Report**

[35] https://sustainabletechnologies.ca/app/uploads/2019/06/Procurement-Guidance-Parking-Lot-Snow-and-Ice-Mgmt.pdf
[36] https://landscapeontario.com/attach/1424793666.Salt_Rate_Study-University_of_Waterloo-_Final_Summary_Report.pdf

The summary of the major findings from this survey are as follows:

- Approximately 65% of municipalities reported that de-icing - either plowing and salting or salting only is the main method of snow and ice control, whereas only 5% reported that they had performed anti-icing.
- To prevent snow-pavement bonding, most municipalities reported that they performed plowing operations before total snow accumulation reaches 5 cm.
- Few municipalities had reported using materials other than ordinary road salts. As for the types of snow control chemicals being used, 65% of municipalities used regular sodium chloride, while 35% reported using other chloride-based materials such as magnesium chloride. 16% of the respondents reported using abrasives (e.g., sand) for improving pavement surface friction.
- 64% of the municipalities indicated that regular dry sodium chloride was used for snow control while 36% used pre-wetted salts.
- Nearly half of the respondents indicated that they have no guidelines in determining the best application rate for parking lots during a given snow event. Some use the guidelines implemented for roadside maintenance, despite the fact that significant differences exist between roads and parking lots.

Detailed information on parking lot winter maintenance operation was found to be limited across the Province, but some guidelines were found online for the Township of Edwardsburgh-Cardinal, the Town of Fort Erie, and the Town of Whitby.

The Township of Edwardsburgh-Cardinal provides winter maintenance at the parking lots of municipally operated buildings and facilities in a prioritized sequence. During a storm, snow clearing at Priority 1 locations will commence to the main bays access area following 5 cm of snow accumulation and resume at 5 cm intervals. At Priority 2 and 3 locations, access to these lots will be restricted to the driving lanes between the parking rows or to the front of the facility. Similarly, the Town of Whitby maintains parking lots after 5 to 8 cm of snow accumulation, where the main aisles of parking lots are treated and/or cleared to facilitate access. For both agencies, complete plowing of the parking lots is scheduled after the snowstorm has ended and typically occurs when the lot is either in a no-use or low-use period (i.e. before the next day facility opening).

The Town of Fort Erie treats parking lots as a Class 6 in the road class system (i.e. not subject to legislated MMS). If snow plowing of parking lots is required, it is not included as part of regular plow routes and is typically cleared at the end of an event during overnight hours (similar to the Township of Edwardsburgh-Cardinal and the Town of Whitby) in a snow packed condition.

### 4.10.2. Current Practice

**Table 17** provides an assessment of the agencies' current practices with respect to parking lot winter maintenance and compared with one another based on the STEP best practices discussed previously. It is noted that Perth County currently has a facility removal contract for parking lots (i.e. paramedical services, courthouse, archive buildings, etc.) and are not conducting any parking lot winter maintenance as a result. Similar to sidewalk winter maintenance, parking lot winter patrols involve a patroller who inspects parking lot conditions while performing the roadway winter patrol.

**Table 17: Parking Lot Policy Comparison**

| Agency / Criteria | St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|
| **Written and defined service levels related to adjacent road class** | NO | NO | NO | NO | NO |
| **Written and defined service levels related to type of municipal services utilizing the parking lot (observed in policy)** | NO | NO | NO | NO | NO |
| **Written and defined service levels related to storm severity** | NO | NO | NO | NO | NO |
| **Type of material used** | Sand (only if it's below -14) and salt/sand mix | Salt | Sand | Salt (only when icy) | Salt/sand mix |
| **Application rate** | 230 kg/lane km (sand) and 115 kg/lane km (mix) | 50 kg/lane km | Operator's Discretion | 130 kg/lane km | 125 kg/lane km |
| **Trigger for Deployment** | Winter patrol | Winter patrol, current/forecasted weather conditions, snow accumulation | Winter patrol | Winter patrol and current/forecasted weather conditions | Winter patrol and current/forecasted weather conditions |
| **Procedure for Parking Lot Maintenance** | Plowed at the operator's discretion (no dedicated route) | Generally plowed prior to opening of regular business as part of a dedicated route | Cleared as part of the patrol route originating from Downie Yard or a tractor is sent after regular roadway maintenance operations to plow them | Plowed at the operator's discretion (no dedicated route) | Plowed as part of in-house and contracted roadway plow routes (most Listowel parking lots maintained in-house (remaining are contracted out), Atwood and Monkton parking lots contracted out) |

All Perth agencies did not have defined service levels related to the adjacent road class (i.e. arterial, collector, local), type of municipal services utilizing the parking lot (observed in policy), and storm severity (i.e. specific actions taken when there is less than 8 cm of snow, greater than 8 cm of snow, heavy storm conditions, etc.). The materials used in parking lots fit the requirements of MMS, but the materials used in parking lots vary between the Perth agencies. Application rates estimated from client information range from approximately 50 to 130 kg/km for salt and 115 to 230 kg/km for sand and salt/sand mix. However, application rates for parking lots in Perth South were reported to vary at the operator's discretion. Deployment for parking lot maintenance is typically dictated by the roadway winter patrol for all Perth agencies, along with current/forecasted weather conditions and/or snow accumulation for some agencies. The procedures for parking lot maintenance varies between the agencies, ranging from a list of predefined parking lots plowed at the operator's discretion (i.e. no dedicated route) to being cleared as part of a roadway maintenance route or even a dedicated parking lot route.

**Figure 40** displays the number of parking lots serviced by each maintenance yard for the Perth agencies and indicates which are serviced as part of a plow route and which are serviced independently. Additionally, characteristics of parking lot snow clearing equipment used by the Perth agencies is summarized in **Table 18**.

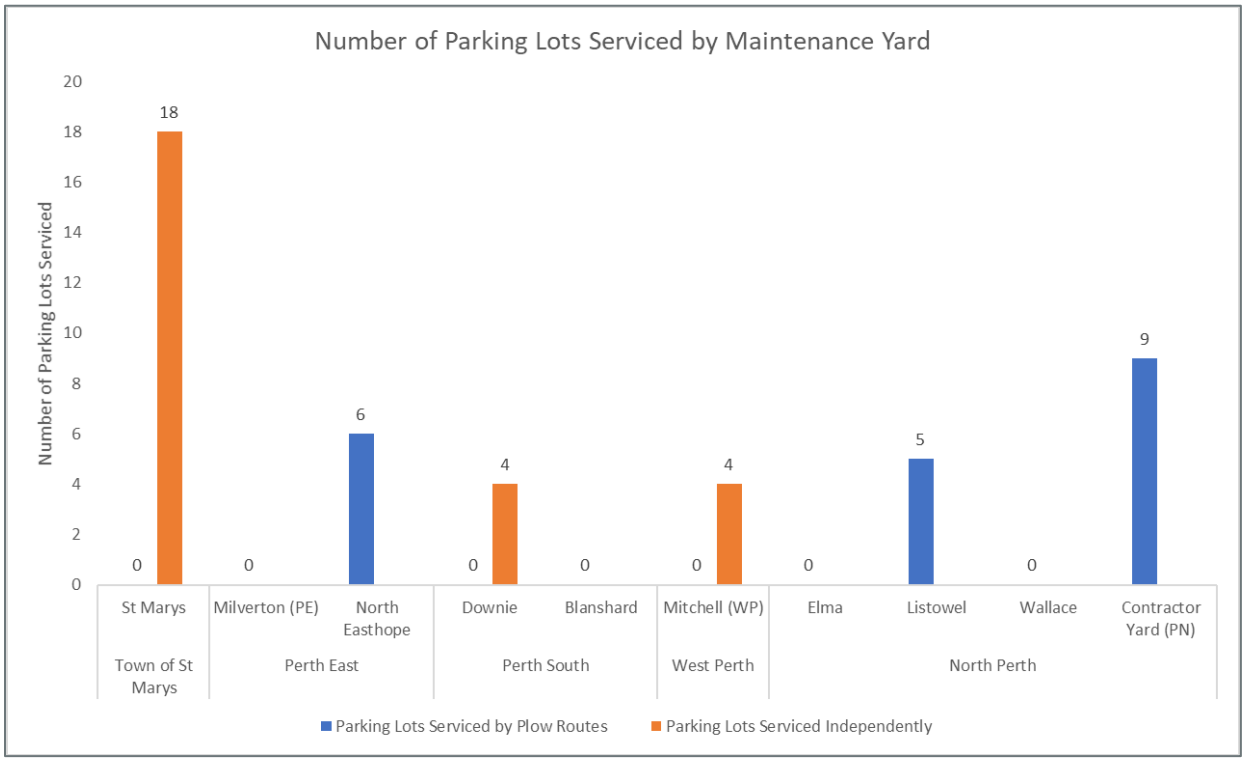



**Figure 40: Number of Parking Lots Serviced by Plow Routes for each Maintenance Yard**

**Table 18: Parking Lot Equipment**

| Municipality | Origin Yard | Parking Lot Vehicle ID | Vehicle Type | Vehicle Age (years) | Spreader Capacity (tonnes) | Number of Parking Lots Maintained | Total Area of Serviced Parking Lots ($m^2$) |
|---|---|---|---|---|---|---|---|
| **Town of St Marys** | St Marys | T60 | Pick Up Truck | 2 | 2.5 | 18 | 41,864 |
| **Perth East** | North Easthope | M54 | Wheel Loader | 13 | N/A | 2 (plow-only) | 9,200 |
| **Perth East** | North Easthope | M11 | Pick Up Truck | 3 | 2.0 | 6 (salts 6 and plows 4) | 17,300 |
| **Perth South** | Downie | Truck #45 | Pick Up Truck | 0 | 1.5 | 4 | 3,530 |
| **West Perth** | Mitchell (WP) | #100 Dodge 2500 or #101 Ford 250 | Pick Up Truck | 1 | Not Specified | 4 | 19,475 |
| **North Perth** | Listowel | 3733 | Single Axle | 6 | 8.8 | 5 | 14,039 |
| **North Perth** | Contractor Yard (PN) | H&H Contractor #1 | Single Axle | 10 | 4.9 | 6 | 13,957 |
| **North Perth** | Contractor Yard (PN) | H&H Contractor #2 | Single Axle | 10 | 4.9 | 3 | 5,908 |

Equipment load capacity for spreading material ranges from 1.5 to 8.8 tonnes. The parking lot application rates provided by the Perth agencies (**Table 17**) were converted from kilograms per lane kilometre to tonnes per $m^2$ assuming a typical lane width of 3.5 metres in order to determine the suitability of the spreader capacities assigned to each route. It was determined that all parking lot operations, with the exception of the Town of St Marys and West Perth, can be conducted with a single fill. Perth South indicated that their application rate for parking lots maintenance varies at the operator's discretion, so St Marys' sand application rate of 230 kg/lane km was assumed for Perth South.

It is important to note that since St Marys applies either sand or salt/sand mix at parking lots depending on the weather conditions, the more critical case of sand was used since it has a higher application rate of 230 kg/lane km compared to salt/sand mix which is 115 kg/lane km.

For West Perth, the vehicles that were assigned to service parking lots do not have spreading capabilities, but it was indicated that salt is applied sometimes only when it is icy. It was estimated based on the provided application rate and area of serviced parking lots that a vehicle with a spreader capacity of 1 tonne should be sufficient to service all of West Perth's parking lots with a single fill.

Lastly, for North Perth, it was noted that all parking lot operations are conducted by vehicles responsible for roadway routes as well. However, it was found that the spreader capacities for all three trucks are sufficient (marginally sufficient for Truck 3733) to service both their assigned route and parking lots. upon further review.

The majority of the parking lot vehicles are 6 years old or newer, with 3 vehicles that are 10 years old or greater, indicating good life cycle management.

**Figure 41** illustrates the locations of all maintained parking lots within Perth County and the yards responsible for servicing them.

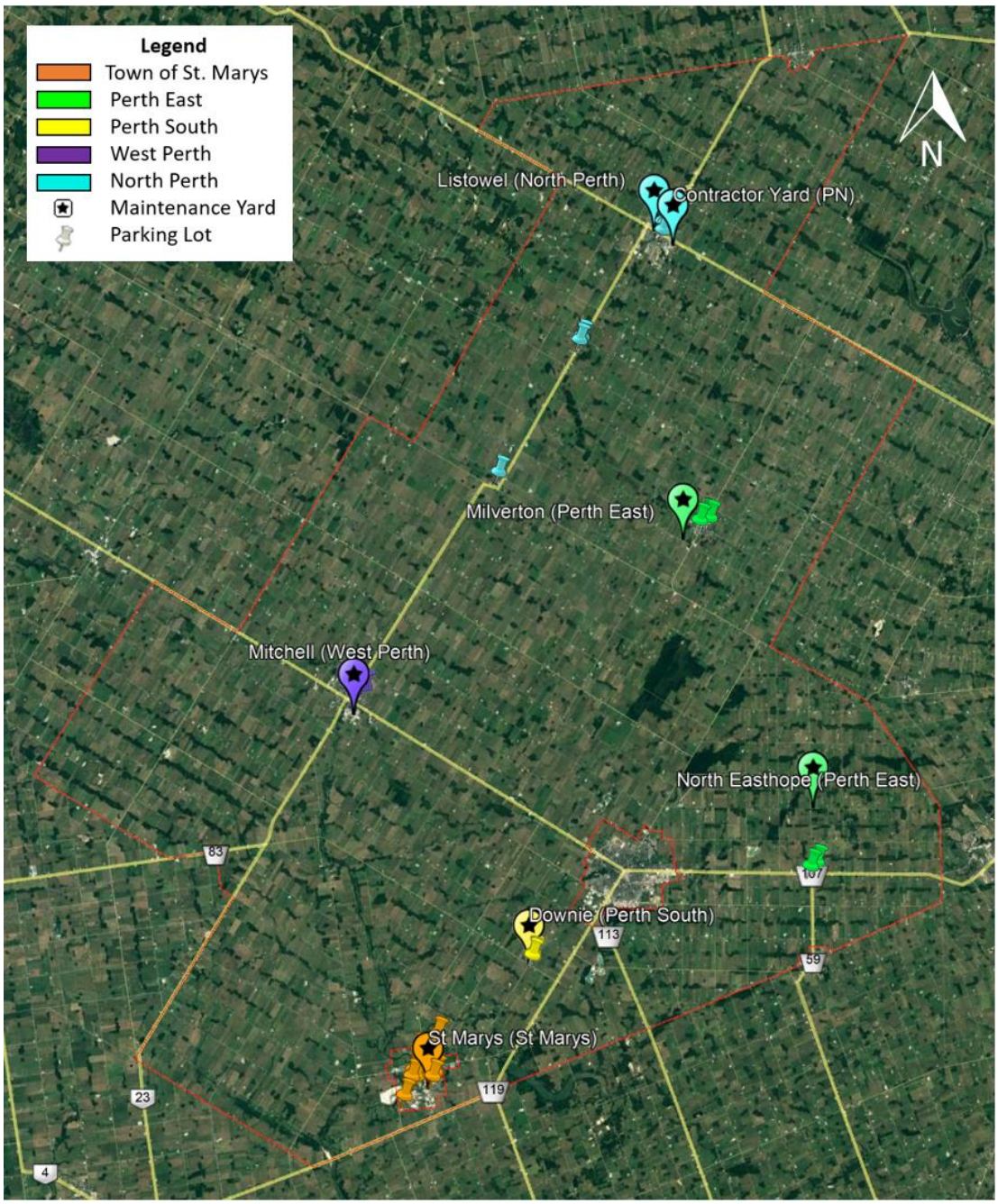



**Figure 41: Parking Lot Locations of Perth Agencies**

As depicted in **Figure 41**, most parking lots within Perth County are clustered together and are located within a reasonable distance to a maintenance yard, so it is expected that the agencies will be able to service the parking lots in a timely manner. In this figure, the parking lots that are the furthest from a nearby yard are observed to be the two parking lots in Shakespeare approximately 4 km south of Perth East's North Easthope yard and the three parking lots in Atwood (2) and Monkton (1) approximately 9 km and 20 km south of North Perth's Contractor Yard, respectively. Assuming a travel speed of 60 km/h, vehicles from the nearest yard can reach Perth East's two Shakespeare parking lots and North Perth's two Atwood parking lots within 10 minutes, which is a reasonable response time. However, the one

parking lot in Monkton is slightly further from its maintenance yard, resulting in response time of approximately 20 minutes. However, it is noted that this parking lot is serviced by contractors as part of North Perth's regular roadway snowplow route in Monkton (Beat K), so it is expected that this parking lot will also be serviced in a timely manner.

### 4.10.3. Conclusions and Recommendations

The winter maintenance of parking lots is not subject to any legislative standards; however, some industry best practices/benchmarks (i.e. The STEP's Procurement Guidance for Parking Lot Snow and Ice Management report) were outlined previously. All Perth agencies lack written and published policies regarding parking lot winter maintenance, exposing the agencies to liability for potential parking lot accidents.

The parking lot equipment fleet is generally new and modern, and the majority of vehicles can service their assigned parking lots on a single fill. Parking lot locations are naturally grouped by agency and each group is distant from the others. Thus, optimization across the County would be difficult.

The following actions are recommended to maximize the effectiveness and efficiency of parking lot maintenance operations:

As a **Priority 1 Action**, develop and implement consistent, harmonized parking lot maintenance policies (i.e. common criteria for clearly defined servicing and priority levels) between all Perth agencies. Additionally, ensure that service guidelines clearly define triggers for deployment related to snow or ice accumulation, priority levels/service times related to parking lot function, equipment types, and material application rates. These policies should also be communicated clearly and made easily accessible to the public on each agency's respective website.

As a **Priority 1 Action**, all agencies should develop written rules of practice for winter materials used in parking lots. The objective of written rules is to provide more consistent levels of service and to support defense of claims beyond an individual's practical experience. Additionally, harmonize material usage in parking lots to streamline the potential future integration of services.

As a **Priority 1 Action**, develop a resourcing plan for an integrated parking lot service that is resourced with the types of equipment appropriate for the lots being serviced, and capable of plowing and applying material.

As a **Priority 1 Action**, all agencies should expand the use of stockpile-treated salt for parking lot maintenance. As discussed previously in **Section 4.6**, the expanded implementations will help to reduce salt usage with the added benefits of reducing spreading costs and reducing salt loadings to the roadside environment.

## 4.11. Service Delivery

### 4.11.1. Background

Service delivery can be defined as the relationship between the service provider and the client. The service provider may be the municipal employee or a contractor, while the client may be thought of as the road agency or the public road user. Legislation does not speak to the method of service delivery and many examples of different options in winter maintenance can be found at all tiers of government.

Outsourcing services has been a common practice in winter operations since at least the 1980's. Some objectives of privatized operations include: fulfilling short-term or seasonal resource needs, changing labour relationships, transferring funding sources between capital and operating, or transferring financial risk between the public and private sector.

Turn-key privatization of winter maintenance is sometimes perceived as a cost saving measure, but after decades of turn-key operation by some provinces the results are not clear, and each case needs to be considered on its own merits.

The scale of outsourcing follows an agency's intended objectives, from seasonal staff to contracted equipment/operators to multi-year, multi-function contracts that may be structured by the inputs such as tonnes of salt spread and outputs such as bare pavement regain time or reduced winter accidents. The Ontario Ministry of Transportation progressed through all these scales of outsourcing since 1995 and has not yet identified a single contract model that applies in all areas.

In the Greater Toronto and Hamilton Area (GTHA), Oakville, Burlington, Milton, Hamilton, Mississauga, Brampton, and York Region have all contracted a portion of their winter maintenance operations with varying contract structures/outsourcing models. It is common that the equipment is priced by the hour with a guaranteed minimum hours per month, operator included. Larger outsourcing operations may involve contracting out an entire maintenance yard or district where the contractor supplies, unloads, and loads all materials, along with conducting winter patrols as part of the contract.

### 4.11.2. Benchmarks

Benchmarks for outsourcing winter maintenance are not specified in MMS or any prevailing winter maintenance guidelines because there is no 'one size fits all' solution since its scale depends on an agency's intended objectives from outsourcing work and any specific issues that they want to be addressed. For example, outsourcing has been used successfully to address a range of specific issues such as:

- Funding shortfall within one envelope that can be contributed by another (capital vs. operations);
- Spreading financial risk (averaging variable expenditures out over several years using lump sum annual payments);
- Sharing road liability risk;
- Promoting innovation;
- Filling short term or seasonal needs (trucks, people);
- Servicing locations distant from maintenance yards; and
- Providing specialized services.

Two case studies are provided to illustrate the advantages and risks of different outsourcing models for winter maintenance. One is for the Virginia Department of Transportation (VDoT) and the other for the Ministry of Transportation of Ontario (MTO).

### VDoT Case Study

A report titled 'Development of a Toolkit for Cost-Benefit Analysis of Specific Winter Maintenance Policies, Equipment and Operations Phase 2'[37] by Clear Roads highlights three possible methods for the delivery of winter maintenance contracting used by the VDoT, as summarized in **Table 19.**

[37] http://clearroads.org/wp-content/uploads/dlm_uploads/11-01-Ben-Cost-Toolkit-II-Final-Report.pdf

**Table 19: Virginia DOT Contracted Plows vs. State Owned Trucks**

| Outsourcing Model | Approach | Advantages | Disadvantages |
|---|---|---|---|
| **Full Asset Maintenance Contract** | Lump sum monthly fee | • Budget costs are fixed so contractor absorbs any additional costs in years of extreme winter events (Agency)<br>• Oversight of operations is reduced so that the agency does not need to track hours of operations for equipment for payment (Agency)<br>• Poor performance can be penalized, ensuring that services not provided are not paid (Agency)<br>• The contractor assumes the majority of the risk (Agency)<br>• Agency no longer has a large capital investment in equipment (Agency)<br>• Ability to manage operations (Contractor)<br>• Ability to utilize new technologies or methods (Contractor) | • Staff is no longer in direct control of operations (Agency)<br>• Agency may be competing with the contractor for staff or materials for which they would normally be the sole source of procurement<br>• Once staff and equipment are lost to subcontracting it is frequently difficult, if not impossible, to increase to prior staff and equipment levels if the contract is not renewed (Agency)<br>• There is no reduction in cost for mild winters (Agency)<br>• Need to train and keep staff available for events that are infrequent (Contractor)<br>• Assumption of risk (Contractor)<br>• The possibility of high penalties for poor performance (Contractor)<br>• No additional payment for severe winters (Contractor)<br>• Higher cost for procurement of materials purchased from an agency (Contractor) |
| **Line Item Contract** | Payment by the hour per piece of equipment operated | • Agency in complete control of how winter events are managed (Agency)<br>• Agency can adjust operations to accommodate changes in conditions (Agency)<br>• Very little risk (Contractor)<br>• Capital expenses can be covered by mobilization fees (Contractor)<br>• Use of agency infrastructure, including equipment yards and salt storage (Contractor) | • Agency runs the risk of significantly overrunning winter budget during severe winters (Agency)<br>• All risk is assumed by the agency (Agency)<br>• Agency can be subjected to pressure from constituents to perform at a higher level than snow plan dictates (Agency)<br>• Agency routinely has to guarantee minimum payments once contractor is notified to respond, as well as pay an annual mobilization for each piece of equipment (Agency) |

| Outsourcing Model | Approach | Advantages | Disadvantages |
|---|---|---|---|
| | | | • Tracking hourly equipment usage takes significant resources and staff to manage to verify invoices for payment (Agency)<br>• Need to train and keep staff available for events that are infrequent (Contractor)<br>• Need to keep large complements of equipment in good working order for a worst-case scenario winter event (Contractor)<br>• Few opportunities to make a profit during mild winters (Contractor) |
| **Hybrid Contract** | Fixed payment up to a certain snow depth and reimbursement per Inch beyond that point | • Budget costs are fixed for the majority of winter events (Agency)<br>• Oversight of operations is reduced for the majority of events (Agency)<br>• Poor performance can be penalized, ensuring that serviced not provided are not pair for (Agency)<br>• The contractor assumes the majority of the risk for the majority of winter events (Agency)<br>• Decreased risk (Contractor)<br>• Less opportunity for penalties (Contractor) | • Staff is no longer in direct control of most winter operations (Agency)<br>• May be difficult to redirect staff or subcontractors when there is a major event (Agency)<br>• Subcontractors who do not routinely work on routes may not be familiar with the winter operations plan or have knowledge of the area and specific issues such as cold spots or bridge joints (Agency)<br>• Coordination and communication may be more difficult, especially if there are several contractors who may utilize different technologies (Agency)<br>• Costs for major events can have severe impacts on budgets (Agency)<br>• Opportunity for poor communication and coordination (Contractor)<br>• Lack of ability to control additional subcontractors (Contractor<br>• Risk of safety issues with additional subcontractors (Contractor) |

As indicated in **Table 19**, there are number of benefits that an agency can achieve through any of these models. However, these must be carefully considered with regards to the potential disadvantages that an agency may encounter as well.

### MTO Case Study

Before 2009, the MTO mainly outsourced winter highway maintenance using a combination of Managed Outsourcing (MO) and Area Maintenance Contract (AMC) contract models. MO contracts were for specific services such as plowing, salting, and sanding. Ministry staff were responsible for conducting the necessary patrolling of highways to determine how much equipment and material was needed to keep highways clear and safe. Ministry staff then directed the contractors in delivering the services needed, following the best practices and operational procedures developed by the Ministry. Contractors were paid on a unit-cost basis for the work they completed. Some of the Ministry's best practices and procedures include:

- Patrolling highways at least once a day;
- Closely monitoring weather reports to predict harsh winter weather in advance;
- Keeping circuit lengths and equipment speeds at prescribed levels, and using this information to calculate the minimum amount of equipment needed to effectively service the area's highways;
- Following prescribed procedures to prioritize plowing operations for different highway segments such as main lanes, left-turn lanes, shoulders, and ramps; and
- Following prescribed procedures for applying treatment material such as anti-icing liquids, sand, and salt.

For AMCs, a large portion of the MTO's provincial highway network was divided into 16 areas, where the contractor that won the contract for each area was responsible for planning and managing the work specified in the AMC. Although Ministry staff no longer patrolled the highways to direct contractors' work, the AMCs still required contractors to follow the Ministry's best practices and procedures, as listed previously.

However, the MTO has shifted to 'performance-based' contracts since 2009, where contractors bid to plow the Ministry's winter highways and give the contractors full autonomy in determining how they would meet the Ministry's winter highway maintenance outcome targets (standards) to clear the highways of snow and ice within prescribed time frames. In Ontario, 100% of MTO's winter maintenance was outsourced as of the 2013/2014 winter season.

The reasons for the MTO's transition to 'performance-based' contracts are summarized as follows:

- The costs for the awarder of the contract should decrease (including, under long-term contracts, fewer resources needed for contract administration);
- With long-term contracts allowing the contractor more time to pay off the costs of equipment, the contractor has the incentive to invest in the best-value equipment and methods, which may improve efficiency and further lower costs; and
- Giving the contractor extensive freedom to manage the work may encourage the contractor to find innovation and try out experimental winter materials, which may improve quality of service.

The MTO's Auditor General report on Winter Highway Maintenance[38] from 2015 provides some key observations from the Ministry's experience using 'performance-based' contracts between 2009 and 2014, as summarized in **Table 20**.

[38] https://www.auditor.on.ca/en/content/specialreports/specialreports/winterhighway_en.pdf

**Table 20: Key Observations on the MTO's Experience Using Performance-Based Contracts**

| Report Topic | Key Observations |
|---|---|
| **Deterioration of Service under Performance-Based Contracts** | • Winter highway maintenance service levels declined with the introduction of the performance-based contractors over the last five years, but performance-based contracts resulted in significantly lower winter highway maintenance costs for the Ministry, enabling it to control the upward trend in costs that would likely have been incurred under the previous contract model<br>• Contractors used less equipment, which resulted in reduction of service<br>• Contractors used less treatment material to service highways<br>• Contractors patrolled less often, resulting in service failures<br>• Contractors were unable to meet contract requirements (about 50% of these incidents were an inability to complete circuits on time) |
| **Process to Procure Performance-Based Contracts** | • Procurement process did not adequately factor in contractors' ability to deliver required services<br>• Procuring the lowest-bidding contractor can cost more in the long run |
| **Ministry Oversight of Contractors** | • Audits not risk-based or the most effective<br>• Audit targets not being met<br>• Over-reliance on contractors' self-reporting of their performance<br>• Monitoring tools lacking<br>• Waiving of fines inconsistent<br>• Information for decision-making lacking<br>• Potential increased legal costs not considered |

As indicated in **Table 20**, the MTO noted that the usage of 'performance-based' contracts has led to a decrease in winter highway maintenance service levels across the province, contractors took longer to achieve bare pavement, and highway maintenance during storms declined. However, while 'performance-based' contracts have caused winter highway maintenance service levels to decline, 'performance-based' contracts resulted in significantly lower winter maintenance costs for the Ministry, which allowed them to control the upward trend in costs that would likely have been incurred under the previous contract model (combination of MO contracts and AMCs). However, in recent years, the MTO has added additional services to existing contracts at extra cost to improve the level of service.

### 4.11.3. Current Status

A low level of outsourcing is currently being undertaken in Perth County: four agencies contract some roadway routes, two agencies contract sidewalk operations, one agency contracts parking lot maintenance, and three agencies have agreements with neighbouring municipalities to maintain boundary roads.

Perth County's experience with outsourcing two of their roadway routes to a private contractor is positive overall. The County's existing contract with their contractor guarantees a minimum flat rate per day per truck during the winter season. When winter maintenance is required, the contractor is then paid per hour that the truck is running along with per hour that the operator works. The frequency of service for the contracted routes is the same as the in-house routes, where the County will conduct the winter patrol and call the contractor in as needed. The County's main reason for outsourcing is to minimize the number of snowplows in their fleet because they are not utilized as much in the summer as they used to. The County's experience with their snowplows is that they tend to run into more issues when they are left unused and lying around, leading to increased maintenance/operational costs.

The relative unavailability of contractors in Perth County area has resulted in little or no competition for contracts, and cases where no bids were attracted.

The current status of outsourced winter maintenance for the Perth agencies is summarized in **Table 21**.

**Table 21: Current Status of Outsourced Winter Maintenance of Perth Agencies**

| Winter Maintenance Service Area | Perth County | Town of St Marys | Perth East | Perth South | West Perth | North Perth |
|---|---|---|---|---|---|---|
| **Roadways** | Two contracted routes (Routes #2 and #3) | N/A | N/A | One contracted route in Sebringville due to narrow streets | N/A | Three contracted routes (Beats A, C, and K) |
| **Sidewalks** | N/A | N/A | N/A | Sidewalks in Sebringville contracted to Perth East | N/A | Sidewalks in Atwood and Monkton are maintained by contractor |
| **Parking Lots** | N/A | N/A | N/A | N/A | N/A | Parking lots in Atwood and Monkton are maintained by contractor |
| **Boundary Roads Maintained by Other Agencies** | Some roads maintained by Oxford County, Waterloo, Huron County, and Wellington County | None | None | Some roads maintained by the Township of Lucan-Biddulph, Perth East, St Marys, Stratford, and West Perth | Some roads maintained by Perth East, Perth South, Huron East, and South Huron<br><br>OMIS maintains Highways #8 and #23 within limits of the former town of Mitchell on its Class 2 Connecting Link Road | None |

### 4.11.4. Conclusions and Recommendations

Alternative service delivery is commonly used in winter maintenance operations over a variety of scales. Case studies illustrate the importance to have a clearly defined reason for outsourcing and to structure contracts or agreements to achieve the desired objectives.

Outsourcing in Perth County consists in the sharing of roadway or sidewalk routes among bordering agencies using specific agreements, and in contracting equipment and operators for several road and sidewalk routes along with some parking lot winter maintenance. This study did not investigate the detailed objectives nor outcomes of the service delivery agreements.

Considering the difficult experience of much larger organizations in managing contracts to obtain required service levels along with cost savings, expanded outsourcing is not recommended unless specific needs are identified that cannot be met with in-house services or by hiring seasonal staff to operate agency-owned equipment.

**Priority 1 Action** is to explore options for alternative in-house service delivery, such as harmonizing levels of service and operating practices, and partially or fully integrating operations. Additionally, develop and implement a pilot project for service integration for a service that is difficult to resource, (i.e. parking lots or sidewalks).

## 4.12. Public Communications

Public access to government information has been revolutionized in this century. Access to legislation, policies, information about services and direct connection to employees has become the norm. This allows the public to conduct business and life activities in a more efficient way than before. This trend can be seen in winter operations where both tombstone information about policies and standards, and active information about current conditions affecting travel, are available on-line.

For this study, a web survey of provincial, county and municipal agencies was conducted to identify the types of information posted about winter operations. MTO has the most extensive information, managed by the Traveller Information Office and focussed on an externally hosted 511 system. Grey County operates a system similar to 511. Benchmark information content was identified from MTO and Grey County sites (**Table 22**).

The benchmarks include tombstone information that provides the public with an understanding of the levels of service to be expected on different classes or types of roads, the locations of those roads, the exceptions to service level such as Significant Weather Event defined by MMS, contact information to report unusual conditions, active display of the current conditions and operations, and special information for commercial vehicles.

Approximately 45 Ontario municipalities including Perth County and St Marys subscribe to Municipal511, a commercial service for municipalities that is similar to Ontario511. It is used primarily for external posting of planned road hazards such as construction or other road closures or detours but can be used to post active information. Most municipal users have elected not to post winter road conditions such as current and forecast road conditions on MTO's 511 due to the difficulty in maintaining timely updates, but some users post available webcam or Twitter feeds that display current winter conditions.[39]

[39] D. Allpport, Transnomis Solutions Inc.

**Table 22: Winter Maintenance Information on Public Websites**

| Benchmark | MTO[40][41] | Grey[42] County | Perth[43] County | Perth East[44] | West[45] Perth | Perth South[46] | North Perth[47] | St[48] Marys |
|---|---|---|---|---|---|---|---|---|
| **Policies and standards** | Y | Y | Y | Y | Y | N | Y | Y |
| **Contact information for inquiries** | Y | Y | Y | Y | Y | Y | Y | Y |
| **Current road conditions (Municipal511)** | Y | Y | Y, Twitter | N | N | Y | N | Y |
| **Forecast road conditions (Ontario511)** | Y | N | Y, HWY 7 only | N | N | Y | N | Y |
| **Explains Road Condition** | Y | Y | Y | N | N | Y | N | Y |
| **Weather cameras** | Y | Y | N | N | N | Y | N | Y |
| **Road closures** | Y | Y | Y | N | N | Y | N | Y |
| **Current operations (track my plow)** | Y | N | N | N | N | N | N | Y |
| **Seasonal load restrictions for trucks** | Y | Y | Y | Y | Y | Y | N | Y |
| **Total** | 9 | 7 | 7 | 4 | 3 | 7 | 2 | 9 |

Web sites for Perth County agencies were accessed and information rated against the benchmark agencies. **Figure 42**, **Figure 43**, **Figure 44**, and **Figure 45** provide example screen shots from the public websites.

[40] http://www.mto.gov.on.ca/english/ontario-511/winter-highway-maintenance.shtml
[41] https://511on.ca
[42] https://www.grey.ca/roads/road-conditions-closures
[43] https://www.perthcounty.ca/en/living-here/road-conditions.aspx
[44] https://www.pertheast.ca/en/municipal-services/wintermaintenance.aspx#
[45] https://www.westperth.com/en/my-west-perth/snow-removal.aspx
[46] https://www.perthsouth.ca/en/index.aspx
[47] https://www.northperth.ca/en/our-community/seasonal-maintenance.aspx#
[48] https://www.townofstmarys.com/en/living-here/Winter-Maintenance-and-Snowplowing.aspx

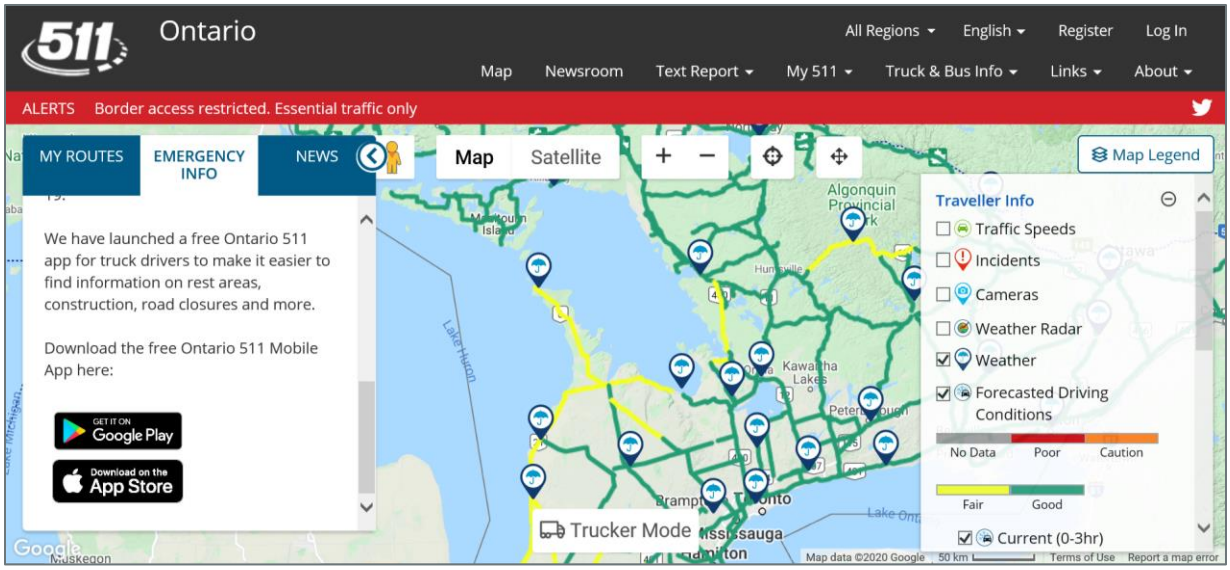



**Figure 42: MTO511 Road Conditions Web Page**

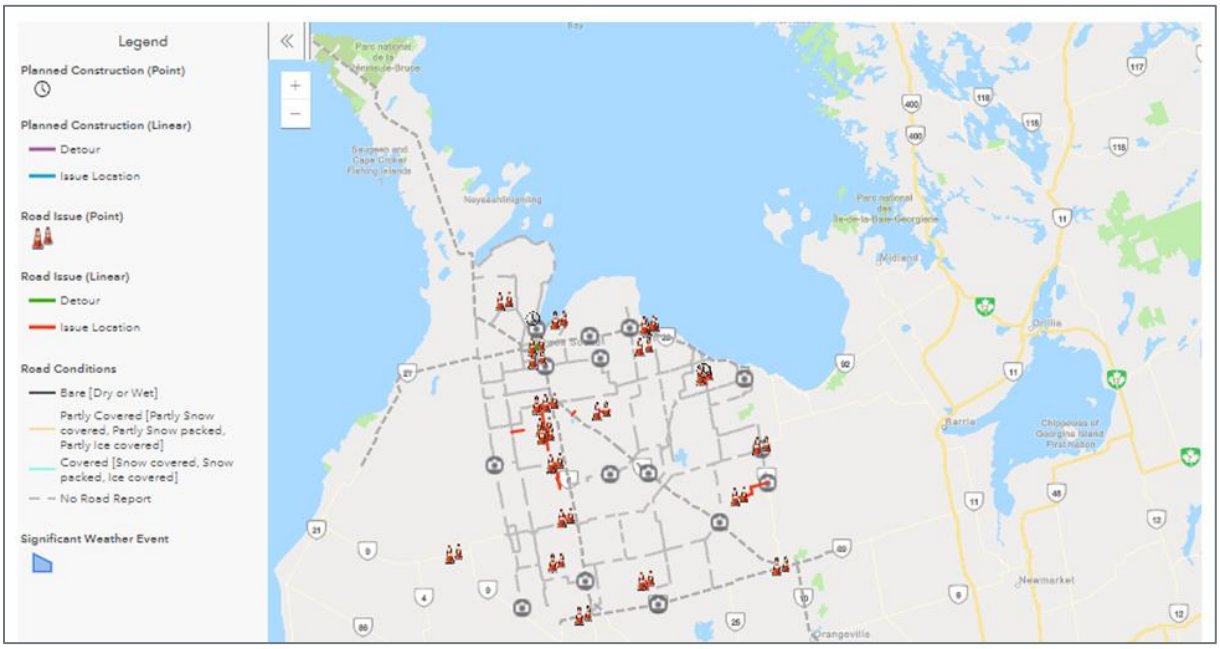
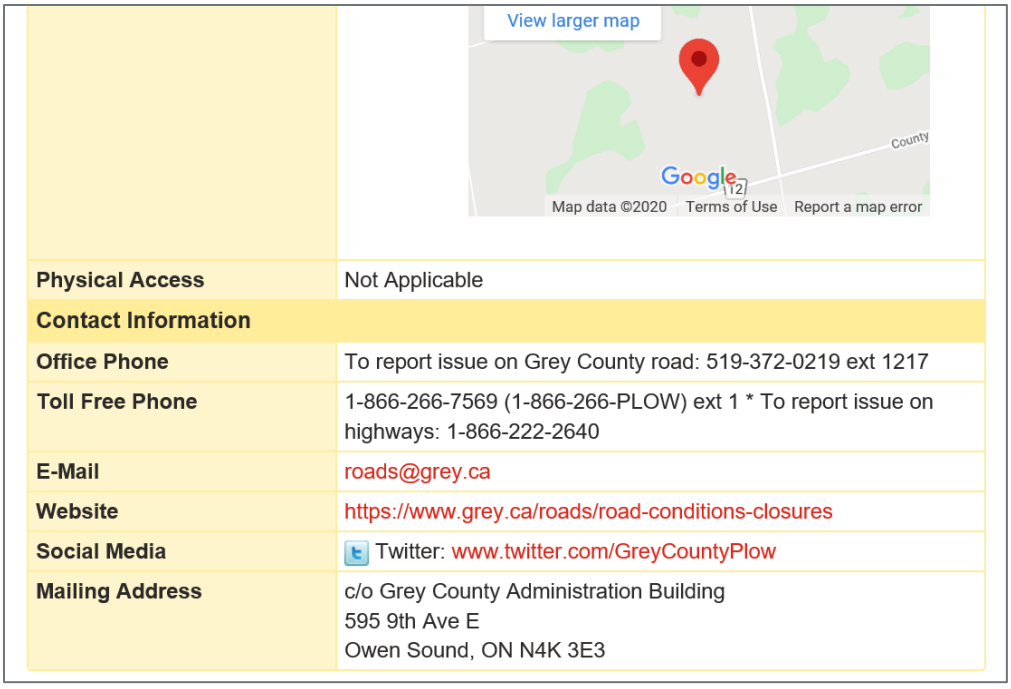



**Figure 43: Grey County Road Conditions Web Page**




| | |
|---|---|
| **Physical Access** | Not Applicable |
| **Contact Information** | |
| **Office Phone** | To report issue on Grey County road: 519-372-0219 ext 1217 |
| **Toll Free Phone** | 1-866-266-7569 (1-866-266-PLOW) ext 1 * To report issue on highways: 1-866-222-2640 |
| **E-Mail** | roads@grey.ca |
| **Website** | https://www.grey.ca/roads/road-conditions-closures |
| **Social Media** | Twitter: www.twitter.com/GreyCountyPlow |
| **Mailing Address** | c/o Grey County Administration Building<br>595 9th Ave E<br>Owen Sound, ON N4K 3E3 |

**Figure 44: Grey County Winter Conditions Reporting Site**

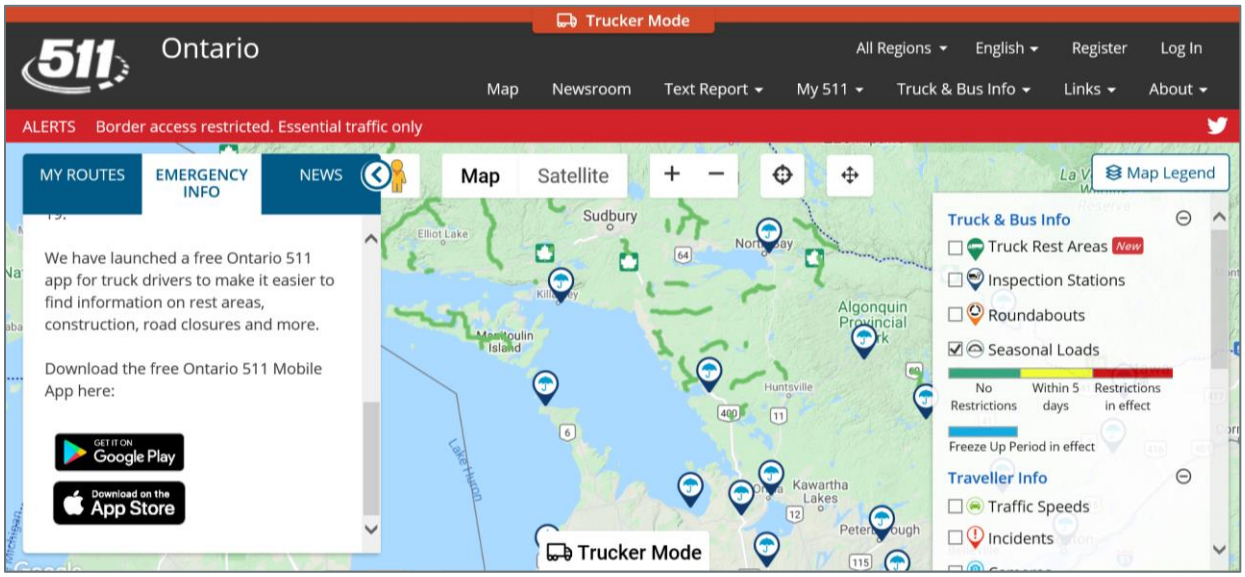



**Figure 45: MTO511 Seasonal Load Restrictions Web Page**

### 4.12.1. Conclusion and Recommendations

The web survey indicated that Perth County, Perth South, and St Marys meet or exceed the Grey County benchmark. They subscribe to the Municipal511 commerical service that provides similar informaton to

MTO511. The pricing model for Municipal511 allows free use by any municipal government within a County that purchases the service.[49]

Other agencies provide tombstone type information but less active information on current operations and road conditions and would benefit from access to Municipal511.

The public driving experience in Perth County can be enhanced with a harmonized approach to information on current road conditions and operations. It is recommended as a **Priority 1 Action** that the Municipal511 service be extended to all agencies within Perth County and that the web link be easily accessible through municipal websites. In addition it is recommended that a roadside webcam network be implemented and linked for display on Municipal to provide real-time, active information on winter road conditions to the public.

## 4.13. Drifting Snow Hazards

### 4.13.1. Background and Status

Drifting snow and whiteouts are a common occurrence in agricultural areas of southwestern Ontario, are a common cause of road closures and are responsible for the longest weather-related closures and the most devastating multi-vehicle accidents, winter or summer (**Figure 46**).[50]

**Figure 46: Drifting Snow Hazard**

Drifting snow and whiteout conditions occur when wind in open areas such as farm fields lift newly fallen snow from the ground and carry it sideways, either through saltation near ground level or suspension at higher levels.[51] Drifting may occur for up to three days following a snowfall until snowflakes melt or pack together and can no longer be lifted by wind action, with drifting occurring on

[49] https://www.transnomis.com/municipal511/
[50] Perchanok, M., 2016. Keynote Address, 2016 Conference of the Standing International Road Weather Commission (SIRWEC)
[51] MTO, R&D Branch Report MAT-98-02, Design and Maintenance to Minimize Impacts from Drifting Snow

20 days on average in the London area. Drifting snow requires constant snow plowing of the travelled portion of the road and the winging back of plowed snowbanks or removal of drifts with a snowblower, as the plowed snowbanks cause whiteouts, icing, and faster accumulation. A study by MTO showed that winter maintenance operations to plow drifting snow in the days following the end of a snowfall event can increase the demand for winter services by 30% in southwestern Ontario, amounting to maintenance expenditure of $3,000 per km per year.[51]

Following an extensive research program, MTO initiated a process for remediation of snow drifting hazards on Provincial highways that involved initial identification of hazard locations, quantifying the relative severity of hazards to prioritize treatment, selection of alternative treatments, and implementation. Modelling and prediction of snow hazard severity is used for high value projects (**Figure 47**).[52] The scope of each of these steps can be modified depending on the potential benefits as related to road traffic volume, from a site review and assessment by a subject matter expert, to sophisticated computer modelling.[53, 54]

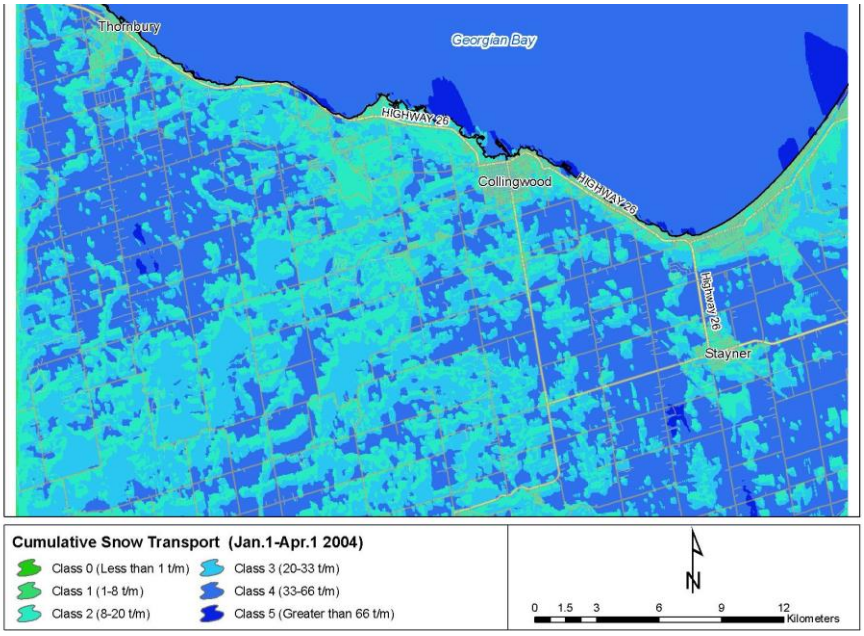



**Figure 47: Drifting Snow Severity Prediction, MTO Hwy 26 Project**

Through these studies, it was found that the excess demand on maintenance can be significantly reduced through the use of temporary or permanence snow fences, snow hedges or standing corn stalks in roadside fields, sometimes in combination with snow storage ditches or other engineering features such as snow storage ditches.[51] A cost-benefit study of alternative treatments showed that the lowest cost long-term solution is a permanent snow hedge,[55] and subsequently more than 150 km of snow hedge has been planted along Provincial highways.[56] Funding to plant snow hedges along roadways may

[52] http://highway26transportationstudy.ca/downloads/July2015/Appendix%20E%20Snow%20Drifting%20Assess%20Study/Appendix%20E%20Snow%20Drifting%20Assessment%20Report.pdf
[53] http://onlinepubs.trb.org/Onlinepubs/trr/1993/1387/1387-015.pdf
[54] https://trid.trb.org/view.aspx?id=1138919
[55] Perchanok and Bacchus, 1993, Cost analysis of snow control structures in Ontario. Eastern Snow Conference, 1993
[56] Personal communications, MTO Central Region Environmental Office

be available through OMAFRA's farm windbreak program, local conservation authorities, or landowner groups.[57][58] Temporary snow fence can be installed by agency forces as a low-cost short-term solution where landowner permission can be obtained.

Perth County agencies reported numerous locations with drifting snow hotspots (**Figure 48**), with no snow fence currently installed.

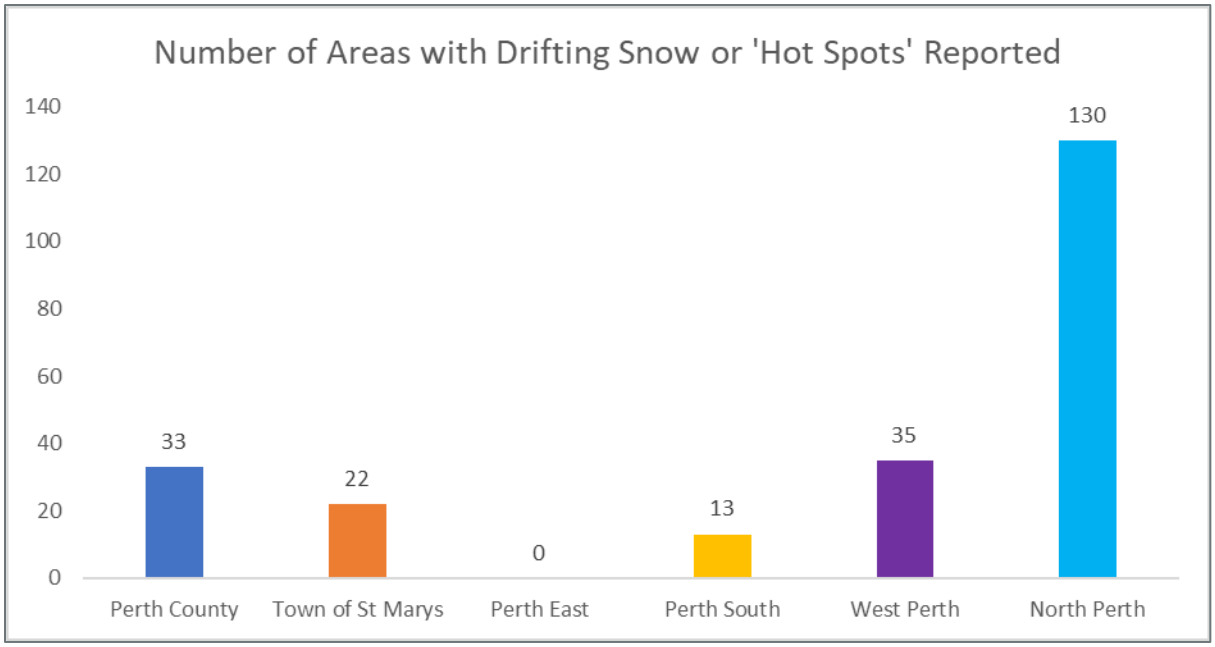



**Figure 48: Number of Reported Drifting Snow and Hotspot Locations**

### 4.13.2. Conclusions and Recommendations

Drifting snow is a common occurrence in the Perth County area and is likely to cause hazardous driving conditions and excess maintenance demand at many locations. Since mitigations are readily available, the agencies are exposed to unnecessary expenditure and risk of liability in the event of winter accidents.

Planning and implementation of mitigations for drifting snow and whiteouts are recommended as a **Priority 1 Action**. This includes review of hazard sites by a subject matter expert, prioritization of sites for treatment, planning and installation of short-term solutions at selected demonstration sites.

Prioritization, cost analysis and planning of long-term solutions at other sites is recommended as a **Priority 2 Action.**

# 5. Summary of Findings

**Table 23** provides a tabulated summary of the findings/gaps, impacts, recommendations, and benefits for each topic discussed in this report.

[57] MTO R&D Branch Report MAT-92-05, Feasibility of Cooperative Snow Control Initiatives
[58] https://www.tac-atc.ca/en/conference/papers/farm-windbreaks-communications-program-and-cooperative-projects

**Table 23: Summary of Findings**

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| 1 | **Legislation MMS (4.1.4)** | Key benchmarks are met.<br>Requires support from Road Salt Management Plan (RSMP) or Winter Operations Plan (WOP) | First step to limiting liability | Harmonized RSMP for all agencies to support defense of claims. | | | Reduced liability risk. |
| 2 | **Legislation CEPA Road Salt Management Plan (4.1.4)** | Present for PC, PS, WP, and St M. Annual review only conducted by PS and WP.<br>Absent for PE and NP | Lacks coordination of LoS plan and WOP | Update existing and develop harmonized plan for all agencies. | | | Promotes state of the art, efficient practices that provide consistent levels of service. |
| 3 | **Maintenance Yard Functional Assessment (4.2)** | Maintenance yards ranked on functional value to a future integrated network. | Used in analysis of the feasibility of maintenance yard reductions. | | Use results to plan future integrated or amalgamated network of maintenance yards | | Provides logical basis for future network optimization. |
| 4 | **Roadway route Optimization with existing municipal boundaries (4.3.2)** | Confirms current routes are efficient. | None | Retain existing routes. | | | Supports current route arrangement. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| 5 | **Roadway route Optimization without existing municipal boundaries (4.3.2)** | Predicts marginal cost savings and service time improvement when two-level route priority system is used. | Needs confirmation due to different model assumption on priority levels. | None | | | Service level increased slightly above current level. |
| 6 | **Route Optimization with Yard Removal, using 2 priority classes (4.3.4)** | Feasible to retire up to 3 lowest rated maintenance yards and their service trucks while meeting basic service standards with 10 yards. | Reduce overall costs, possibly reduce fleet costs. Level of service reduced from current.. | Investigate effect of reduced buffer in spreader capacity on road liability risk. Practical check and adjustment of predicted routes. | Analyze property upgrades required to accommodate revised fleet distribution in retained yards. Analyze potential yard retirement costs and retained yard construction costs. | Staffing implications | Demonstrates feasibility of reducing real estate footprint while meeting basic requirements of MMS. |
| 7 | **Route Optimization: Clean Slate Analysis (4.3.4)** | Smallest feasible network can be reduced to 6 yards if they are ideally located. Can be accomplished using existing | Lower cost savings and more severe reduction in service level than 10-yard option.. | As above, investigate impact of reduced buffer in spreader capacity and service time. Extend analysis using alternative spreader | Analyze upgrades required to existing yards to accommodate revised fleet distribution. Analyze potential yard retirement | Staffing implications | Demonstrates feasibility of reducing real estate footprint to 6 yards within constraints of MMS, and provides guidance in selection of maintenance yards for future optimized network on the basis of geographic route coverage. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | yards near ideal locations | | complement or capacity. | costs and retained yard construction costs | | |
| 8 | **Weather Information OGRA App (4.4.2)** | OGRA basic level weather app used by all except Perth East and North Perth, but not all document access times. | Lower frequency of use impacts defense of claims. | Expand OGRA subscription to include all agencies. Specify frequency in WOP. | | | Reduces liability risk. |
| 9 | **Weather Information RWIS (4.4.2)** | MTO RWIS available at no charge. No local RWIS | Pavement-based forecast, weather cameras, surrounding areas forecast | Expand RWIS sharing agreement to all agencies. | Evaluation of RWIS benefits to patrolling and to effective use of winter materials in future WOP. | Implement County RWIS | Improved operations decisions to plan operations more effectively. |
| 10 | **Patrolling Routes (4.5.4)** | Lengths of some routes do not meet OGRA guidelines. (PE, NP) | Road liability risk. | Review Perth East and North Perth routes to ensure coverage, review all routes to assess feasibility of integrated patrolling. | | | Exceed MMS requirement. Reduce liability risk, improve cost-effectiveness. |
| 11 | **Patrolling Training (4.5.4)** | Training not always documented. | Inconsistent reports, increased liability risk | All agencies, review training options, schedule patroller training. St M, PE, PS, NP develop WOP to | | | Reduced liability, more effective use of resources. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | | | aid patrollers in making decisions on operations to be undertaken. | | | |
| 12 | **Patrolling Technology (4.5.4)** | Some agencies (PC, St M, WP, NP) use only paper patrol reports. | Timeliness, potential clerical errors and chain of custody. | Investigate tabloid or other automated patrol records. | Implement automated patrol records. | | More effective use of resources, reduced clerical effort. |
| 13 | **Winter Materials Rules of practice (4.6.3)** | Lacking written rules of practice to advise material application rates (North Perth, St Marys). | Inconsistent level of service/customer experience, increase road liability risk. | Develop written rules of practice/WOP for material type and application rate. | Harmonize rules of practice across agencies by road class or priority level. | | Reduced liability risk, more consistent service. |
| 14 | **Winter Materials Use of winter liquids (4.6.3)** | Winter liquids not used with rock salt (except PC, PE) | Slower snow removal, more material use, shorter route coverage. | Expand use of pre-treat or pre-wet as appropriate. | | | 10% to 20% material cost reduction |
| 15 | **Winter Materials Sanding/salting (4.6.3)** | Preference for winter sand over salt on some routes. | Lower level of service, spreader capacity limits. | | Review criteria for sanding vs salting under normal conditions. | | LOS, lower spreading costs |
| 16 | **Winter Materials WOP (4.6.3)** | Rules of practice, materials and application | Restricts scope for future integration of maintenance yards and routes | | Harmonize material application rates and other rules of practice | | Supports future network integration, more consistent driving conditions and resource allocation. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | rates vary by agency. | | | as part of a harmonized RSMP | | |
| 17 | **Roadway Fleet Overview (4.7.3)** | Fleet is well matched to requirements and comparators in terms of types, numbers, age and capacity of vehicles. | | | | | N/A |
| 18 | **Fleet ESC/AVL (4.7.3)** | Electronic spreader controllers and/or AVL not fully implemented (St M, WP, NP) | Extra clerical time, risk of clerical errors, less control and documentation of material usage. | Implement ESC (St Marys, North Perth) Implement AVL (St Marys, West Perth, North Perth) | | | Improved financial accountability and reporting on road salt usage. |
| 19 | **Fleet Pre-wet (4.7.3)** | Only one agency equipped for pre-wetting | Does not meet EC Code of Practice; missed opportunity to reduce salt us and provide better service | Develop a plan to outfit spreaders with on-board pre-wet and maintenance yards with liquid storage facilities | | | Up to 20% reduction in material costs, improved LOS. |
| 20 | **Fleet Calibration (4.7.3)** | Spreaders not calibrated annually (Perth East, North Perth) | Incorrect material use. Up to 30% error. | Implement calibration program and documentation as part of WOP. | | | Better control of material usage. |
| 21 | **Fleet** | A few routes use separate | Inconsistent level of service where | | Review WOP for those routes to | | Cost reduction. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | **Combo Units (4.7.3)** | plow or grader and spreader rather than combination unit. | sometimes plowed and other times de-iced. | | assess whether combo unit would provide more consistent service. | | |
| **22** | **Record Keeping AVL support to business processes (4.8.1)** | AVL data not fully incorporated to business information systems and processes (PS, St M, WP, NP) | Unused business resource, excessive clerical time and potential for error. | Integrate data from equipped vehicles to replace manual entry of business information, develop standardized reports and dashboards, demonstrate to all agencies. | Investigate alternative service options for AVL, plan future implementation in all agencies. | | Improved business processes, accountability. |
| **23** | **Record Keeping AVL service delivery (4.8.1)** | Inconsistent approach to delivery of AVL (in-house vs outsource) | Impedes future harmonization of services. | | Investigate alternative methods to deliver AVL to plan future implementation to all vehicles. | | Improved business processes. |
| **24** | **Record Keeping Patrolling technology (4.8.1)** | Automated patrolling technology only partially (PE, PS) implemented | Timeliness of road reports, access to past reports. | | Implement a demonstration of technology to evaluate benefits | | Defense of claims, standardization of business process |
| **25** | **Sidewalks Routes (4.9.3)** | Sidewalks are clustered in urban areas with long | Costly to service when equipment | | Review options to integrate | | Service improvement, efficient deployment of resources. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | deadheading distances between. | must be towed to service areas. | | sidewalk service across agencies. | | |
| 26 | **Sidewalks Policy (4.9.3)** | All agencies have some form of sidewalk policy and service levels but not all (PE, PS, and NP) relate to storm severity. | Potential failure to meet service requirements if the policy does not vary by storm severity. | Review policies to be more specific on priority levels and storm severity, incorporate to WOP.<br>Harmonize policies to support possible future integration of services. | | | Defense of claims, public response. |
| 27 | **Sidewalks Equipment/Routes (4.9.3)** | Equipment type is well suited and modern.<br>Some routes exceed equipment capacity. | Multiple reloads required to complete route. | Consider splitting routes to adjust to equipment capacity or reducing material rates.<br>Install reloading facilities along routes. Use pre-treated salt to reduce quantities needed. | | | Service efficiency, cost reduction. |
| 28 | **Sidewalk Materials (4.9.3)** | Variation in materials and application rates. | Differing levels of service, cost of operations. Lacks support to defense of claims. Need to reload | Review and harmonize WOP regarding materials, consider expanded use of pre-treated salt to reduce application rates. | | | Defense of claims, service improvement |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | | equipment on a route. | | | | |
| 29 | **Sidewalk Areas of Service (4.9.3)** | Trend in urban centers to service all sidewalks. | Reduces risk of complaints from unserviced areas<br>Reduces cost of bylaw enforcement for landowners who do not clear sidewalks. | | Review policies and estimate cost to service all sidewalks. | | Service improvement |
| 30 | **Sidewalk Service Delivery (4.9.3)** | Roadway staff services sidewalk routes. | Inconsistent service due to roadway priority. | | Review options to resource sidewalk operations independent of roadway operations. | | Service improvement |
| 31 | **Parking Lot Policy (4.10.3)** | No written policies on parking lot maintenance. | Potential liability exposure.<br>Difficult to plan resources. | Implement consistent policies and procedures as part of WOP.<br>Consider expanded use of pre-treated salt to reduce application rates. | | | Service improvement, resource allocation |
| 32 | **Parking Lot Priority (4.10.3)** | St M, PS and WP service parking lots after roadway routes. | Service time varies with roadway conditions. | Implement policy to service as independently resourced plow routes or part of | | | Service improvement |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | | | existing plow routes. | | | |
| 33 | **Parking Lot Fleet (4.10.3)** | Vehicle used to service parking lots are new, modern and well suited to the service requirements. | N/A | N/A | | | N/A. suitable equipment is provided |
| 34 | **Service Delivery (4.11.4)** | Currently, 5 contracted roadways routes, contracted sidewalk routes, contracted parking lots, and boundary agreements to fill specific needs. Difficulty to attract contractors for competitive bids, difficulty for contractors to obtain insurance. | Contracting for specific local needs on one-off basis.<br>Larger scale outsourcing such as MTO or City of Toronto has far-reaching objectives, complex implementation and does not always result in cost-saving. | Review specific objectives for outsourcing in relation to benchmarked experience to develop recommendations.<br>Research the history and objectives of service delivery agreements currently in place. | Develop and implement a pilot project to integrate service among agencies for a service that is difficult to resource (i.e. parking lots or sidewalks) | | Clarify objectives to develop common policy. |
| 35 | **Public Communications (4.12.1)** | Three agencies (PC, PS, St M) meet or exceed the benchmark. Other agencies | Public is not informed of local winter driving hazards and delays. | Share Enterprise level subscription to OGRA Weather App and provide active road | | | Public awareness, webcam support to patrolling.. |

| # | Topic (Section Reference) | Findings/Gaps | Impact | Recommendation | | | Benefits |
|---|---|---|---|---|---|---|---|
| | | | | Priority 1 | Priority 2 | Priority 3 | |
| | | do not communicate current road conditions through a public web site. Municipal511 can be extended to all agencies at no additional cost. | | condition information using webcams. | | | |
| **36** | **Drifting Snow Hazards (4.13.2)** | Snow drifting hazards sites were included with other hotspots identified by participants. No remedial measures are currently implemented by participants. | Huge safety and financial impact at sites susceptible to drifting; up to 30% of winter maintenance expenditure, longest duration road closures due to weather and largest multi-vehicle accidents. | Review hazard sites and prioritize for treatment. Implement short-term solutions (snow fence, etc.) as demonstrations at selected sites. | Prioritize and plan long term solutions. | | Cost reduction, safety improvement, defense of claims |

# 6. Implementation Plan

The winter operations of Perth County and partner municipalities exceed minimum standards in nearly all respects to provide roadway services at enhanced levels, with a well balanced and well managed roadway and sidewalk fleet. Variation in levels of service and operating practices among the agencies result in an increased risk of claims and inconsistent service to taxpayers. The maintenance yard network was found to include inefficiencies in having yards close together and of varying functional status. Some sidewalk routes are inefficient due to excessive length in relation to material spreading capacity and to geographical separation, and level of service policies vary among agencies. Policies for parking lot service, weather tracking, winter patrolling, and road salt management require update and can benefit from harmonization. Documentation and information management practices are inconsistent and not always up to modern standards except for Perth county which meets modern standards.

Integration of the maintenance yard network can provide efficiencies in real estate costs but with a significant reduction in levels of service. An optimum network design was predicted but additional analysis is required to optimize fleet and route characteristics to maintain the current high levels of service and then to accurately cost a transition plan to the optimized network.

Inconsistent policies and resourcing to service sidewalks, parking lots and patrolling can be addressed in stages by first strengthening and harmonizing policies and operating practices, and then by planning a pilot project to integrate one or more of these services. A small number of routes are contracted on a day rate basis but difficulty in attracting competitive bids due to high insurance costs argues against expanded contracting and for stronger internal resourcing.

Expansion of the partially implemented winter materials practices of pre-treated and pre-wet salt can generate significant annual savings while improving road safety.

Implementation of roadside infrastructure to mitigate snow drifting and whiteouts can generate ongoing safety improvements and cost savings.

The implementation plan to address modernization of practices and network integration comprises five initiatives; Policies and Legislation, Network Optimization, Managing Operations, Improving Road Safety, and Communicating with the Public. Costs and savings associated with each initiative are summarized in **Table 24** and **Figure 49**, and details of the activities, priority, costs, scope and key tasks, and duration of each initiative are provided in **Table 25**. The estimated total one-time costs including expert advice and capital expenditures is $1.52M and the estimate net annual savings from implemented initiatives is $0.85M, excluding capital costs associated with future maintenance yard refit or retirement.

**Table 24: Implementation Plan Annual and One Time Costs**

| Initiative | Annual | One Time |
|---|---|---|
| Policies and Legislation | $0 | $120,000 |
| Network Optimization | -$310,000 | $150,000 |
| Managing Operations | $77,000 | $447,000 |
| Improving Road Safety | -$616,000 | $769,000 |
| Communicating with the Public | $0 | $30,000 |
| TOTAL | -$849,000 | $1,516,000 |

(-) indicates savings

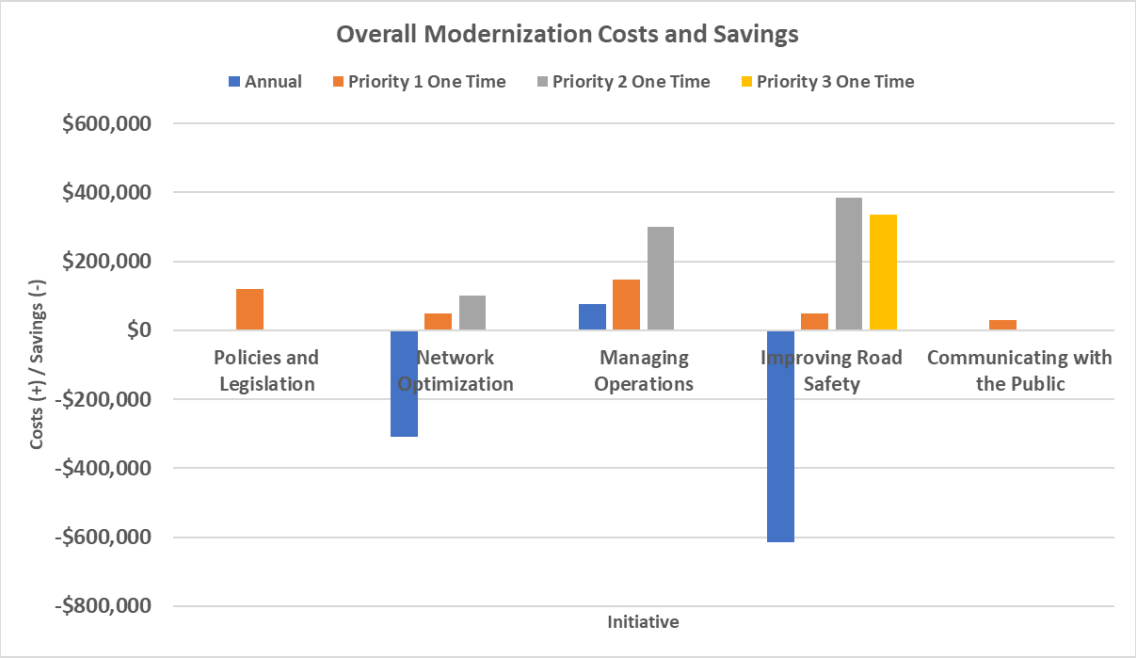



**Figure 49: Implementation Expenditures (+) and Savings (-)**

**Table 25: Implementation Plan**

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **Policies and Legislation** | | | | | |
| **Harmonized Level of Service and Winter Operations Plan covering roadway, sidewalk, parking lot, service delivery method** | 1 | $0 | $80,000 (Consultant Assignment) | Perth County and its municipal partners subscribe to and meet Ontario's Minimum Maintenance Standards. They use individual levels of service and operating practices that provide service levels above the minimum standards in all cases but that vary among agencies, resulting in different resourcing demand and different risk to travellers. The following work is recommended to address this concern:<br>• Review of all agency levels of service and priority level policy, funding mechanisms and levels, and best practices (winter operations plan) related to winter maintenance services on roadways, sidewalks and parking lots, including patrolling, supervision, operations, equipment, materials, in-house and contracted services.<br>• Use financial and risk performance indicators to recommend harmonized levels of service that maintain or exceed current levels. | 6 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | • Develop a harmonized winter operations plan that will provide the recommended levels of service.<br>• (see: Service Integration Pilot Project) | |
| **Harmonized Road Salt Management Plan** | 1 | $0 | $40,000 (Consultant Assignment) | Four of Perth County and its partner agencies have a Road Salt Management Plan (RSMP) as required by CEPA. North Perth and Perth East are required to develop a plan, and the existing plans have not all been reviewed annually as required. Taking a harmonized approach to road salt management will promote a consistent approach and resourcing to protect the shared natural environment. The following work is recommended to address this concern:<br>• Review existing Road Salt Management Plans and provide a tabular comparison of gaps or updates required.<br>• Using the existing models create a template for a new RSMP for North Perth and Perth East.<br>• Coordinate information gathering among the client agencies to update the existing plans and create a new plan for North Perth and Perth East.<br>• Represent the client agencies at a meeting of the Environment Canada Road Salt Working Group. | 6 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **Network Optimization** | | | | | |
| **10 depots and 37 combination trucks** | 3 | Est. Yard Rental Cost: $0.77M<br><br>Est. Fleet + Labour Cost: $1.48M | Yard Rental Cost: $0.70M (Annual)<br><br>Fleet + Labour Cost: $1.24M (Annual) | A network integration and route optimization modelling analysis for winter operations of Perth County and its partner municipalities predicted that winter operations can be accomplished at significantly lower cost using a network of fewer maintenance yards. The predicted annual cost reduction is $310,000. While minimizing costs, the analysis also predicted a 9% increase in average service time (i.e. reduction in service level) from the current time that substantially exceeds minimum standards, to an average service time that somewhat exceeds minimum standards. The analysis only included estimated maintenance yard rental costs and fleet operations costs and did not include one-time costs associated with maintenance yard refit or retirement, staff relocation, and other uses of the property. A planning study is recommended to further optimize the selection of maintenance fleet characteristics that will maintain current levels of service, and to estimate one-time costs associated with changes in maintenance yard property. | Long Term |
| **Additional scenario analysis to optimize fleet** | 1 | - | $50,000 (Consultant Assignment) | Additional scenario analyses are recommended to predict the cost of providing current levels of service using alternative fleet and winter materials characteristics with the reduced network. The | 6 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | following work is recommended to address this concern:<br>• Review maintenance fleet and winter materials assumptions of the existing network analysis model.<br>• Update winter materials assumptions to correspond with the proposed implementation of pre-treated and pre-wet salt and other changes to winter materials recommended in a harmonized level of service plan.<br>• Develop a suite of alternative fleet scenarios in consultation with clients including; fleet numbers and equipment types appropriate to urban and rural road network characteristics and proposed priority levels.<br>• Implement the network integration and optimization model using the updated materials assumptions and the alternative fleet scenarios to predict resulting yard rental, fleet rental and winter materials costs and level of service indicators.<br>• Report on the predicted results in comparison with the initial study results. | |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **Property analysis; adjusted fleet, staff, depot retirements** | 2 | - | $100,000 (Consultant Assignment) | The following work is recommended to estimate planning and capital costs associated with the integrated network scenario:<br>• Review existing Owners Program of Requirements such as: office/training building, fleet repair, maintenance and storage building, salt storage/management building, parking areas, site civil works, stormwater and washwater management, re-fueling area, and storage tanks<br>• Review existing site related assessments, reports and studies<br>• Conduct a high-level programming session and develop one project concept<br>• Engage environmental consultant and seek comments from MNR or other authorities to initiate Municipal Class EA process<br>• Provide a feasibility/recommendation report identifying the extent of existing and future site constraints<br>• Clearly define client objectives, goals, and project values<br>• Acquire digital base drawing files | 4 months |
| **Managing Operations** | | | | | |
| **Implement OGRA Weather Tracker App** | 1 | - | $12,000 (Annual) | Perth County and three of its municipal partners use the OGRA weather app or a | Ongoing service |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **service, expand MTO RWIS sharing** | | | | commercial equivalent to plan winter operations and two agencies use public weather information. Three agencies can access the MTO road weather information system (RWIS). Access to a common, high quality weather forecast service that meets OGRA guidelines will help to provide a similar, high level of service in planning and scheduling equipment call-outs. A common service will be essential in the event of future service integration. Three agencies access the MTO RWIS system to provide more detailed information about approaching, lake-effect storms, icing conditions and highway pavement temperatures. Access can be provided to all agencies by extending the existing, no-cost sharing agreement. The following work is recommended to address this concern:<br>• Perth County to subscribe to OGRA's Enterprise level Winter Weather App to provide local forecast information in each agency locality along with information 'push' to designated staff.<br>• Each agency to submit an RWIS sharing agreement to MTO obtain no-cost access to MTO's RWIS network observations and forecast. | |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **RWIS procurement and installation / Ongoing service agreement** | 1 | $0 | $25,000 (One-Time Planning) | Local RWIS stations on agency roads provide pavement temperature and risk of freezing estimated from salt content on the pavement, in addition to local atmospheric observations and forecast. This local information aids in more precise adjustment of material type (salt, sand, mix) and application rate to current and forecast conditions, resulting in material application "in the right amount, in the right place, at the right time". The following work is recommended to address this concern:<br>• RWIS location study to identify three representative, priority locations for county RWIS sites.<br>• Review of alternative RWIS instrumentation to define requirements for the selected sites.<br>• Development of a procurement model and RFP for RWIS site instrumentation, installation and ongoing data collection, forecast, web display and archiving services. | 3 months |
| | 2 | | $300,000 (One-Time Implementation) | Procurement and installation of three roadside RWIS data collection sites. The following work is recommended to address this concern:<br>• Using the procurement model developed in the planning study, agency staff will manage | 8 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | procurement and installation of three RWIS sites.<br>○ Required permitting for roadside installation to be managed by the agency.<br>○ Turn-key approach with procurement and installation tendered as a single contract. | |
| | 3 | | $10,000 (Annual Service) | Operation of an RWIS system includes electronic polling, a web-based system for display, a 24/7 weather forecasting system and equipment maintenance/repair. There is a competitive market for these services which are often tendered on a three-year basis. The following work is recommended to address this concern:<br>• Using the template developed in the planning study, agency staff to manage procurement of RWIS polling, display and forecast services.<br>• Service agreement should include performance measures that are reviewed annually, and financial recourse for performance failures. | 2 months |
| **Patroller Training, Tablets (6), Webcam Patrolling** | 1 | $8,000 | $16,000 (Annual) | The current status of road patrolling during inclement winter weather varies among agencies in terms of patrolled road length, recording and communication of observed | Ongoing |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | Webcams: See Communications | conditions, available types of road-weather information, training and detail of guidelines for calling-out operations. Future goals of harmonizing levels of service and integrating operations among agencies require the support of consistent and timely road patrol information. The following work is recommended to address this concern:<br>• Integrated annual training or refresher for all patrollers<br>  ○ Harmonized road patrol descriptors<br>  ○ Technology and communication training<br>  ○ Winter operations plan<br>  ○ Road network characteristics<br>• Implementation of a common patroller tablet or phone app platform including harmonized road condition descriptors, automated reporting and archiving, and access to winter operations plan or best practices in relation to observed conditions.<br>  ○ Tablet or phone app requirements to be specified (agency)<br>  ○ Procurement or required hardware and services (agency)<br>• Mobile access to shared roadside webcam network (see Public Communications) | |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | • Coordination with integrated services pilot project, if patrolling is selected. | |
| **Fully implement AVL (St M, WP, NP) using service model** | 1 | $35,640 (PC, PE, PS), various types | $62,000 (Capital for 31 Units)<br><br>$39,000 (Annual Service Cost for 65 Units) | Automated Vehicle Location (AVL) systems collect on winter service vehicles collect data on plowing and spreading operations, truck location and speed and other information at frequent intervals along the road. This provides detailed, reliable and automated information that is essential for fleet, material and operations management, Road Salt Management Plan, and defense of claims. The following work is recommended to address this requirement:<br>• Equip 31 winter service vehicles with AVL that are not currently equipped.<br>• Agency to procure the equipment and installation.<br>• Provide a web-based data polling, archiving and graphical/tabular data display and query system with standardized management report generation.<br>  ○ The system must provide common access to all 65 AVL-equipped vehicles.<br>  ○ The service agreement to include hardware maintenance and repair and communications cost. | 6 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | ○ Agency to procure the service | |
| **Integration of AVL and RWIS into management reporting** | 1 | - | $30,000 (Consultant Assignment and Implementation) | AVL systems and archives provide detailed, location- and time-based data on equipment operations and material usage that supports fleet, materials and other management systems necessary for winter operations at the local and agency scale. The information is not always used to full advantage as specific expertise in data management systems and technologies may be required to automate data manipulation and transfer processes. The following work is recommended to address this requirement:<br>• Review of current agency management systems for winter operations to identify opportunities for automate reporting and inputs from AVL.<br>• Design automated reports and automated data transfer protocols from AVL to management systems.<br>• Design other automated reports, queries, graphical displays and dashboards in consultation with agency staff. | 3 months |
| | 2 | | | • Train agency staff in using queries, reports and interfaces.<br>• Coordinate with agency IT staff re automated inputs to existing systems. | 1 month |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **Service Integration Pilot Project** | 1 | - | $30,000 (Consultant Assignment) | • In-depth review of sidewalk, parking lot and patrolling policies, routes, operating plans and cost structure.<br>• Review and identify factors of service integration for each activity.<br>• Develop a short-term service integration plan for suitable activities.<br>• Identify constraints on service integration for other activities. | 3 months |
| **Improving Road Safety** | | | | | |
| **Phased Implementation of Pre-Treated and Pre-Wetted Salt** | 1 | Est. $1.93M<br><br>23% pre-treat<br>42% pre-wet | $1.86M (Annual)<br><br>53% pre-treat<br>47% pre-wet | Perth County and Perth East have implemented pre-treating or pre-wetting to improve service and reduce the cost of road salt. These methods also provide an opportunity to extend the length of maintenance routes. These advantages can be extended to all agencies through a harmonized level of service and winter operations plan (see: Legislative Requirements and Harmonization). These benefits can be achieved through a 3-phase implementation plan including procurement of truck-mounted equipment to handle winter liquids, and maintenance-yard based equipment to store and load winter liquids. Both activities are handled through agency-based procurement and guided by the harmonized winter operations plan. | 1 year |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | • The initial phase is the transition of all current rock salt procurement to pre-treated salt procurement, resulting in estimated annual material cost savings of $65,000 (4%).<br>• Pre-wet implementation is maintained at its current level in Phase 1. | |
| | 2 | | $1.83M (Annual)<br><br>40% pre-treat<br>60% pre-wet | • Phase 2 is a 30% increase in pre-wetting and equivalent reduction to pre-treating.<br>• Estimated total annual reduction in material cost of $95,000 (5%).<br>• Includes equipping 15 combination units and 4 maintenance yards for pre-wetting (see: Staged Implementation of Pre-Wetting Equipment) | 1 year |
| | 3 | | $1.57M (Annual)<br><br>5% pre-treat<br>95% pre-wet | • Phase 3 is transition to 95% pre-wetting and reduction in pre-treating.<br>• Pre-treating of 5% is retained for locations where logistics are difficult for pre-wetting.<br>• Estimated total annual reduction in material cost of $360,000 (19%).<br>• Includes equipping an additional 11 combination units and 2 more maintenance yards for pre-wetting (see: Staged Implementation of Pre-Wetting Equipment). | 1 year |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| **Staged Implementation of Pre-Wetting Equipment** | 2 | - | $360,000 (Capital) | Implementation of Phases 2 and 3 of the winter materials plan to achieve winter material cost savings requires the procurement and installation of truck-mounted equipment to handle winter liquids, and maintenance-yard based equipment to store and load winter liquids.<br>• The Phase 2 procurement is for pre-wetting systems retrofitted to 15 existing combination plow/spreader trucks and for liquid storage tanks, pumping systems and spill barriers at 4 maintenance yards. Procurement is handled by the agencies and guided by requirements defined in the harmonized winter operations plan. | 6 months |
| | 3 | | $264,000 (Capital) | • The Phase 3 procurement is for pre-wetting systems retrofitted to 11 existing combination plow/spreader trucks and for liquid storage tanks, pumping systems and spill barriers at 6 maintenance yards. Procurement is handled by the agencies and guided by requirements defined in the harmonized winter operations plan. | 6 months |
| **Prioritize and implement snow drift remediation at 100 sites** | 1 | - | $25,000 (Consultant Assignment for One-Time Planning) | More than 200 winter hazard hotspots were identified including many due to drifting snow and whiteouts. MTO studies have shown that up to 30% of winter maintenance deployments on provincial highways in the | 3 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | $24,000 (Capital)<br><br>Estimated annual savings of $51K and indirect savings of $1M | vicinity of Perth County is due to drifting snow in the three days after the end of a snowfall event. Provincial and many municipal agencies have successfully implemented treatments such as snow fences, snow hedges and snow storage ditches to mitigate drifting snow hazards. The following activities are recommended to address drifting snow hazards:<br>• Develop a priority scheme for remediation based on site orientation, exposure, geometry and traffic impact.<br>• Consult with agency staff, review satellite imagery and review all sites to identify and prioritize site for snow fence or other treatment as priority 1, 2 or 3.<br>• Provide product specifications, installation guidelines and a procurement template to agency.<br>• Agency to procure materials and installation of mitigative treatments for 20 priority 1 sites (capital) | |
| | 2 | | $24,000 (Capital)<br><br>Estimated annual savings of $102K and | • Agency to procure materials and installation of mitigative treatments for 20 priority 2 sites (capital). | 3 months |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | indirect savings of $2M | | |
| | 3 | | $72,000 (Capital)<br><br>Estimated annual savings of $256K and indirect savings of $10M | • Agency to procure materials and installation of mitigative treatments for 60 priority 3 sites (capital). | 2 years |
| **Communicating with the Public** | | | | | |
| **Extend Municipal511 subscription to all** | 1 | $2,700 (paramedic PC)<br><br>$7,300 (paramedic St M) | $0 | All County agency websites provide some degree of tombstone information about winter operations policies and three agencies provide active information about current or planned road closures, construction and detours through the commercial Muncipal511 website. The County subscription to Municipal511 can be extended to integrate all county municipalities at no additional charge to provide the opportunity to post twitter feeds or maps depicting current winter conditions and seasonal load restrictions. This can be accomplished by:<br>• Agencies to designate one representative for integrated 511 winter operations and seasonal loads feeds (“Winter 511 Coordinator”). | 1 month |

| Action | Priority | Current Annual Cost | Estimated Future Cost | Scope of Work | Project Duration |
|---|---|---|---|---|---|
| | | | | • Coordinator to update Municipal511 subscription with Transnomis to include all municipalities and feeds from six roadside webcams (see below). | |
| **Install 6 roadside webcams to provide real-time conditions to Municipal511** | 1 | - | $30,000 (One-Time) | Posting of active winter road conditions information in a timely manner is often not feasible because agencies do not have resources to patrol frequently and communicate information on rapidly changing conditions. This issue can be addressed by installing a network of roadside webcams with direct feed to Municipal511. The scope of work includes:<br>• Winter 511 Coordinator to work with all agency staff to identify one representative site for roadside webcam installation.<br>  ○ Obtain necessary permits and arrange services (power, communications).<br>  ○ Develop procurement specification (may be linked with RWIS Planning consultant assignment).<br>  ○ Agency procurement of six roadside webcams as turn-key assignment including roadside infrastructure, cameras and lighting, services hook-up and communication link to Municipal511 website. | 6 months |

# A

# Appendix A: Current Practices Client Questionnaire

**Appendix A: Current Practices Client Questionnaire**

Information on the following topics is requested for roadways, parking lots, and sidewalks.

1. Winter Maintenance Routes and Service Standards (plow and patrol)
    a. Routes maps with direction of travel, turning points, cul-de-sacs, start/end point, total lane-kilometers, and Class or priority for each route or segment (if a route includes multiple classes)
    b. Always the same or adjusted to circumstances?
    c. Route shared with other towns/counties?
2. Deployment Practices
    a. Trigger for deployment
    b. Directed by Manager, foreman, operator?
    c. Source of weather or road condition information
    d. Material types and application rates
        i. Rock salt
        ii. Winter sand
        iii. Liquids if used (pre-wet or anti-icing)
        iv. Application rates (vary by weather condition or route class?)
        v. Application rate set by operator, foreman or manager?
        vi. Is sand applied continuously, or only hills and curves or danger spots?
3. Maintenance/material and vehicle storage yard locations
    a. Buildings, facilities, storage capacity (salt, sand, winter liquids)
    b. Structure type, construction, age, deficiencies, general performance
    c. Vehicle maintenance facilities and equipment
    d. Fueling facilities and capacity
4. Vehicles and Related Equipment
    a. Number and type (load weight capacity, # rear axles)
    b. Spreader capacity
    c. Material discharge type
        i. Side (ahead of drive wheels) or Rear (tailgate)
    d. Spreader controller type
        i. Manual
        ii. Electronic, ground-speed control of chain, auger or gate
        iii. (brand name if available)
        iv. Electronically logged on-board?
        v. Logged remotely by GPS/AVL/telematics?
5. Winter Operations Staffing and Shift Plan
6. Patrolling and Winter Condition Reporting
7. Record Keeping of time and materials
    a. Manual/office software/GPS reports
8. Service Delivery Type
    a. Maintenance Operations: In-house/leased trucks/contracted drivers/turn-key service
    b. Equipment Maintenance: In-house/contracted service
9. Winter Season Resource Use
    a. Labour
    b. Equipment hours or km
    c. Rock salt
    d. Winter sand

    e. Winter liquids
10. Snow fences or hedges?
11. Road Salt Management Plan?

# B

# Appendix B: Maintenance Yard Functional Assessment

**Appendix B: Maintenance Yard Functional Assessment**

**Maintenance Yard Functional Factors Used for Analysis:**

| Functional Factor | Weight |
|---|---|
| Storage capacity | 5 |
| Availability of fueling facilities | 5 |
| Yard acreage | 5 |
| Building condition | 4 |
| Use of facility for other purposes/seasons and availability of amenities | 4 |
| Access to service | 3 |
| Environmental sensitivity | 2 |
| Road class of the adjacent road | 2 |
| Land use/zoning | 1 |

## Maintenance Yard Evaluation Spreadsheet (Storage Capacity and Fueling Facilities):

| Yard Name | Municipality | Address | Salt Storage Capacity | Sand Storage Capacity | Liquid Storage Capacity | Storage Capacity Score (0-5) | Weighted Storage Capacity Score | Fueling Facilities Present On-Site? | Fueling Facilities Score (0-5) | Weighted Fueling Facilities Score |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mitchell (PC)** | Perth County | 4 Napier Street, Mitchell, ON | 500 tonnes | 3500 tonnes | 45000 L | 3.7 | 18.5 | Yes | 5 | 25 |
| **Stratford** | Perth County | 4312 Perth County Road 119, Gads Hill, ON | 500 tonnes | 4500 tonnes | 45000 L | 3.7 | 18.5 | Yes | 5 | 25 |
| **Milverton (PC)** | Perth County | 6372 Perth Road 131, Milverton, ON | See Notes | See Notes | None | 1 | 5 | No | 0 | 0 |
| **St Marys** | St Marys | 408 James St S, Lakeside, ON | 350 to 500 tonnes | 3000 tonnes | None | 3 | 15 | Yes | 5 | 25 |
| **Milverton (PE)** | Perth East | 4700 Line 61, Perth East, ON | 500 tonnes (all pre-treated salt) | 3500 tonnes | None | 3 | 15 | Yes | 5 | 25 |
| **North Easthope** | Perth East | 2188 40 Line, New Hamburg, ON | 200 tonnes | 1000 tonnes | None | 1.5 | 7.5 | Yes | 5 | 25 |
| **Downie** | Perth South | 3193 County Rd 122, Saint Pauls Station, ON | None | None | None | 0 | 0 | Yes | 5 | 25 |
| **Blanshard** | Perth South | 1766 Perth Rd 139, Granton, ON | 1200 tonnes (SHARED TOTAL WITH SAND) | 1200 tonnes (SHARED TOTAL WITH SALT) | None | 0 | 0 | No | 0 | 0 |
| **Mitchell (WP)** | West Perth | 50 Arthur Street, Mitchell, ON | None | None | None | 0 | 0 | No | 0 | 0 |
| **Elma** | North Perth | 171 Monument Rd, Palmerston, ON | None | 400 tonnes | None | 1 | 5 | Yes | 5 | 25 |
| **Listowel** | North Perth | 580 Main Street West, Listowel, ON | None | None | None | 0 | 0 | Yes | 5 | 25 |
| **Wallace** | North Perth | 5882 88 Line Gowanstown, ON | 25 tonnes | 1200 tonnes | None | 1.5 | 7.5 | Yes | 5 | 25 |
| **MTO Listowel** | North Perth | 245 McDonald St E, Listowel, ON | 180 tonnes | 2500 tonnes | None | 2.5 | 12.5 | No | 0 | 0 |

## Maintenance Yard Evaluation Spreadsheet (Land Use/Zoning):

| Yard Name | Municipality | Is surrounding land use residential? | Additional Land Use/Zoning Information | Land Use/Zoning Score (0-5) | Weighted Land Use/Zoning Score |
|---|---|---|---|---|---|
| **Mitchell (PC)** | Perth County | Yes | Yard is Institutional Zoning surrounded by Residential Zoning with Future Development to the east and west | 1 | 1 |
| **Stratford** | Perth County | No (adjacent to a mature wood lot and a gravel pit) | Yard is Industrial Zoning surrounded by Agricultural Zoning | 5 | 5 |
| **Milverton (PC)** | Perth County | No (adjacent to a mature wood lot and farmland) | Yard is Institutional Zoning surrounded by Agricultural Zoning and Natural Resources to the north | 3 | 3 |
| **St Marys** | St Marys | Yes (BUT there is still a lot of room for expansion) | Some Residential, majority General Industrial Zone | 5 | 5 |
| **Milverton (PE)** | Perth East | No (adjacent to farmland) | Yard is Institutional Zoning surrounded by Agricultural Zoning and some Natural Resources + Parks and Recreation Zoning to the east. Additionally, there is Future Development planned to the northeast of the yard | 2 | 2 |
| **North Easthope** | Perth East | No (adjacent to farmland and a mature wood lot) | Yard is Agricultural Zoning surrounded by Agricultural Zoning and some Natural Resources Zoning to the south | 3 | 3 |
| **Downie** | Perth South | Yes | Yard is Institutional Zoning and surrounding land use is parks & recreation + hamlet village residential + agricultural | 1 | 1 |
| **Blanshard** | Perth South | Yes | Yard is Institutional Zoning and surrounding land use is hamlet village residential + agricultural + light & Ag Industrial | 1 | 1 |
| **Mitchell (WP)** | West Perth | No (located in the middle of an industrial area) | Zoning designation is Urban Industrial, Commercial, and Institutional (ICI) | 5 | 5 |
| **Elma** | North Perth | Yes | Yard is Institutional Zoning surrounded by Residential Zoning to the south and east and Agricultural to the north and west | 2 | 2 |
| **Listowel** | North Perth | Yes | Yard is Institutional Zoning surrounded by Residential Zoning | 2 | 2 |
| **Wallace** | North Perth | No (adjacent to farmland) | Yard is Institutional Zoning surrounded by Agricultural Zoning | 4 | 4 |
| **MTO Listowel** | North Perth | Yes (commercial land use to the west) | Yard is Institutional Zoning surrounded by Residential and Commercial Zoning. Additionally, there is a cemetary to the east and some Future Development to the north. | 2 | 2 |

## Maintenance Yard Evaluation Spreadsheet (Environmental Sensitivity, Yard Acreage, and Building Condition):

| Yard Name | Municipality | Proximity to Wetlands or other Environmentally Sensitive Areas | Environmental Sensitivity Score (0-5) | Weighted Environmental Sensitivity Score | Acreage of Yard (hectares) | Yard Acreage Score (0-5) | Weighted Yard Acreage Score | Building Condition (Good, Fair, Poor) | Building Condition Score (0-5) | Weighted Building Condition Score |
|---|---|---|---|---|---|---|---|---|---|---|
| Mitchell (PC) | Perth County | None | 5 | 10 | 4 ha | 2 | 10 | Good | 5 | 20 |
| Stratford | Perth County | None | 5 | 10 | 2 ha | 1 | 5 | Fair | 3 | 12 |
| Milverton (PC) | Perth County | None | 5 | 10 | 2 ha | 1 | 5 | Fair | 3 | 12 |
| St Marys | St Marys | None | 5 | 10 | 3.1 ha | 2 | 10 | Good | 4 | 16 |
| Milverton (PE) | Perth East | None | 5 | 10 | Situated on a 32.4 ha parcel with 4.05 ha suitable for yard | 5 | 25 | Good | 5 | 20 |
| North Easthope | Perth East | Adjacent to a creek to the east that leads to a pond located 500 m northwest of the yard. Also near two small ponds (200 m southwest and 550 m southeast) | 2 | 4 | 1.4 ha | 1 | 5 | Fair | 3 | 12 |
| Downie | Perth South | Source water protection area on N/W corner of property but there are no environmentally sensitive areas nearby. | 0 | 0 | 0.2044 ha | 0 | 0 | Fair | 3 | 12 |
| Blanshard | Perth South | None | 5 | 10 | 0.839 ha | 0 | 0 | Fair | 3 | 12 |
| Mitchell (WP) | West Perth | 900 m to Wetlands – On site Well #4 water distribution supply (source water protected) | 0 | 0 | 1.4 ha | 1 | 5 | Good | 5 | 20 |
| Elma | North Perth | None | 5 | 10 | 0.41 ha | 0 | 0 | Poor | 2 | 8 |
| Listowel | North Perth | None but there is a Municipal Well on site | 1 | 2 | 0.74 ha | 0 | 0 | Good | 5 | 20 |
| Wallace | North Perth | None | 5 | 10 | 2.73 ha | 1 | 5 | Good | 5 | 20 |
| MTO Listowel | North Perth | None | 5 | 10 | 2.35 ha | 1 | 5 | Fair | 3 | 12 |

## Maintenance Yard Evaluation Spreadsheet (Use of Facility for Other Purposes/Seasons and Availability of Amenities):

| Yard Name | Municipality | Other Uses for Yard | Availability of Maintenance Facilities | Availability of Employee Amenities | Use of Facility for Other Purposes/Seasons and Availability of Amenities Score (0-5) | Weighted Use of Facility for Other Purposes/Seasons and Availability of Amenities Score |
|---|---|---|---|---|---|---|
| **Mitchell (PC)** | Perth County | Used for all other public works functions (but not sewer and water operations at county level) | 1 wash bay, 3 garage bays, 2 additional equipment storage sheds are located at this property (1 is heated) | Department admin offices | 5 | 20 |
| **Stratford** | Perth County | Used as a secondary yard for public works functions | 1 pick-up bay | None | 1 | 4 |
| **Milverton (PC)** | Perth County | Used as a depot in the summer | None | None | 1 | 4 |
| **St Marys** | St Marys | All public works functions (i.e. water, sanitary, ambulance, police, finance, admin, building, IT etc.) | Wash facilities with oil separator, 1 bay for maintenance (i.e. crane and work bench) | Lunch room for operators, supervisors offices, womens and mens locker room (with shower) | 5 | 20 |
| **Milverton (PE)** | Perth East | Water/Wastewater, Parks, Turf Maintenance, Year-Round Road Maintenance, generally 5 FT employees report to this yard; Department Administration occurs at the municipal office. | Operations centre, washbay, equipment storage, parts storage, maintenance area, 5 tonne pedestal crane | 2 foreman offices, lunch room, staff room, training room, municipal vault | 5 | 20 |
| **North Easthope** | Perth East | Predominately year-round road maintenance operations, generally 4 FT employees report to this yard | Operations centre, equipment storage, maintenance area, 3 tonne overhead crane | 1 foreman office, lunch room | 3 | 12 |
| **Downie** | Perth South | Used for roads summer maintenance and parks/cemetaries | None | Foreman's office and lunch room. Adjacent to Municipal Office and Park / Sports fields | 3 | 12 |
| **Blanshard** | Perth South | Public Works (all seasons) | None | Lunch room | 3 | 12 |
| **Mitchell (WP)** | West Perth | All year facility for Public Works, Operations, Environmental Services, and Parks Administrations (20 employees) | None | Office space (20 ft x 80 ft), training room, storage, and break room | 4 | 16 |
| **Elma** | North Perth | Public Works Road Maintenance | Service Bay (no hoist) | Office space and lunch room (but they're both minimal). Offices DO NOT meet modern health and safety standards. | 2 | 8 |
| **Listowel** | North Perth | Public Works Road Maintenance | Service Bay (no hoist, just floor jacks) | Office space, lunch room. | 2 | 8 |
| **Wallace** | North Perth | Public Works Road Maintenance | Service Bay (a hoist is present) | Office space, lunch room | 3 | 12 |
| **MTO Listowel** | North Perth | None, just a bit of dry storage in the shed | None | Very small office with a tiny wall heater, but not used for any office type work | 1 | 4 |

## Maintenance Yard Evaluation Spreadsheet (Access to Services and Adjacent Road Class)

| Yard Name | Municipality | Access to Services (sewer, water, power, communications) | Access to Services Score (0-5) | Weighted Access to Services Score | Road Class of Adjacent Road | Road Class Score (0-5) | Weighted Road Class Score |
|---|---|---|---|---|---|---|---|
| **Mitchell (PC)** | Perth County | Municipal water, Municipal sewer, power, and internet | 5 | 15 | Class 4 | 4 | 8 |
| **Stratford** | Perth County | Power and internet | 2 | 6 | Class 2 | 5 | 10 |
| **Milverton (PC)** | Perth County | Power and internet | 2 | 6 | Class 3 | 4 | 8 |
| **St Marys** | St Marys | Sewer, water, power, and fibre optic communications all present (SWM with quality control onsite)<br><br>Onsite standby generator with autostart present | 5 | 15 | Class 4 | 4 | 8 |
| **Milverton (PE)** | Perth East | Private water, municipal sewer, 3-phase hydro, propane and wood heating, on-site storm pond, stand-by diesel generator, fiber internet & land line phone | 3 | 9 | Class 6 | 3 | 6 |
| **North Easthope** | Perth East | Private on-site water and sewer, propane, phone & internet, stand-by diesel generator, single-phase hydro | 3 | 9 | Class 4 | 4 | 8 |
| **Downie** | Perth South | Access to municipal water (no fire capacity), shares septic system with adjacent municipal office, and has fiber optic communications | 3 | 9 | Class 5 | 3 | 6 |
| **Blanshard** | Perth South | Has private well, septic system, and fiber optic communications | 2 | 6 | Class 3 | 4 | 8 |
| **Mitchell (WP)** | West Perth | Sewer, water, storm, gas, 3 phase power, backup generators, and fibreoptic communications | 5 | 15 | Class 4 | 3 | 6 |
| **Elma** | North Perth | Municipal water, Municipal sewer, power, and internet | 5 | 15 | Class 4 | 3 | 6 |
| **Listowel** | North Perth | Municipal water, Municipal sewer, power, and internet | 5 | 15 | Class 4 | 3 | 6 |
| **Wallace** | North Perth | Power and internet | 2 | 6 | Class 4 | 3 | 6 |
| **MTO Listowel** | North Perth | Power and internet (Access to Municipal water and sewer on the street but not directly into building) | 4 | 12 | Class 4 | 3 | 6 |

## Maintenance Yard Evaluation Spreadsheet (Total Weighted Score and Ranking)

| Yard Name | Municipality | Additional Notes (i.e. shared yard?) | TOTAL RAW SCORE | TOTAL WEIGHTED SCORE | Murray's Ranking of Existing Operations (Raw) | Murray's Ranking of Existing Operations (Weighted) |
|---|---|---|---|---|---|---|
| **Mitchell (PC)** | Perth County | -Material shared with West Perth<br>-Perth County's plow truck at St Marys fills brine tank from Mitchell Yard to pre-wet salt | 35.7 | 127.5 | 3 | 2 |
| **Stratford** | Perth County | Material shared with Perth South only | 30.7 | 95.5 | 4 | 4 (tied) |
| **Milverton (PC)** | Perth County | -Material storage facility is located off-site at nearby Perth East Milverton Yard and shared with Perth East<br>-All salt stored at this yard is pre-treated salt | 20 | 53 | 10 | 11 |
| **St Marys** | St Marys | Perth County parks one plow truck here (#6) and loads that truck with salt/sand using St Marys stock (County tracks its material usage and submits usage to Town of St Marys on a monthly basis).<br><br>Note: Perth County stated it would make sense if Perth South shared this yard as well | 38 | 124 | 1 | 3 |
| **Milverton (PE)** | Perth East | -Material storage facility is shared with Perth County (shared material storage ONLY)<br>-Everything else on yard is owned and operated by Perth East. County pays for materials and will invoice Perth East<br>-All salt stored at this yard is pre-treated salt | 36 | 132 | 2 | 1 |
| **North Easthope** | Perth East | -Not shared | 25.5 | 85.5 | 6 | 5 |
| **Downie** | Perth South | All required materials are purchased directly from Perth County's Stratford Yard and loaded directly onto truck for Perth South's use | 18 | 65 | 11 (tied) | 9 |
| **Blanshard** | Perth South | Salt/sand is purchased from Perth County's Stratford Yard and is replenished throughout the season as needed in the storage at Blanshard yard | 18 | 49 | 11 (tied) | 12 |
| **Mitchell (WP)** | West Perth | All required materials are purchased directly from Perth County's Michell Yard and loaded directly onto truck for West Perth's use | 23 | 67 | 8 (tied) | 8 |
| **Elma** | North Perth | Not shared | 25 | 79 | 7 | 6 |
| **Listowel** | North Perth | Not shared | 23 | 78 | 8 (tied) | 7 |
| **Wallace** | North Perth | Not shared | 29.5 | 95.5 | 5 | 4 (tied) |
| **MTO Listowel** | North Perth | -Not shared<br>-This yard is a short term rental from MTO | 21.5 | 63.5 | 9 | 10 |

C

# Appendix C: Yard and Fleet Rental Rates (Perth County)

**Appendix C: Yard and Fleet Rental Rates (Perth County)**

Items except #4 and #12 provided by client on August 7, 2020:

1. County Mitchell Shop: $8.68/sq.ft.of building space
2. County Milverton Shop: $5.84/sq.ft.
3. County Stratford Shop: $4.17/sq.ft.
4. For modelling purposes, we will assume $6.00 as a working figure for all other yards.
5. Tandem Plow: $110/hr
6. Tri-Axle Plow: $115/hr
7. Loader: $65/hr
8. Pick-up Truck: $30/hr
9. Single Axle: $68/hr
10. Sidewalk Machine: $55/hr
11. One-Ton: $50/hr
12. Assumed service speed 40 kph

# D

# Appendix D: Agency Specific Constraints for Route Optimization

**Appendix D: Agency Specific Operating Constraints**

Responses to updated data request for locations of left turn, u turn, hotspots, cold spots, one-way roads (September 18).

**Summary of Operational Restrictions by Municipality:**

| | Roadway needs a single axle truck | U-turn intersections | Left-turn intersections | Cold spot locations | One-way roads | Number of Provided PDF files |
|---|---|---|---|---|---|---|
| **Perth East** | Map attached | Only when dead-heading<br>That means traveling from maintenance yard to start of route, or end of route back to maintenance yard.<br>(No map attached) | SHOULD BE ONLY WHEN DEADHEAD (TRAVELLING TO OR FROM START OF ROUTE) IN OTHER WORDS IT IS NOT ALLOWED WHERE SPREADING OR PLOWING TAKES PLACE<br>(No map attached) | 129 between line 61 and line 64 | Map attached | 3 |
| **Perth South** | None | Map attached | Map attached | None | Map attached | 1 |
| **North Perth** | Urban areas of listowel, monkton and atwood: *route a.b,c and k* | Highway 23 (road 164), county road line 55, county road line 72, county road line 86, county road line 88, county road line 91, county road line 93, county road 178, county road 140, county road 147, municipal boundary roads 140, 172 and 173.( Map Attached) | N/A (No map attached) | N/A | N/A | 0 |

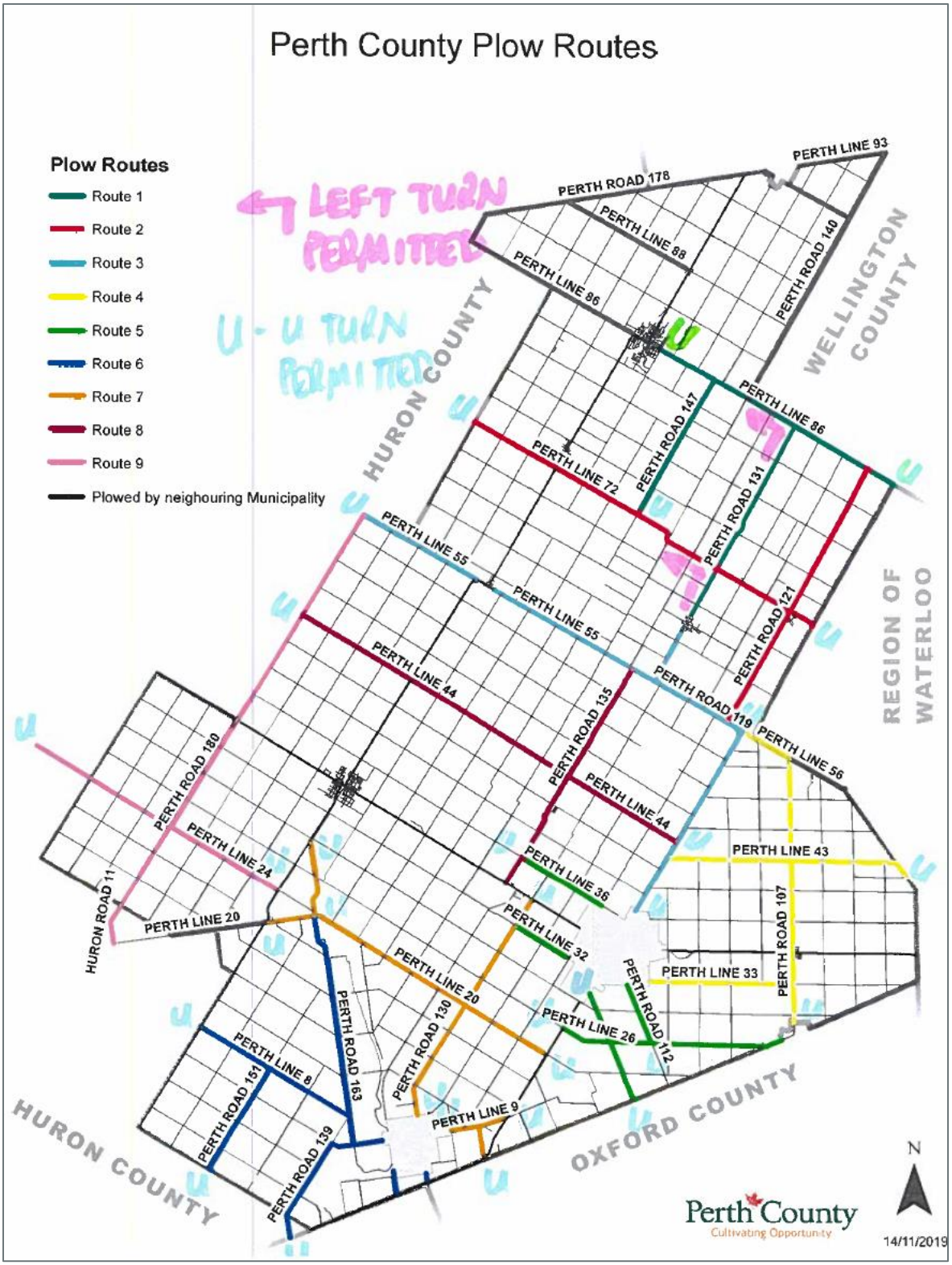
| | Roadway needs a single axle truck | U-turn intersections | Left-turn intersections | Cold spot locations | One-way roads | Number of Provided PDF files |
|---|---|---|---|---|---|---|
| **West Perth** | Mitchell only | Do u-turn when coming to a county or provincial road or highway. (No map attached) | Not allowed (No map attached) | None | None | 1 |
| **Town of St Marys** | Map Attached | Map Attached | Map Attached | Map Attached | Map Attached | 1 |
| **Perth County** | None | Map Attached | At the ends of plow runs or county boundary. | None | None | 1 |

**North Perth**

- Straight Salt Only on 3-lane connecting link Road in Listowel: Beat B truck used
  - Wallace Ave North from Main St. to town limit at 87
  - Main west from 165 to Wallace Avenue
  - Main East from Wallace Ave. to Tremaine Ave.
- Single Axle Routing for urban areas of Listowel, Monkton and Atwood: *Route A.B,C and K*
- Cul-de-sac plowing and sanding average 1.5 minutes to 3 minutes for plowing and sanding.
- 3 point Turn arounds are acceptable at intersections with Highway 23 (Road 164), County Road Line 55, County Road Line 72, County Road Line 86, County Road Line 88, County Road Line 91, County Road Line 93, County Road 178, County Road 140, County Road 147, Municipal boundary roads 140, 172 and 173 .

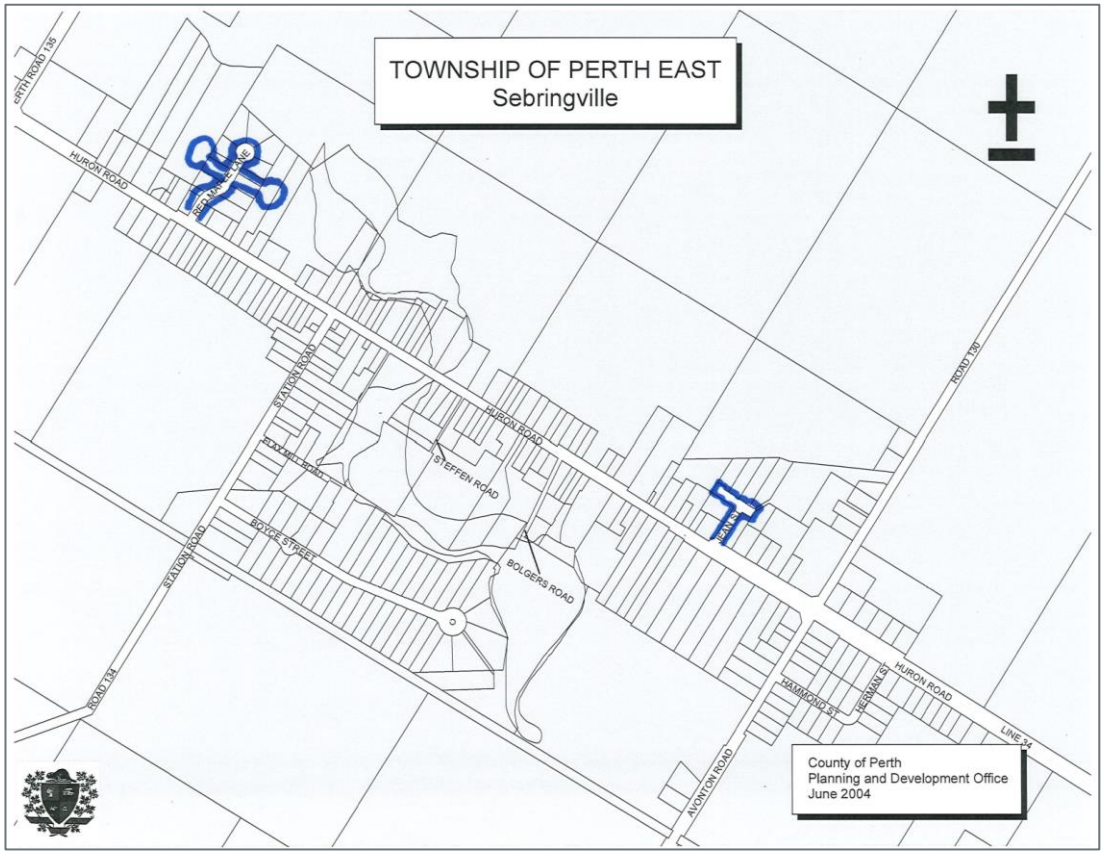
**Perth County**

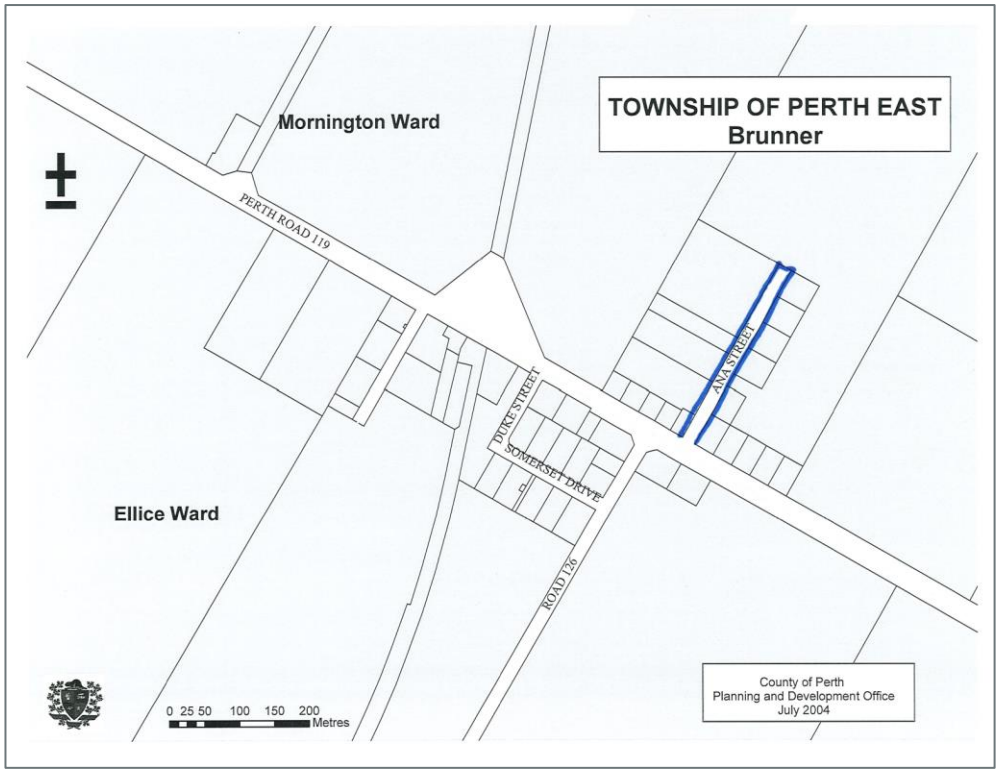
- Indicate on a map roadway locations such as urban areas, where a single axle truck is required (Otherwise for Tasks 3 & 4, sanding routes will be completed by tri-axle trucks and all other routes will be completed by tandem trucks); Not applicable to County
- Provide estimated time (minutes) to maintain a cul-de-sac; Not applicable to County
- Provide estimated delay (minutes) to conduct a U-turn; 3 minutes
- Indicate locations on a map where left turns can be permitted at intersections; At Perth Road 131 and Perth Line 72 & Perth Road 131 and Perth Line 86.
- Indicate locations on a map where U-turns may be allowed; At the ends of plow runs or County boundary.
- Indicate cold spot locations, such as bridges, on a map where a truck should not traverse and why (i.e. overloading bridge weight); and None
- Identify on a map the location of one-way roads (if any). None

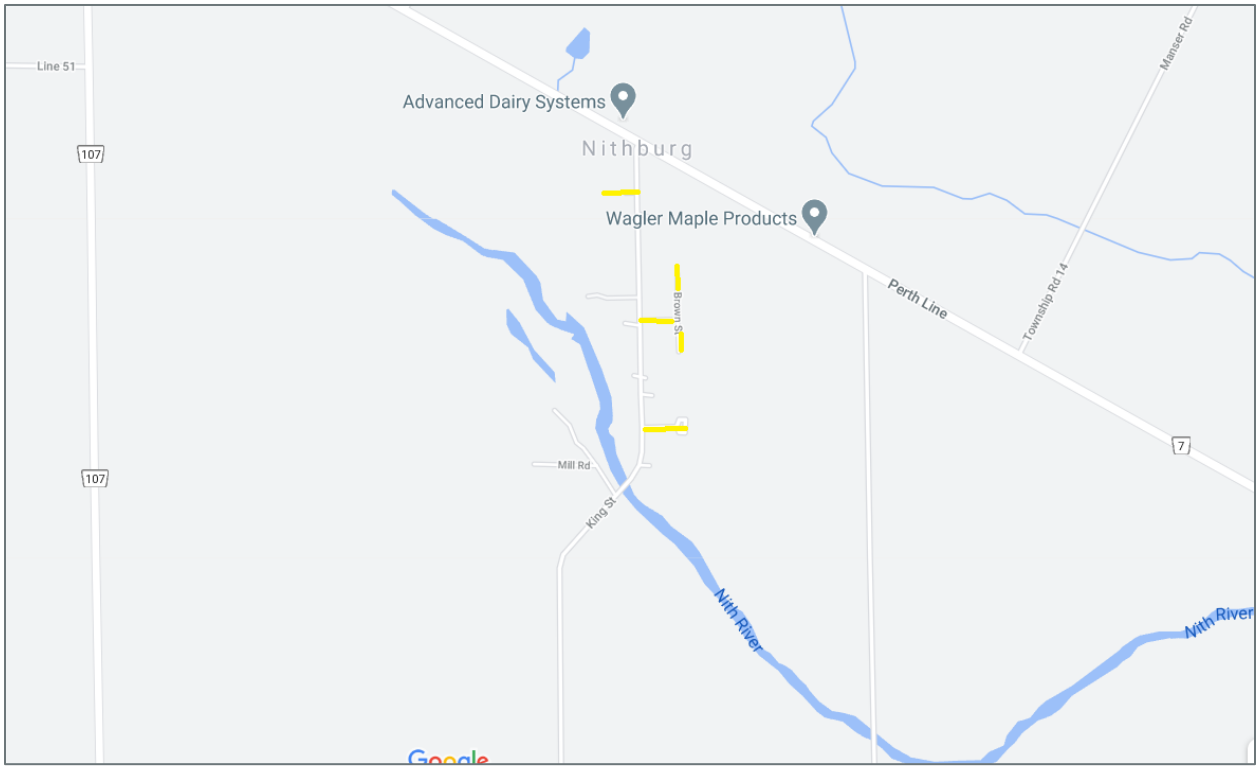

Perth County Plow Routes
Plow Routes
Route 1
Route 2
Route 3
Route 4
Route 5
Route 6
Route 7
Route 8
Route 9
Plowed by neighouring Municipality
LEFT TURN PERMITTED
U - U TURN PERMITTED
PERTH LINE 93
PERTH ROAD 178
PERTH LINE 88
PERTH LINE 86
PERTH ROAD 140
WELLINGTON COUNTY
HURON COUNTY
PERTH LINE 86
PERTH ROAD 147
PERTH LINE 72
PERTH ROAD 131
PERTH LINE 55
PERTH LINE 55
PERTH ROAD 121
PERTH LINE 44
PERTH ROAD 135
PERTH ROAD 119
REGION OF WATERLOO
PERTH LINE 56
PERTH ROAD 180
PERTH LINE 44
PERTH LINE 24
PERTH LINE 43
PERTH LINE 36
HURON ROAD 11
PERTH LINE 20
PERTH LINE 32
PERTH ROAD 107
PERTH LINE 20
PERTH LINE 33
PERTH ROAD 112
PERTH LINE 26
PERTH ROAD 130
PERTH ROAD 163
PERTH LINE 8
PERTH ROAD 151
PERTH LINE 9
PERTH ROAD 139
HURON COUNTY
OXFORD COUNTY
N
Perth County
Cultivating Opportunity
14/11/2019

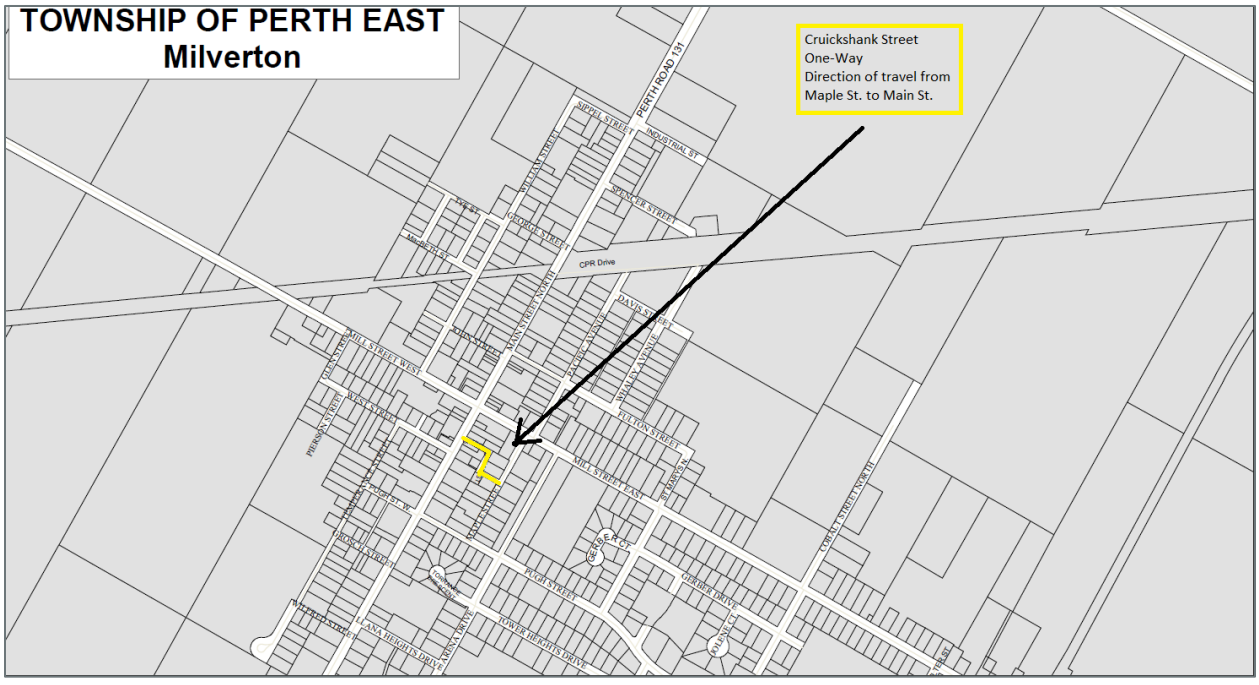
**Perth East**

- Sebringville and Brunner, Nithburg, Milverton maps provided.



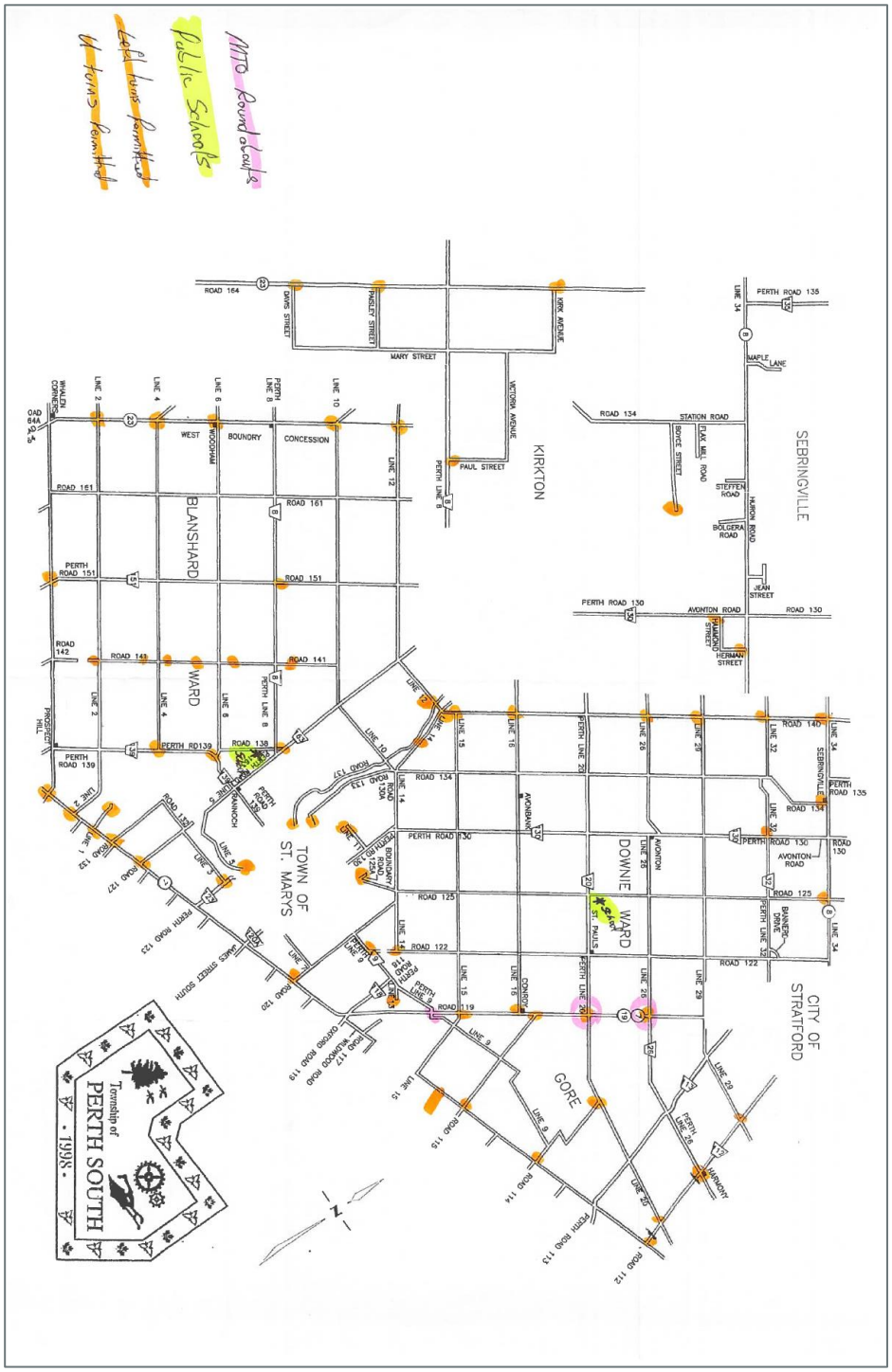



**Perth South**

- We have no single axle routes, and no tri-axle trucks
- We only have 1 cul-de-sac at the end of Boyce Street in Sebringville, I would expect it would only take 1 additional minute to clear (it has grass and our drinking water system in the middle of circle)
- Estimate 2 minutes to conduct a U-turn

- Map Attached, Left turns would be permitted at intersection of Provincial Highways and County Roads but try to keep to a minimum
- Map Attached, U turns would generally be permitted where township roads meet provincial highways and Perth County roadways and at dead ends or T intersections
- No cold spots on Winter maintained roadways
- No one way roads in Perth South



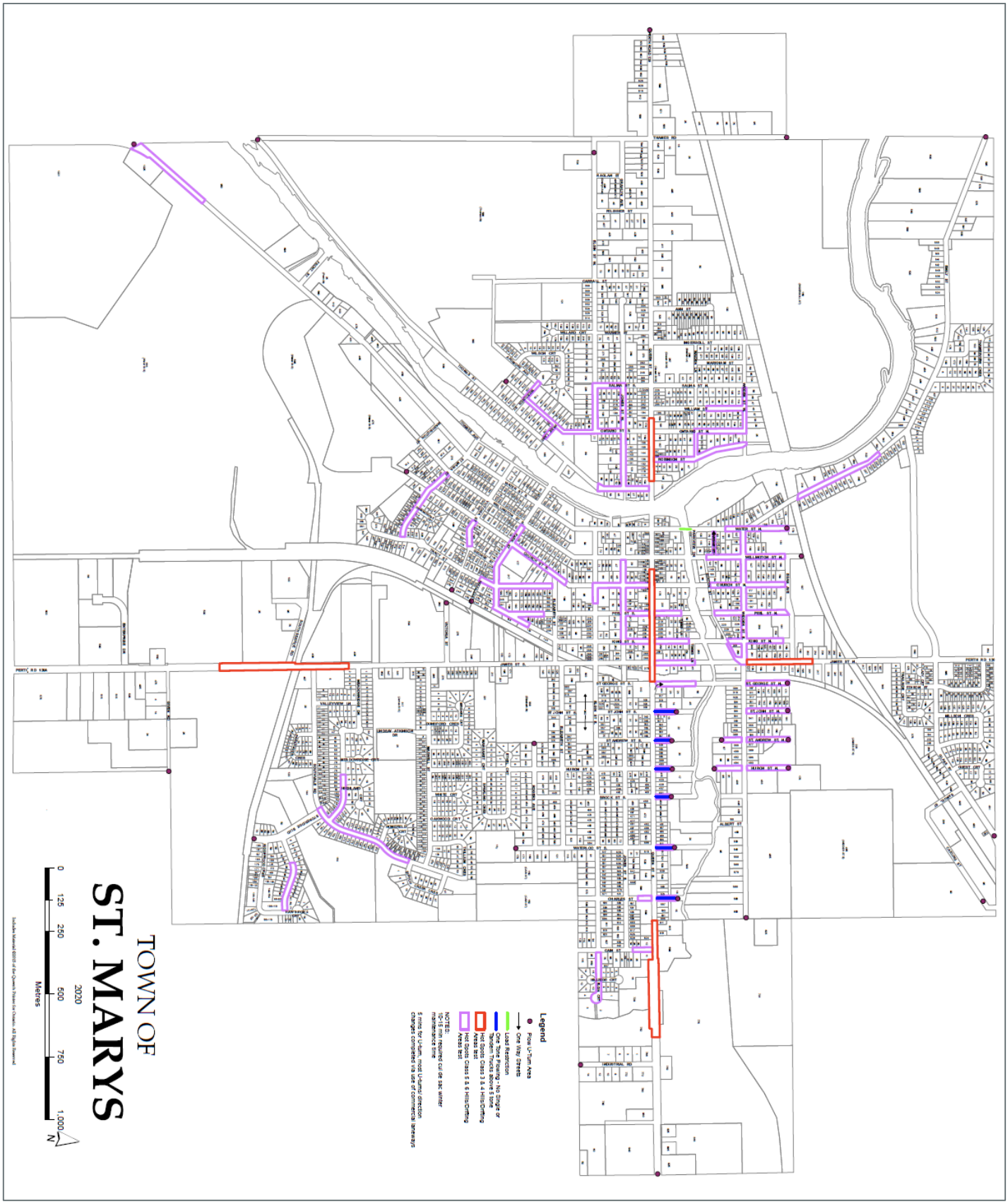
Additional Info provided by Perth South:

- There are 2 Public Schools – shown on map attached roads in close proximity should not be at the end of routes
- MTO has 3 roundabouts on Hwy 7 at Line 9, Line 20, and Line 26 we don't have to maintain but they assist with u turns
- No turning lanes in Perth South
- Sand /Salt routes – we normally use sand only, when calculating sand usage distance might be good to know our road network is approximately 50% pavement and 50% gravel
- Map provided with schools, locations where left turns and u turns permitted.

**Town of St Marys**

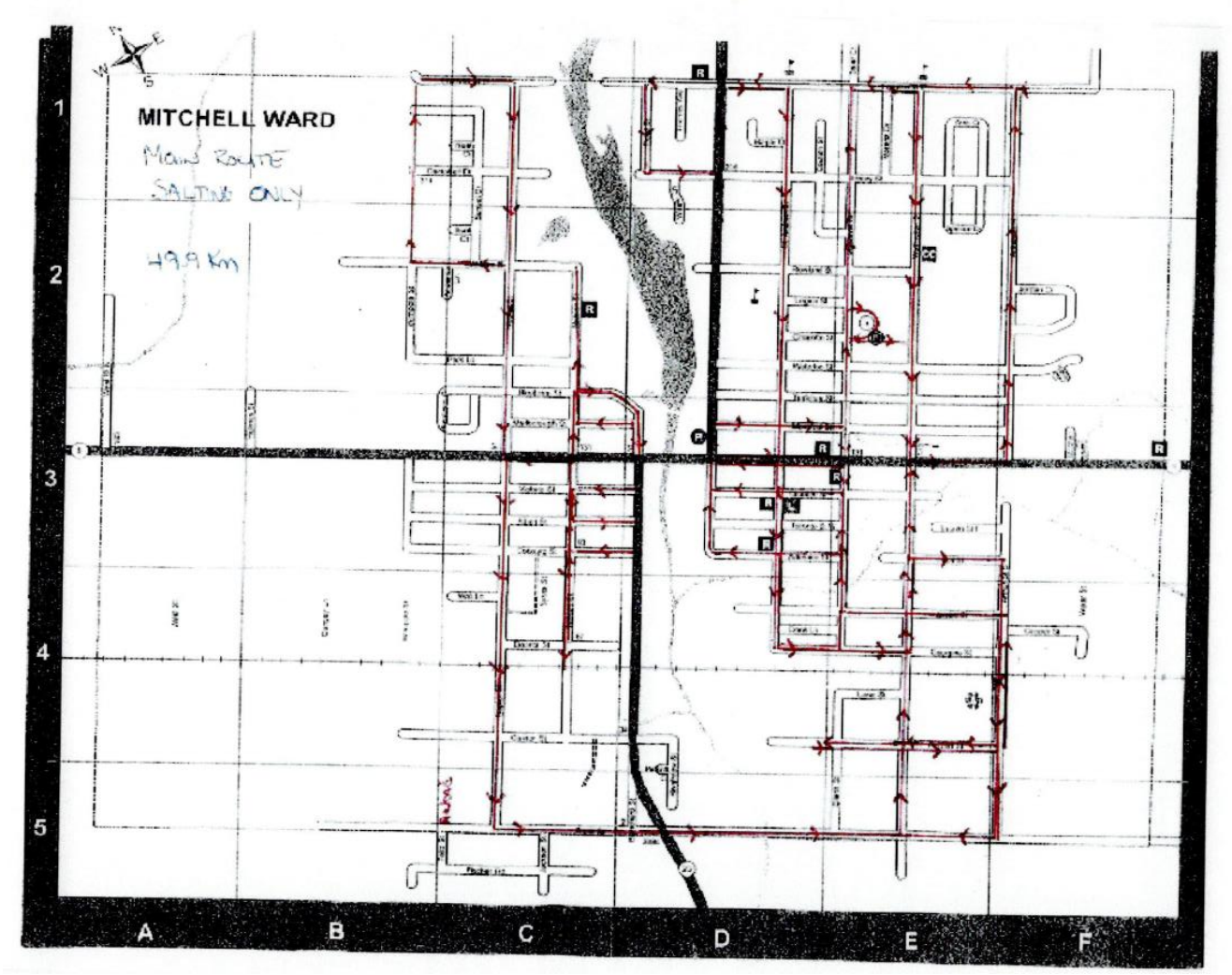
Map provided with the following annotations:

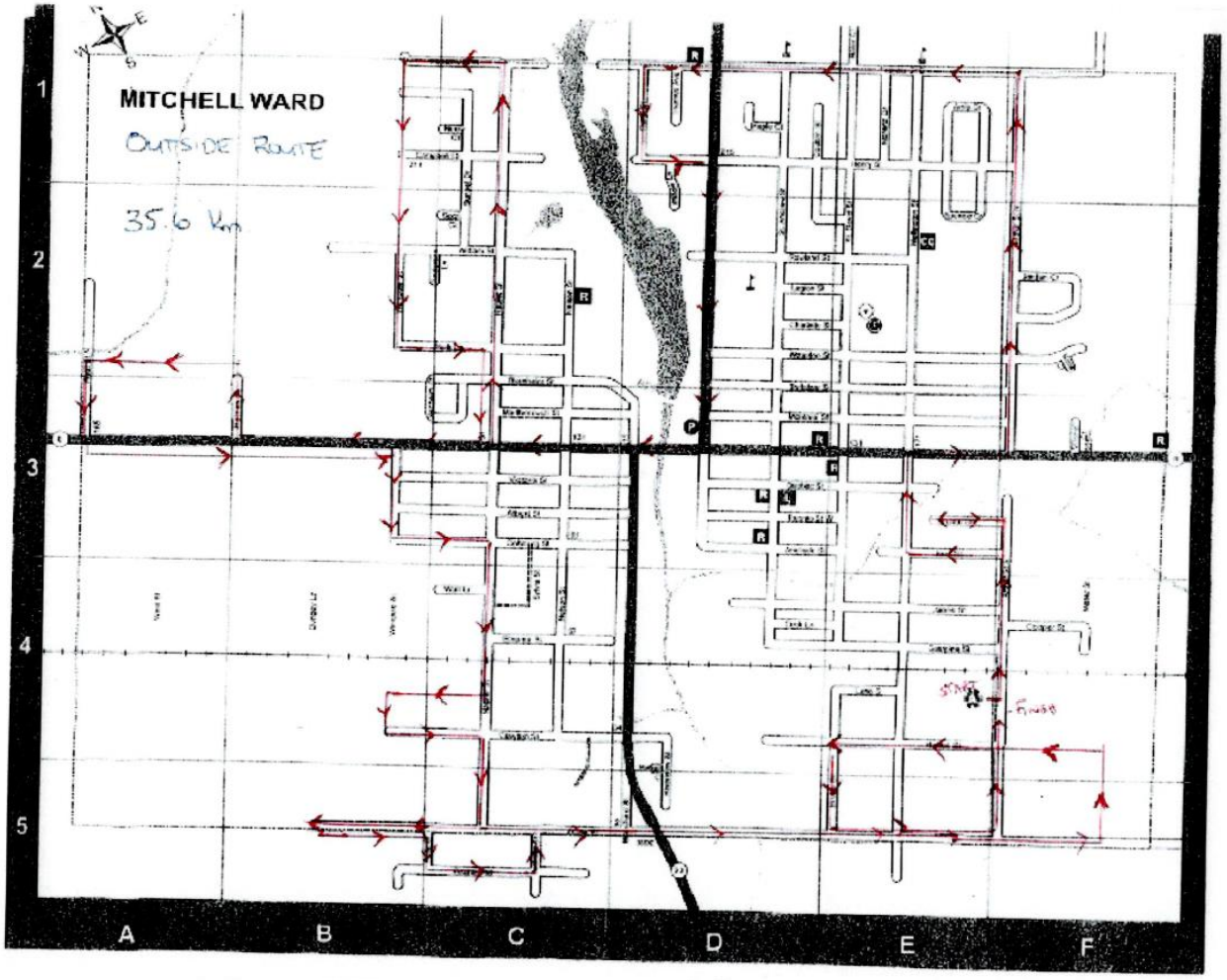
- Plow U-Turn Area
- One Way Streets
- Load Restriction
- One Tone Plowing - No Single or Tandem Trucks above 5 tone
- Hot Spots Class 3 & 4 Hills/Drifting Areas
- Hot Spots Class 5 & 6 Hills/Drifting Areas
- NOTES:
  - 10-15 min required cul de sac winter maintenance time
  - 5 mins for U-turn, most U-turns/ direction changes completed via use of commercial laneways

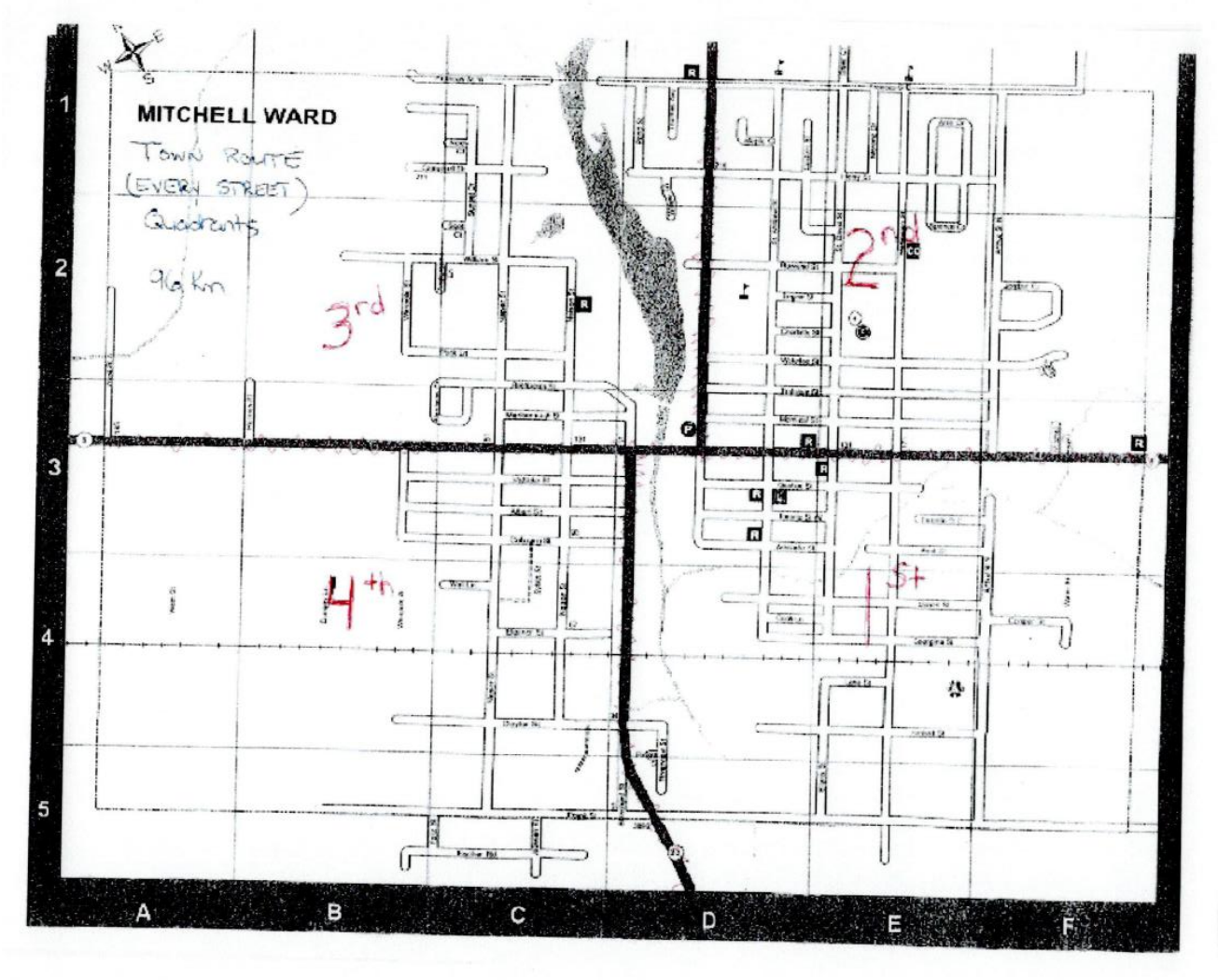

TOWN OF
ST. MARYS
Legend
Flow (+Turn Arcs
One Way Streets
Load Restriction
One Tonn Posting - No Bridge or Tandem Trucks above 5 tonn
Hot Spots Class 3 & 4 Hills/Drifting Areas test
Hot Spots Class 5 & 6 Hills/Drifting Areas test
NOTES:
10-15 min required cul de sac winter maintenance time
5 mins for U-turn, most U-turns/ direction changes completed via use of commercial laneways
0
125
250
500
750
1,000
2020
Metres
N

**West Perth**

- Single Axle truck which is our 5 ton plows Mitchell Only (all routes, see attached). We use a 100% salt in town because of the storm sewer infrastructure. Tandem Truck are all rural and we use a 75% sand 25% salt mix.
- Cul de sacs – Are only in Mitchell so the single axle plow will complete a outside sweep (10-15 seconds) and then we have our Mitchell foreman in a ¾ ton truck which will cleanup the centre of the cul-de-sac (5-7 minutes).
- U-turns time estimate of 3 minutes
- Refrain from making left hand turns (not permitted)
- We don't permit u-turns during a mid block. They will clean up a intersection and turn around. We do this when we come to a County or Provincial road or highway.
- We have no cold spot locations where a truck cannot traverse.
- West Perth does not have any one way streets
- Route maps provided.




MITCHELL WARD
OUTSIDE ROUTE
35.6 Km
1
2
3
4
5
A
B
C
D
E
F


MITCHELL WARD
TOWN ROUTE
(EVERY STREET)
Quadrants
3rd
2nd
4th
1st
1
2
3
4
5
A
B
C
D
E
F

E

# Appendix E: Network Integration Methodology and Data

## Appendix E: Network Integration Methodology and Data

### E.1: Detail of Methodology Used for Route Optimization and Network Integration

The primary objective of this task was to develop a timely and efficient snowplowing operations and resource allocations schemes to further improve the current snow and ice control strategies and to provide a decision support tool for future implementations. In particular, the modelling exercise had four specific tasks:

- Identification of existing plow routes and construction of a comprehensive GIS database (Task 1);
- Optimization of plow routes within the existing boundaries of municipalities (Task 2);
- Optimization of plow routes and depot locations by amalgamating operations of the county and municipalities within it and by reducing the number of maintenance yards and their associated service vehicles (Task 3); and
- Clean slate optimizations of plow routes and depots locations based on computer-generated optimal locations and available resources (Task 4).

Route optimization in this study uses a computer-aided heuristic route analysis developed on the basis of one of the most well-established routing methods, namely, the Chinese Postman Problem (CPP) in conjunction with a tabu metaheuristic algorithm in an attempt to find the optimal routes.[59, 60, 61, 62] The analysis is used to develop the shortest possible network operating distance while meeting legislative and operating requirements including road class priorities, turning restrictions, MMS requirements, material usage and loading capacities, and hotspots. Inputs to the analysis include plow/spreader operating constraints, rules of precedence and assumptions to simulate the logical rules that an analysist could follow to create and test out alternative routing options. The rules have been created with input from the clients over several iterations as analysts and clients came to understand each other's concerns.

Cost implications of each scenario are estimated from the number and particulars of maintenance yard removals and fleet hour reductions using maintenance yard and fleet annual rental rates provided by Perth County (**Appendix C**).

An overview of each of the individual tasks of the modelling approach is presented in the following.

#### Task 1: Create GIS Database

Task 1 involves the identification of existing plow routes and construction of a comprehensive GIS database for benchmarking current winter maintenance operations and services. While all municipalities provided existing maintenance records such as truck type, truck loading capacity and application rates, service routes, deadhead, and route precedence, etc., three municipalities (Perth County, Perth South, and West Perth) have provided complete information pertaining to their existing route precedence and deadhead in a traceable manner. Since the present routing information is critical for establishing a performance baseline for evaluation and comparison purposes in the following Task 2, for those without such information, service routes and their corresponding depot were connected using the shortest path

[59] Guan, M. 1962. Graphic programming using odd and even points. Chinese Math., 1: 237–277.
[60] Malandraki, C., and Daskin, M.S. 1993. The maximum benefit Chinese postman problem and the maximum benefit traveling salesman problem. European Journal of Operational Research, 65(2): 218–234.
[61] Perrier, N., Langevin, A., and Amaya, C.-A. 2008. Vehicle routing for urban snow plowing operations. Transportation Science, 42(1): 44–56.
[62] Ahr, D., and Reinelt, G. 2006. A tabu search algorithm for the min–max k-Chinese postman problem Computers & operations research, 33(12): 3403–3422.

assumption as illustrated in **Figure E1**. It is important to note that the performance evaluation of municipalities without route precedence may not be as valid or conclusive as those with detailed precedence information due to challenges associated with identifying overlapping routes or deadhead.


**Figure E1: Making a Complete Route with the Shortest Route Assumption**

**Task 2: Optimization with Existing Boundaries**

Upon constructing a comprehensive GIS database and establishing a performance baseline (i.e., benchmark) using existing routes and available resources, Task 2 was followed to achieve the following goal of *optimize routes by minimizing the total deadhead distance while satisfying a set of specific operational constraints within existing municipal boundaries*.

The route optimizations were carried out by following two main steps:

**Step 1: Network Partitioning**

This step involved the partitioning of the entire network into a manageable size for computer manipulations. The road network was partitioned by considering the total maximum distance based on the availability of trucks in each depot.

**Step 2: Optimal Route Assignments**

Once the routes were partitioned, the optimal route assignments or optimizations were conducted over many thousands of iterations to minimize the total deadhead distance for all trucks while satisfying the following operational constraints and decisions rules:

- **Road priority:**

- Two priority levels are used: Priority 1: Class 2, 3 and hotspot areas (if provided), Priority 2: Class 4, 5, and 6.
- Routes are serviced based on these two priority levels while satisfying the MMS requirements (route time) for each road class.
- Cold spots such as bridges (if provided) are to be avoided.
- **Note:** It is possible that the optimization may service lower priority roads first in an attempt to reduce a long deadhead. The optimized routes will not necessarily comprise the same road segments as the original routes, but will follow, as closely as possible, MMS classifications so that higher class road segments will be more likely serviced before lower class road segments. It is assumed that all clients use the MMS road classification system and that the class sets the route segment priority. (1=highest priority, 6=lowest priority). MMS maximum circuit times for icy conditions are used for Classes 2-5.

- **Turning restrictions:**
  - The number of left-turn and U-turn is minimized.
  - Left-turn and U-turn are made at permitted intersections, if provided (**Appendix D**).
  - **Note:** Left-turn and U-turn can also be made when trucks deadhead and when there are no realistic alternative routes that result in a long deadhead.
- **Route length and loading capacity:**
  - Sand/salt routes can only be assigned to sand/salt trucks, respectively
  - Salt/sand usage should not exceed the maximum given loading capacity of individual trucks.
  - The route length for each existing truck is limited by its maximum allowed distance provided by Agencies.
- **Truck type:**
  - Single-axle/tandem/tri-axle truck routes can only be serviced by single-axle/tandem/tri-axle trucks, respectively.
  - Gravel/salt/sand routes can only be serviced by graders/truck spreading salt and sand, respectively.
  - Snow blowers and parking lot vehicles are included in the equipment listings but not in the optimization analysis.
- **Other constraints:**
  - Each road segment is serviced exactly once.
  - Truck should start and end at the same depot.
  - No material is used on gravel roads.
  - Current practice uses single axle 5 tonne trucks in some urban areas, presumably because a tight turning radius is needed on urban streets but not always; sometimes it is due to historical aspects of fleet procurement or availability. It is difficult to determine the necessity of a single axle truck from the map and other information provided. It was, therefore, suggested to retain single axle where they are now.
  - Combo unit can deadhead but will not service gravel roads, and graders are not applicable on other routes that require both plowing and salting.
  - Turning lanes and steep hills are not treated separately for route optimizations in Task 2 (and all other tasks) because they are treated outside of normal route operations.

**Task 3: Optimization without Municipal Boundaries**

Task 3 involves the route optimizations with the current yard network by removing municipal boundaries and by enhanced sharing routes or joint operations. In the optimization by removal, existing maintenance depots were removed consecutively in the priority order provided, and for each configuration of remaining depots, plows routes from those depots were re-optimized to service the entire network. The process of depot removal ended when the constraints of service time (i.e., MMS requirements) OR 100% of spreader capacity could no longer be met. The same route statistics used in Tasks 2 are generated.

To reduce the complexity associated with route optimizations and overcome the potential issues that can arise from combining operations by removing municipal boundaries, the following decision rules have been added based on discussions with Agencies in addition to what were used in Task 2:

- When one depot is removed, its road equipment is also removed.
- While gravel routes can only be serviced by graders, sand and salt routes can be serviced by all other trucks to ensure the optimal use of all available resources.
- Similar to Task 2, a back-calculated application rate of 141 kg/single lane km, which is the lowest back-calculated rate for sand, is used for calculating the estimated material usage for optimized routes.

**Task 4: Clean Slate Optimization**

Task 4 involves the optimizations by clean slate where existing maintenance yards are all first removed and optimal configurations for a given number of yards (1 to 13) were generated by applying a classic location model; namely, maximum covering method, within which the algorithm will iteratively search for the optimal locations that yield the maximum route coverage of the serviced roads.[63]

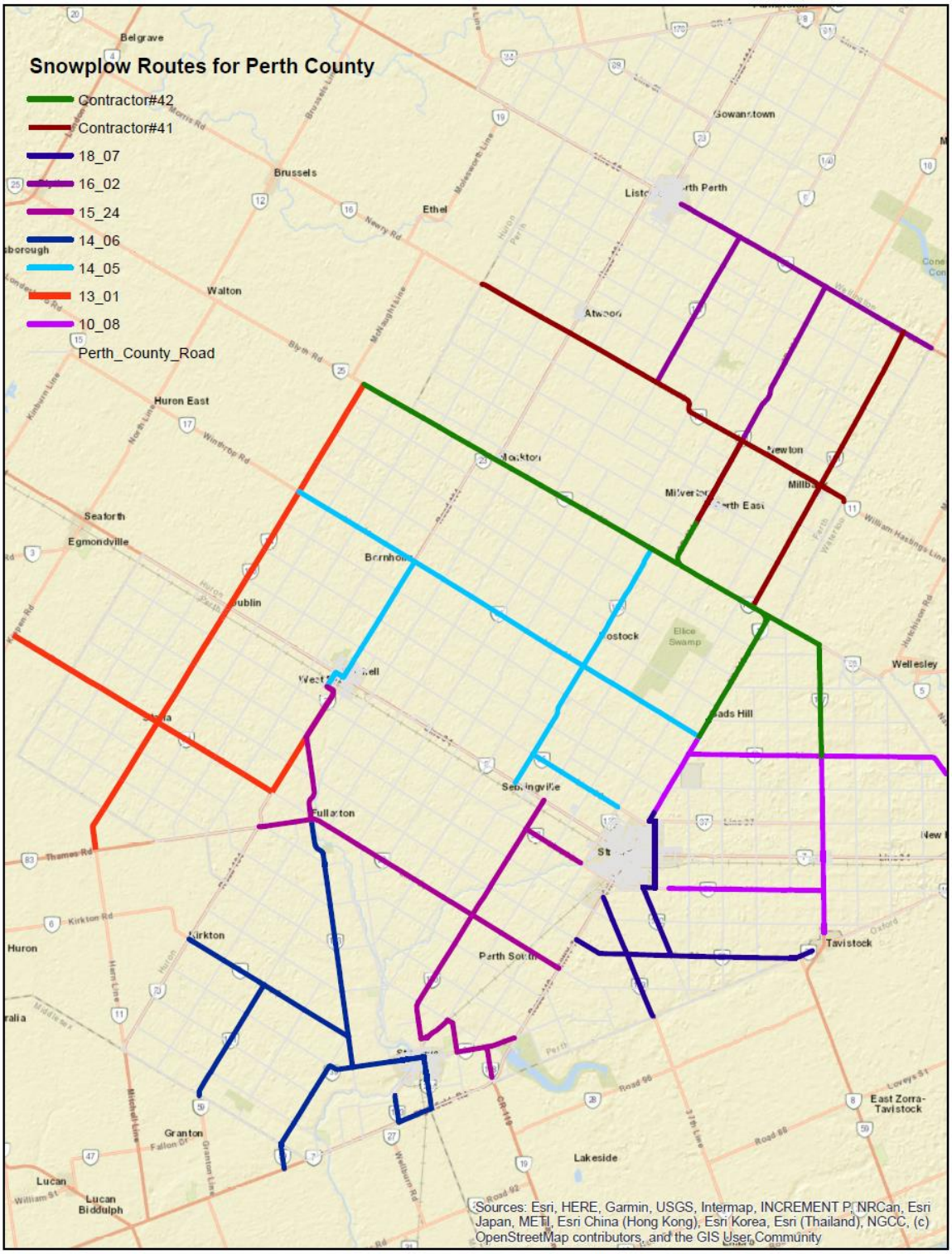
The location optimization model was then implemented to determine the recommended depot number (densities) and their spatial configuration. Since a depot should not be placed anywhere other than a road network, the solution space was limited to the existing road network. The constrained optimization was then run in an iterative fashion by beginning with one depot and by adding one additional depot incrementally to the network until it reaches the maximum of 13 depots.

The availability of resources (i.e., number of trucks) is estimated based on the findings of Task 3 (i.e., the minimum number of trucks needed to service the entire road network while meeting service time and spreader capacity requirements as closely as possible). In doing so, the same constraints used in Tasks 2-3 are applied to Task 4 with an added assumption that a single spreader capacity be used for route optimizations.

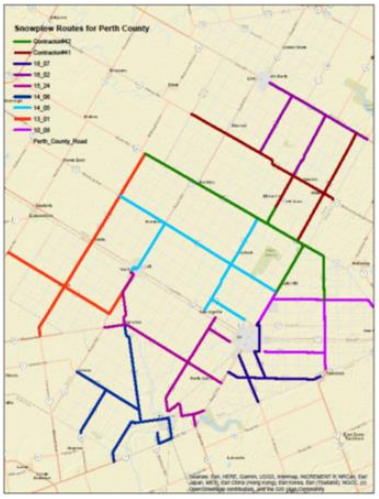
[63] Daskin, M. S., 2011. Network and discrete location: models, algorithms, and applications. s.l.:John Wiley & Sons.

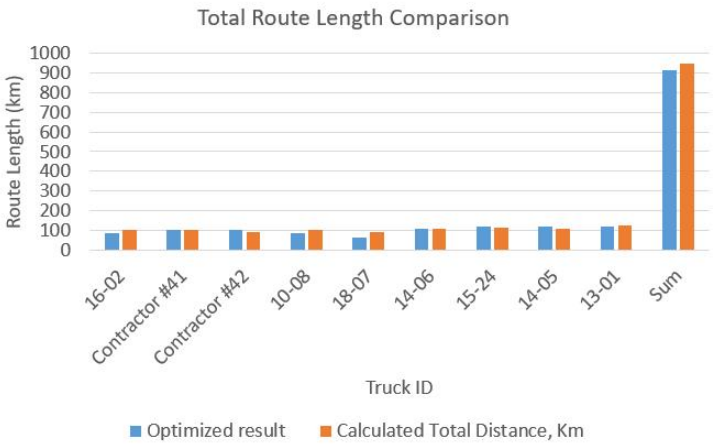
## Appendix E.2: Task 2 Optimization Results: Optimization with Existing Municipal Boundaries to Reduce Deadheading

### Perth County



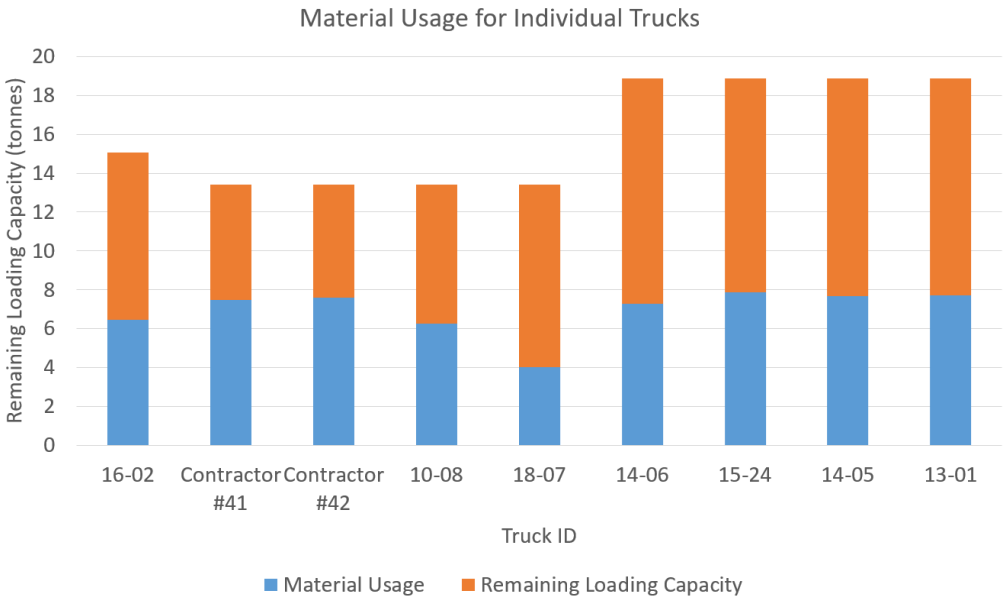
## Case 1 : Perth County-Total Distance

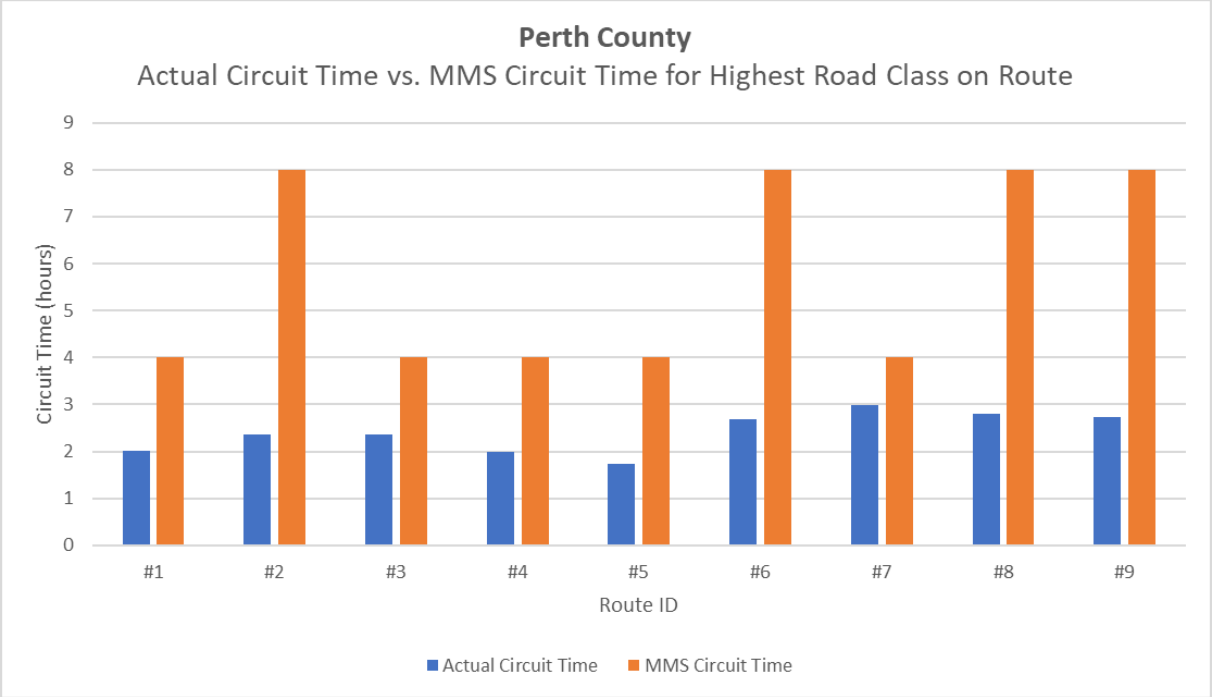


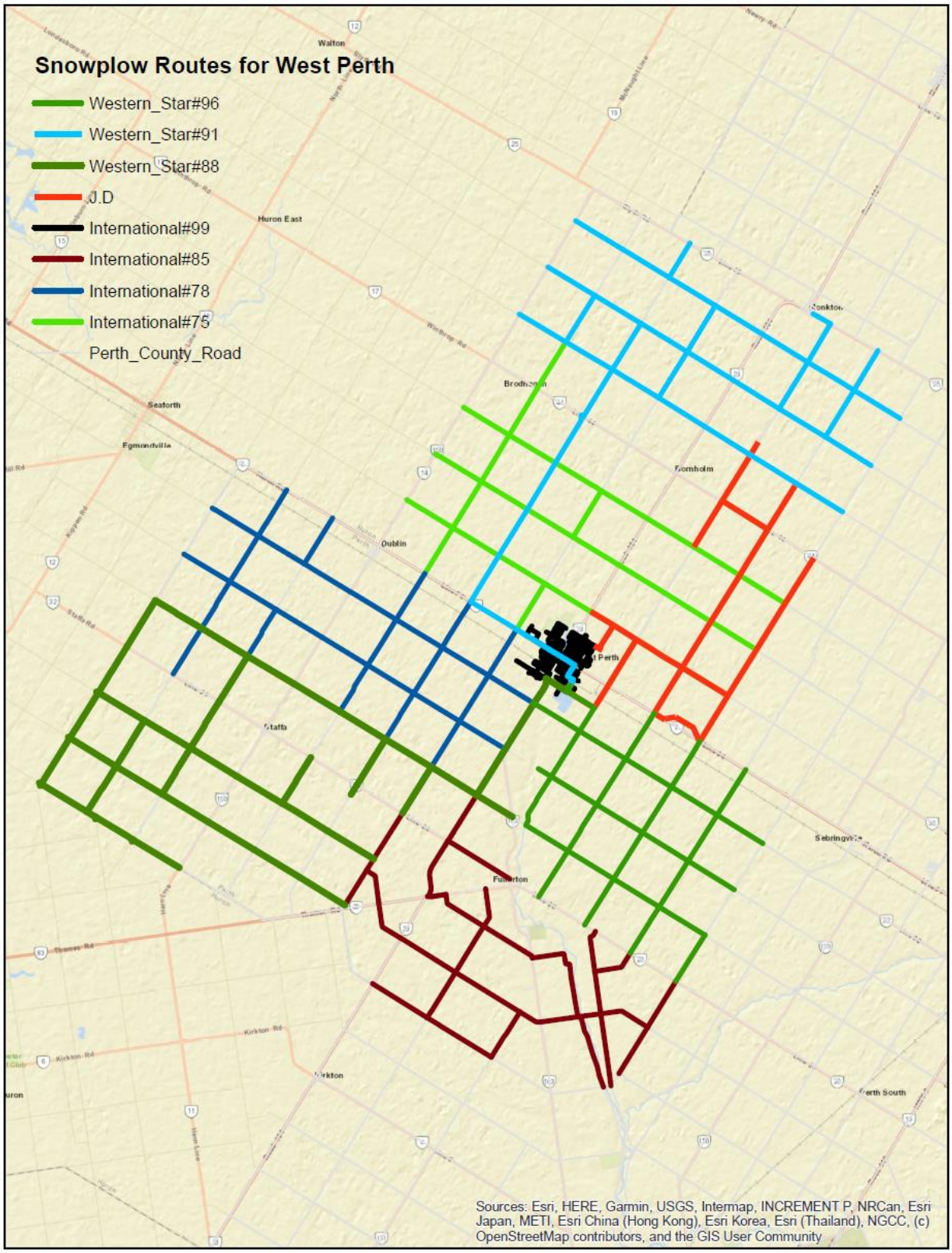

**9 combo units (out of 9 trucks) are used in optimization process, Total Distance Reduction : 3.58%**

## Case 1: Perth County-Material Usage

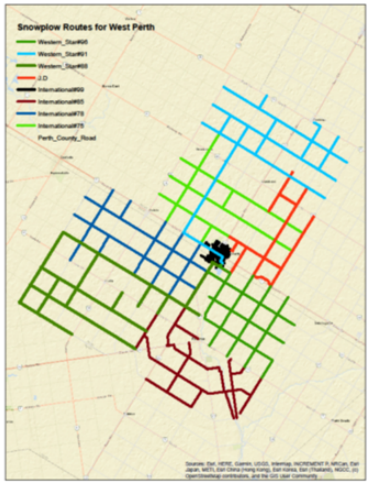


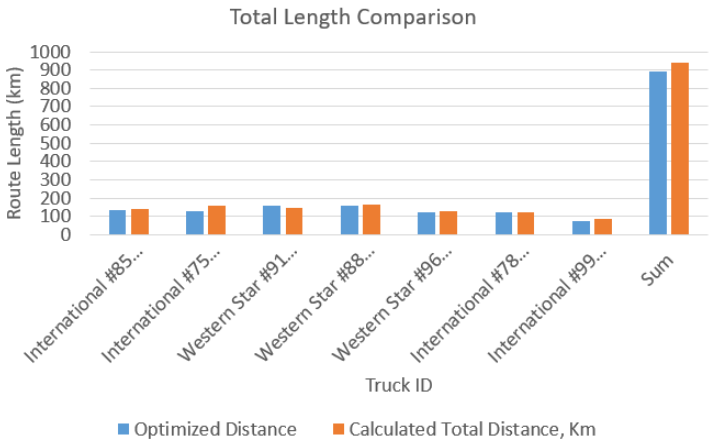

Perth County
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
Circuit Time (hours)
0
1
2
3
4
5
6
7
8
9
#1
#2
#3
#4
#5
#6
#7
#8
#9
Route ID
Actual Circuit Time
MMS Circuit Time

**West Perth**


Snowplow Routes for West Perth
Western_Star#96
Western_Star#91
Western_Star#88
J.D
International#99
International#85
International#78
International#75
Perth_County_Road
Walton
Huron East
Seaforth
Egmondville
Dublin
Brodhagen
Bonnholm
Staffa
Fullerton
Sebringville
Kirkton
Perth South
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

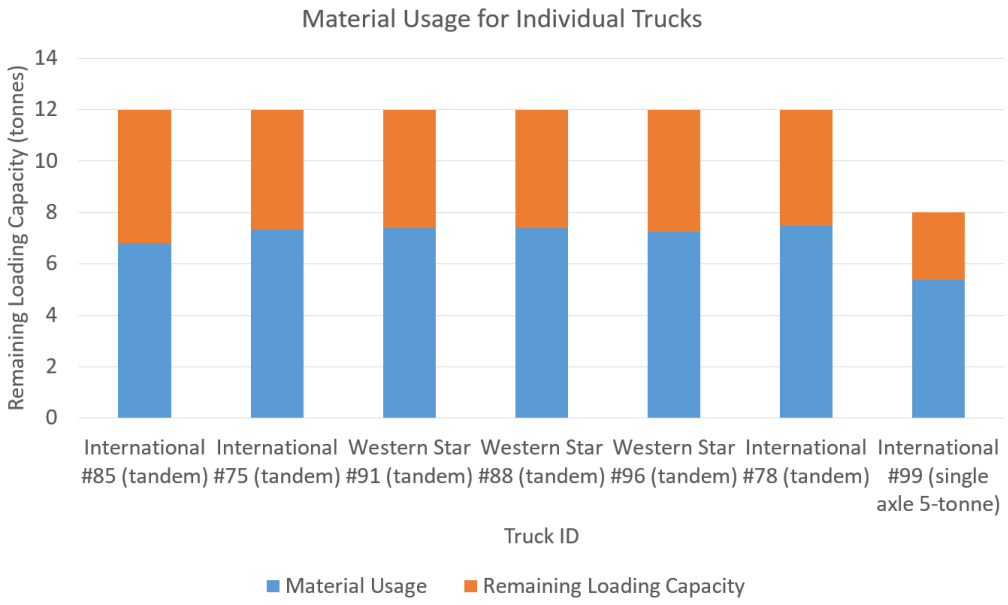
## Case 2: West Perth-Total Operating Distance

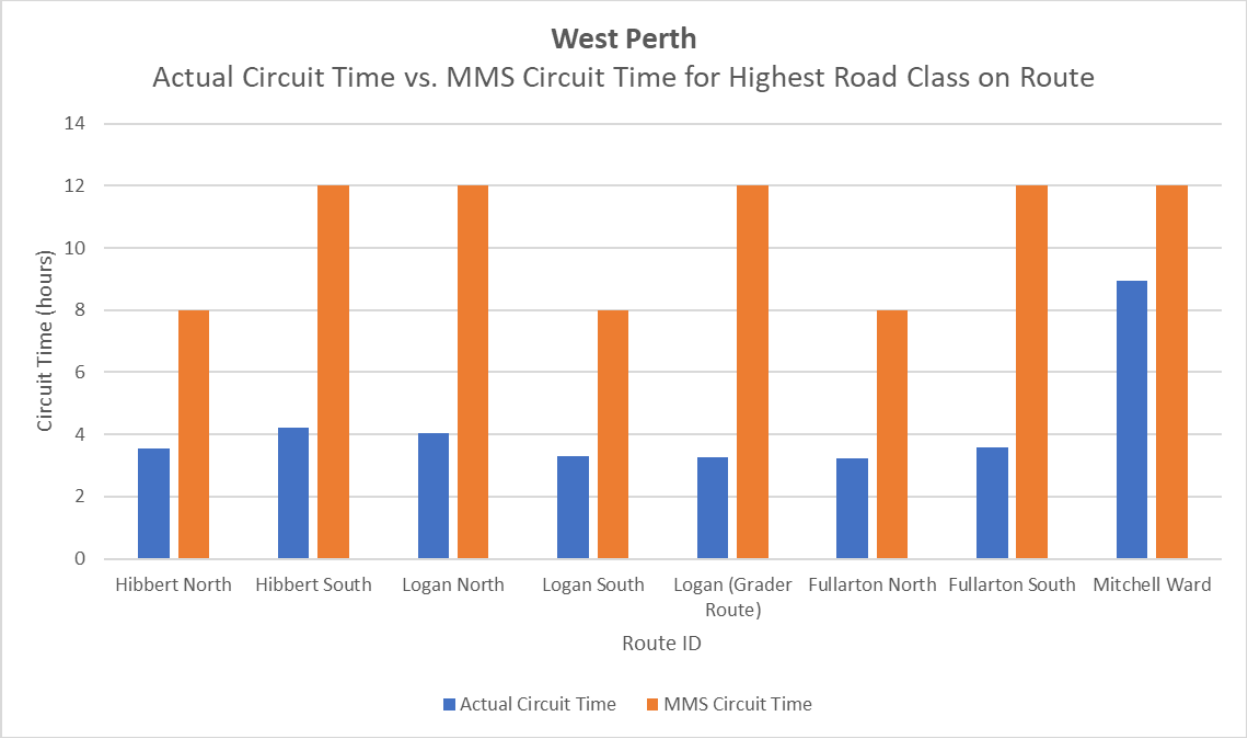


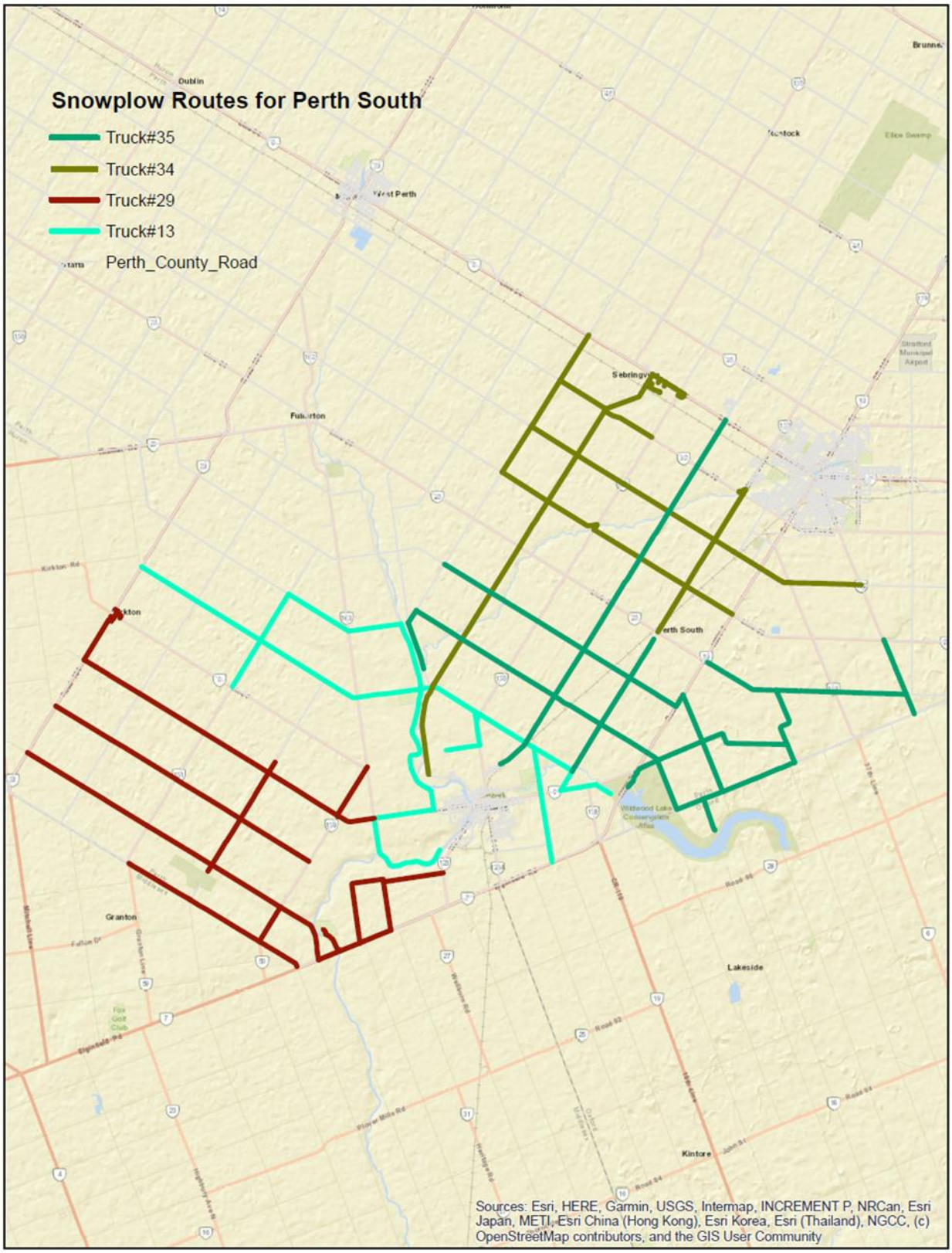

**7 combo units (out of 7 trucks) are used in optimization process, Total Distance Reduction : 5.83%**

## Case 2: West Perth- Material Usage

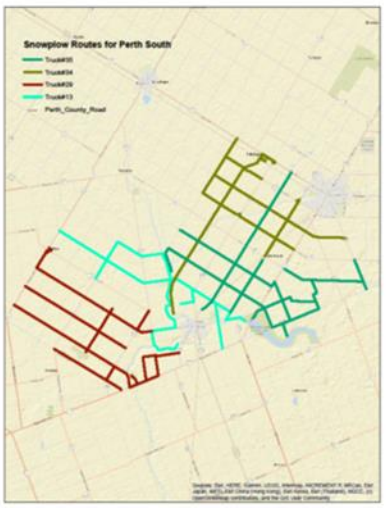


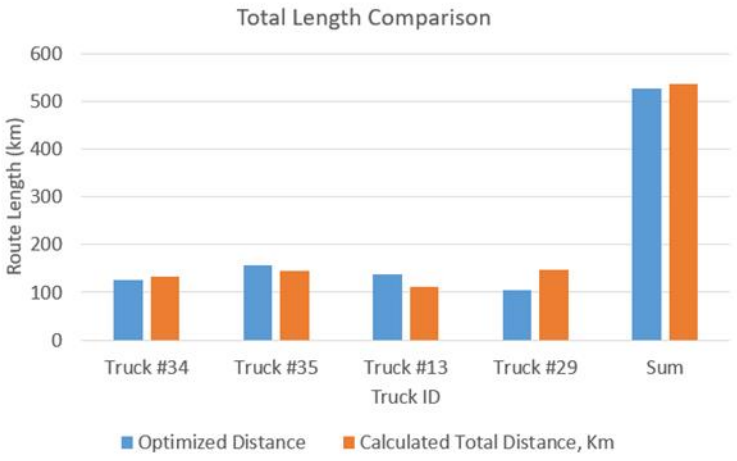

West Perth
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
Circuit Time (hours)
14
12
10
8
6
4
2
0
Hibbert North
Hibbert South
Logan North
Logan South
Logan (Grader Route)
Fullarton North
Fullarton South
Mitchell Ward
Route ID
Actual Circuit Time
MMS Circuit Time

**Perth South**


Snowplow Routes for Perth South
Truck#35
Truck#34
Truck#29
Truck#13
Perth_County_Road
Dublin
Sebringville
Fullarton
Perth South
Granton
Lakeside
Kintore
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

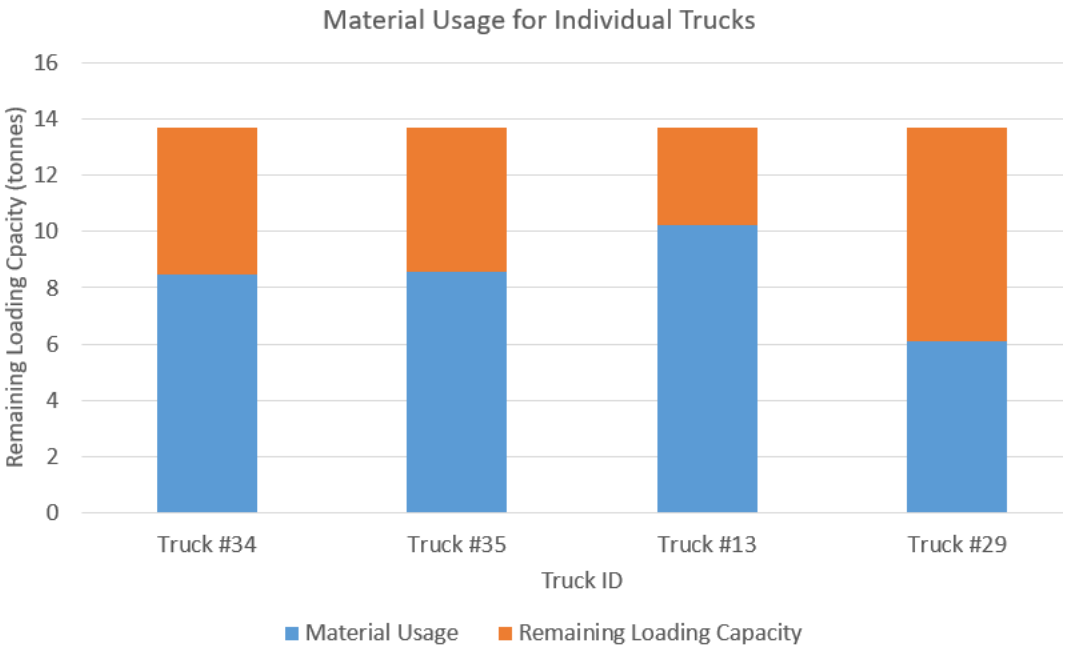
## Case 3: Perth South-Total Operating Distance

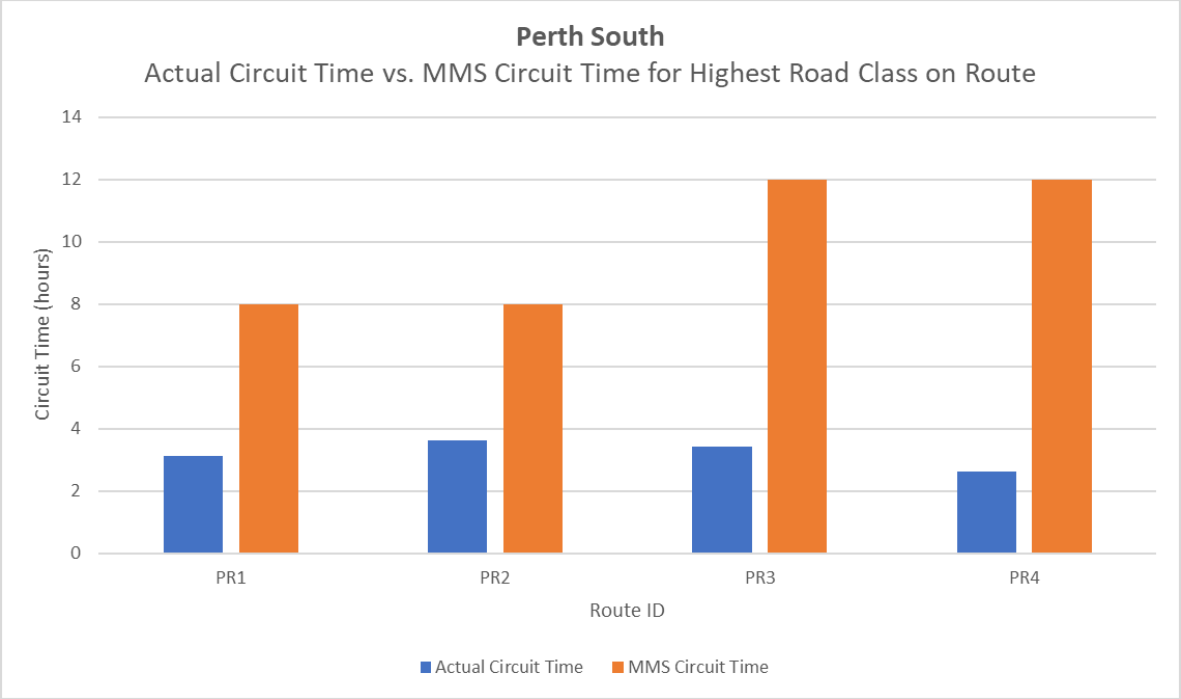


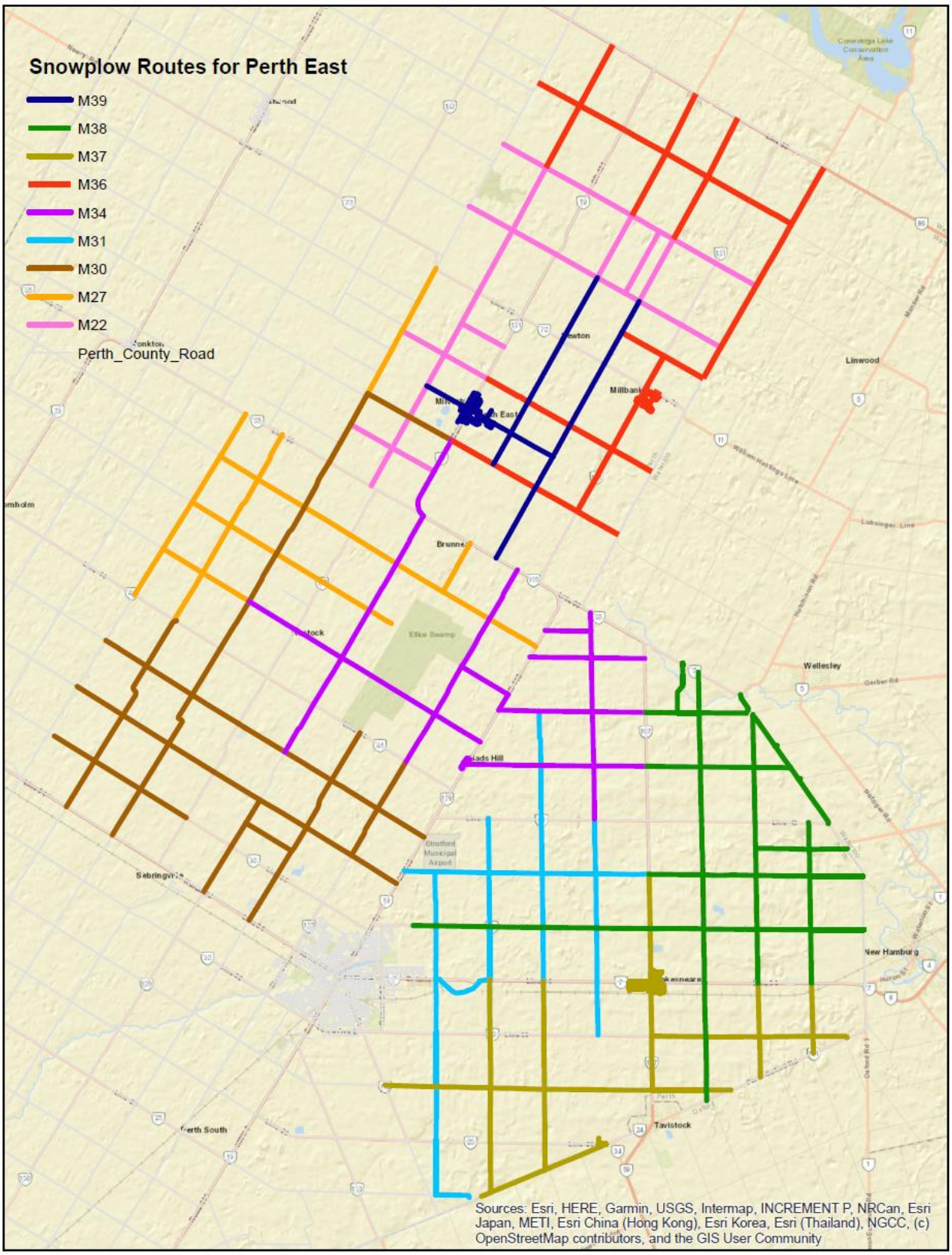

**4 combo units (out of 4 trucks) are used in optimization process, Total Distance Reduction : 2.11%**

## Case 3: Perth South-Material Usage

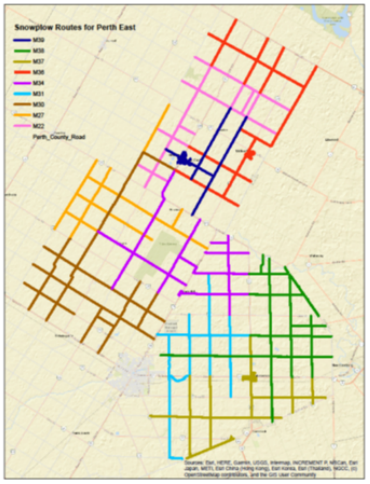


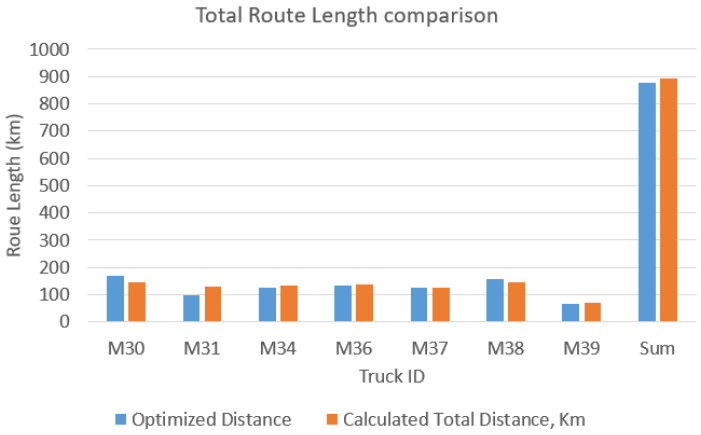

Perth South
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
14
12
10
8
6
4
2
0
Circuit Time (hours)
PR1
PR2
PR3
PR4
Route ID
Actual Circuit Time
MMS Circuit Time

**Perth East**


Snowplow Routes for Perth East
M39
M38
M37
M36
M34
M31
M30
M27
M22
Perth_County_Road
Linwood
Millbank
Brunner
Wellesley
New Hamburg
Tavistock
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

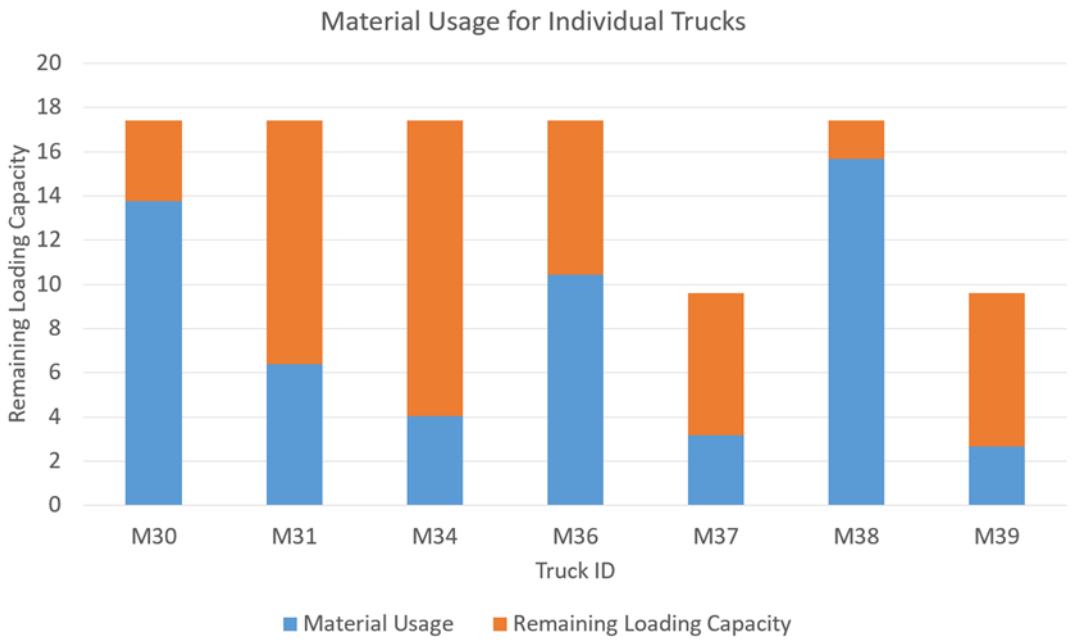
## Case 4: Perth East- Total Operating Distance

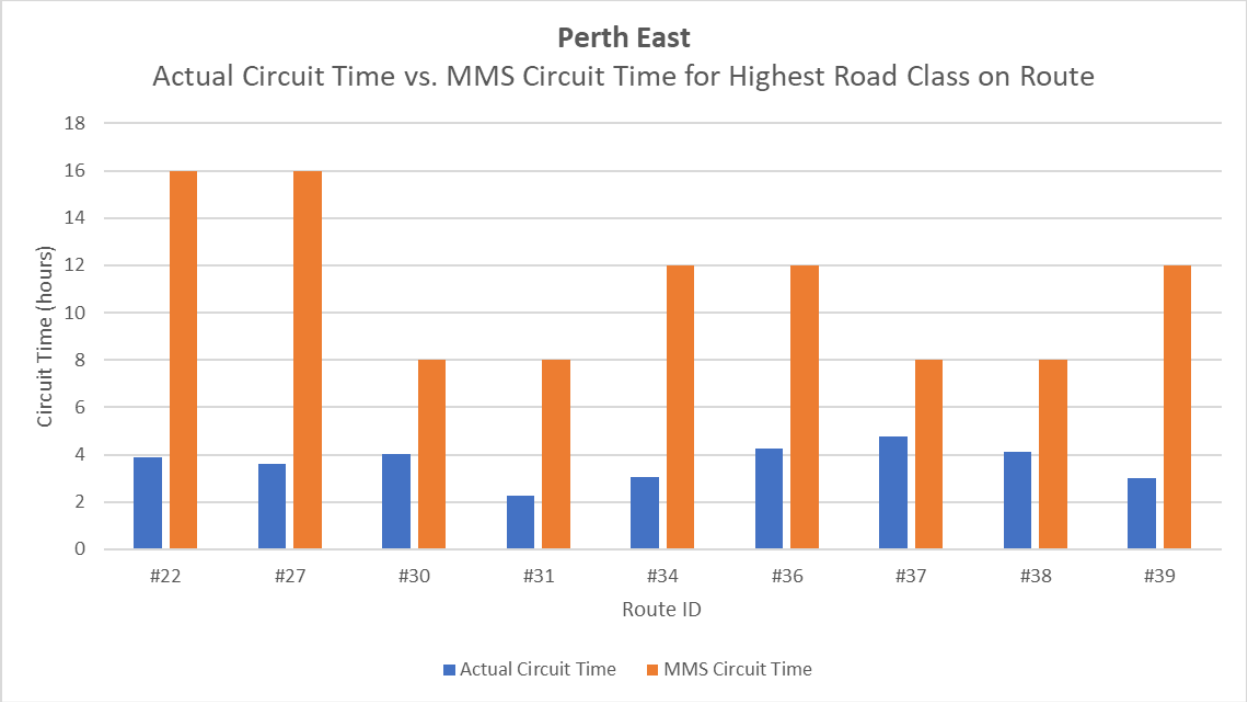


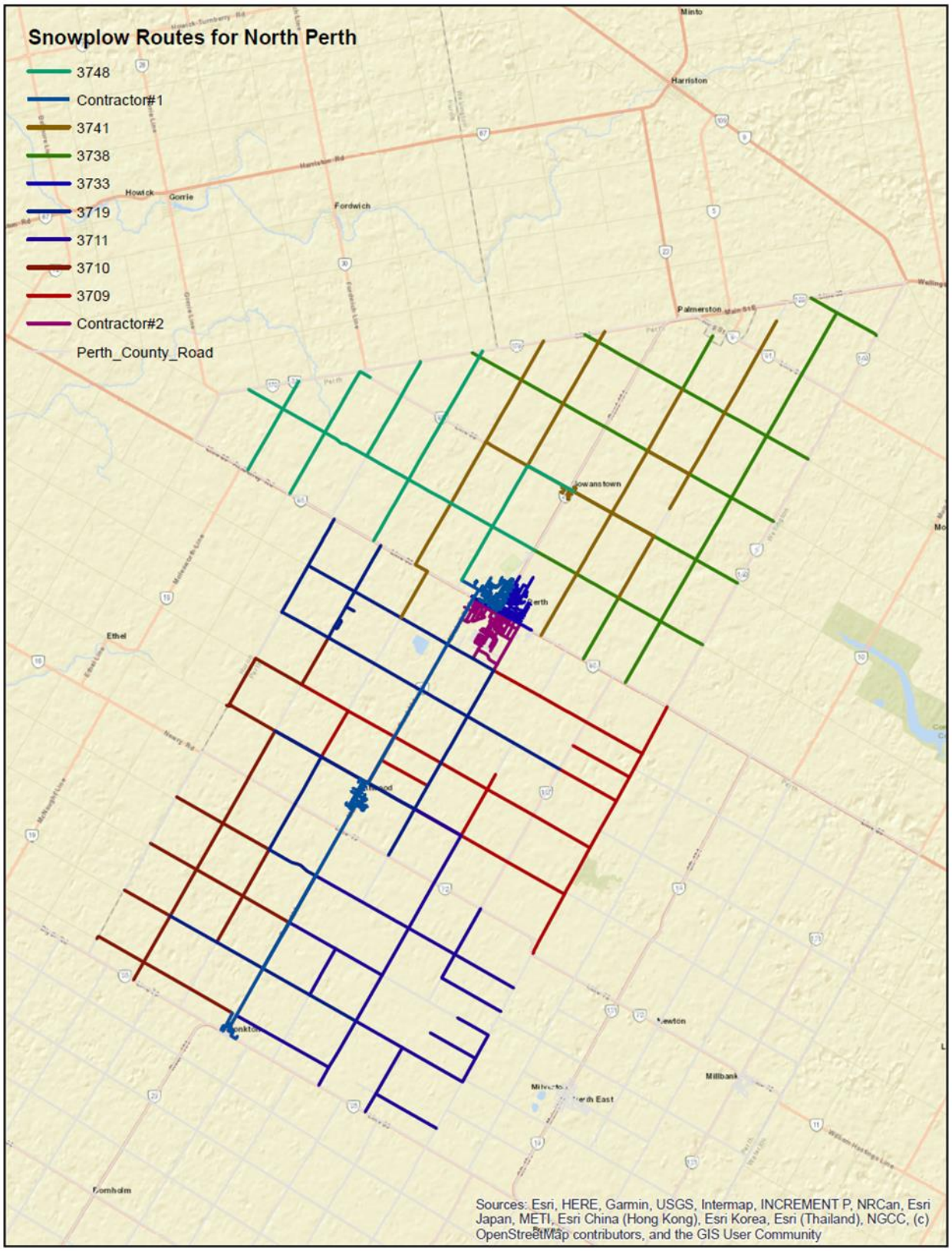

**8 combo units (out of 10 trucks) are used in optimization process, Total Distance Reduction : 1.37%**

## Case 4: Perth East-Material Usage

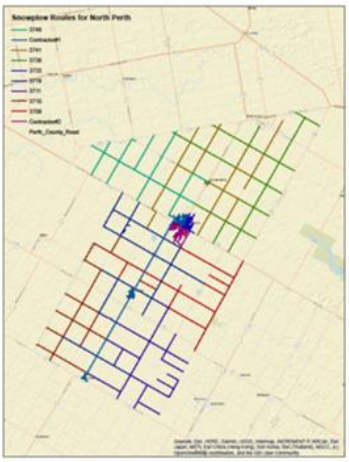


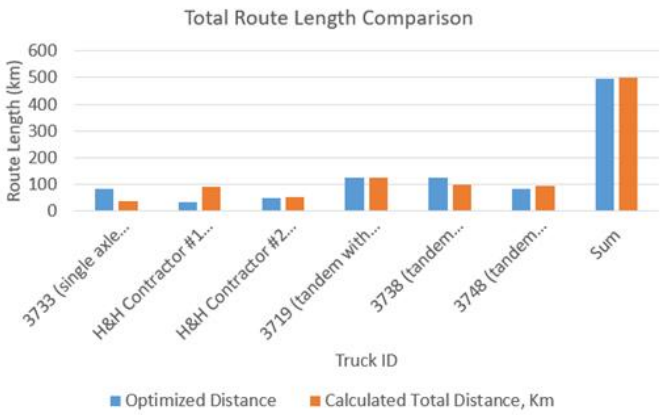

Perth East
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
Circuit Time (hours)
18
16
14
12
10
8
6
4
2
0
#22
#27
#30
#31
#34
#36
#37
#38
#39
Route ID
Actual Circuit Time
MMS Circuit Time

**North Perth**


Snowplow Routes for North Perth
3748
Contractor#1
3741
3738
3733
3719
3711
3710
3709
Contractor#2
Perth_County_Road
Minto
Harriston
Palmerston
Howick
Gorrie
Fordwich
Ethel
Millbank
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

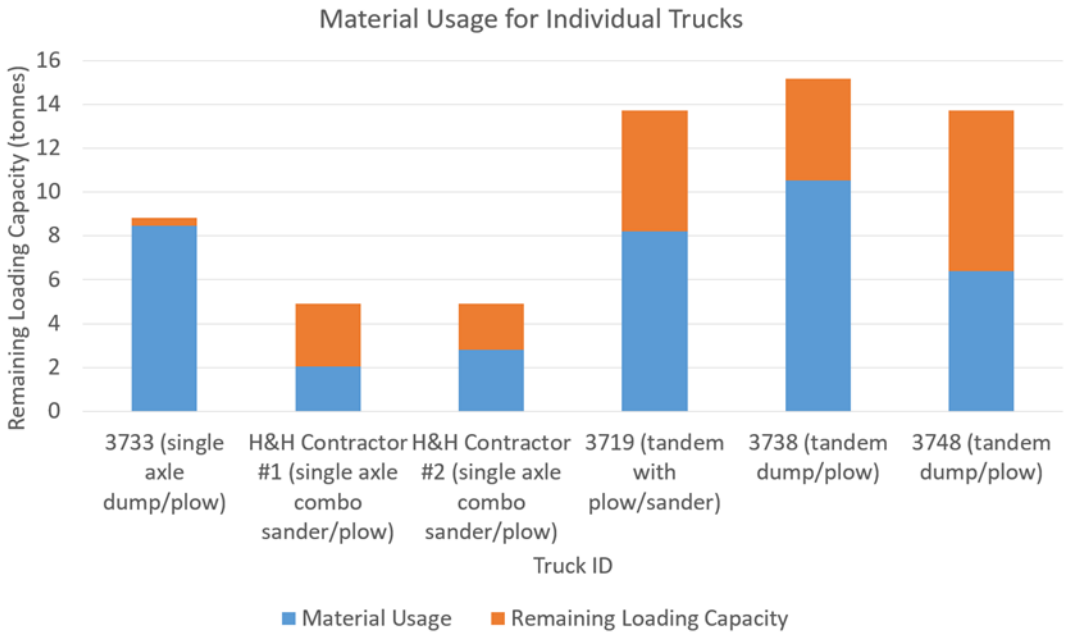
## Case 5: North Perth- Total Operating Distance

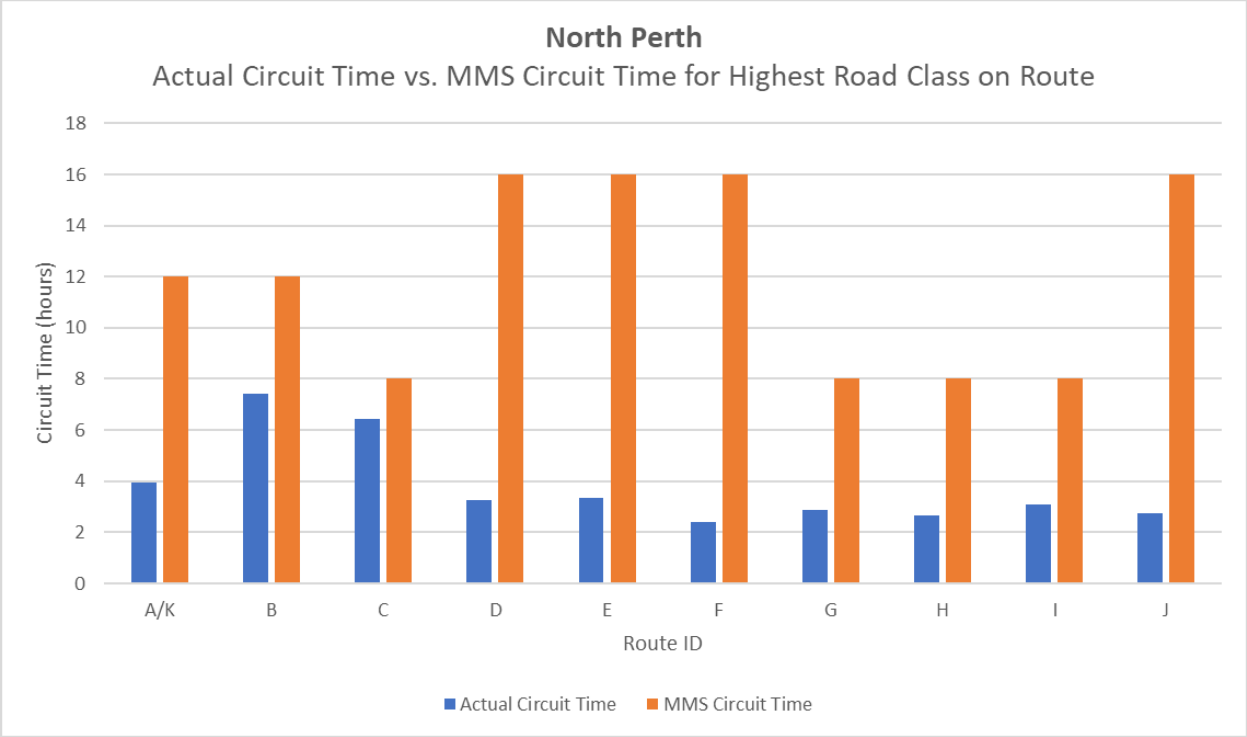




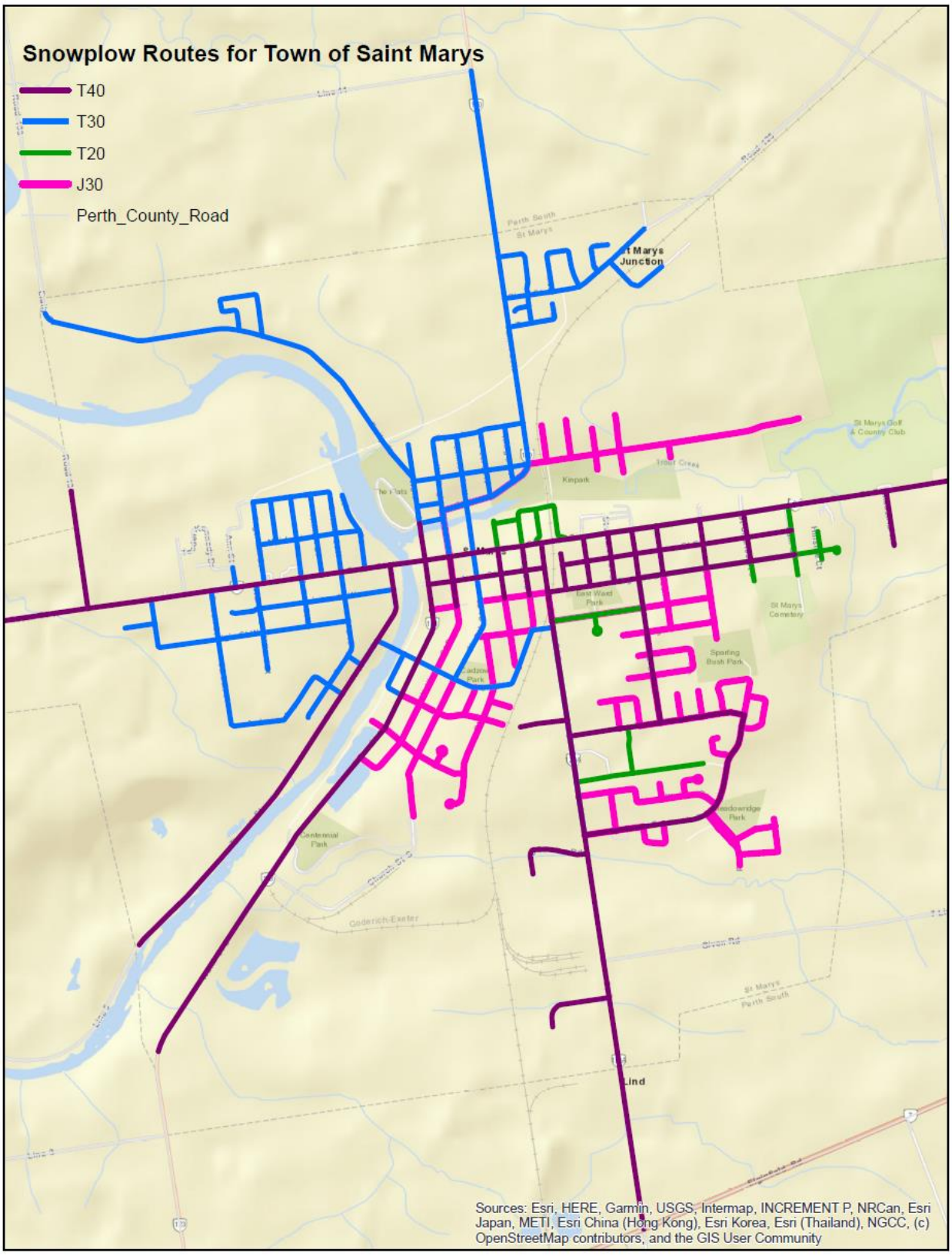

**6 combo units (out of 10 trucks) are used in optimization process, Total Distance Reduction : 0.90%**

## Case 5: North Perth-Material Usage

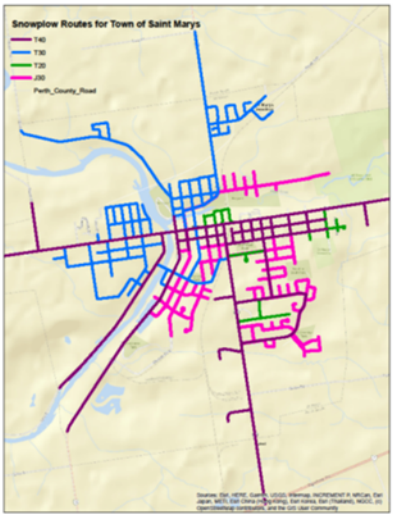


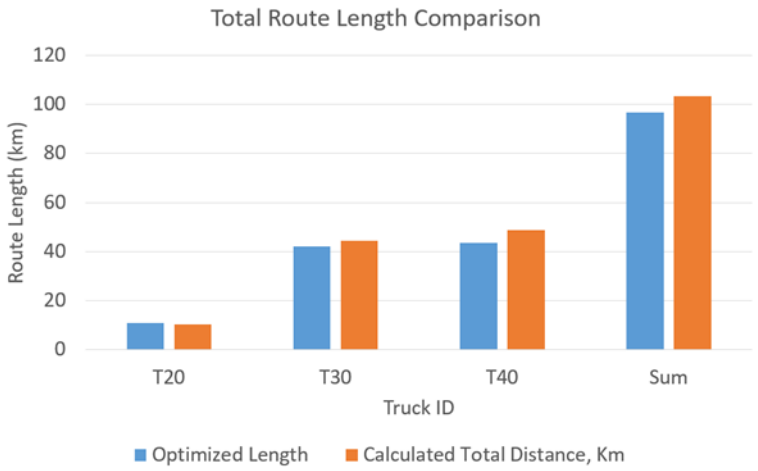

North Perth
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
Circuit Time (hours)
18
16
14
12
10
8
6
4
2
0
A/K
B
C
D
E
F
G
H
I
J
Route ID
Actual Circuit Time
MMS Circuit Time

**Town of St Marys**



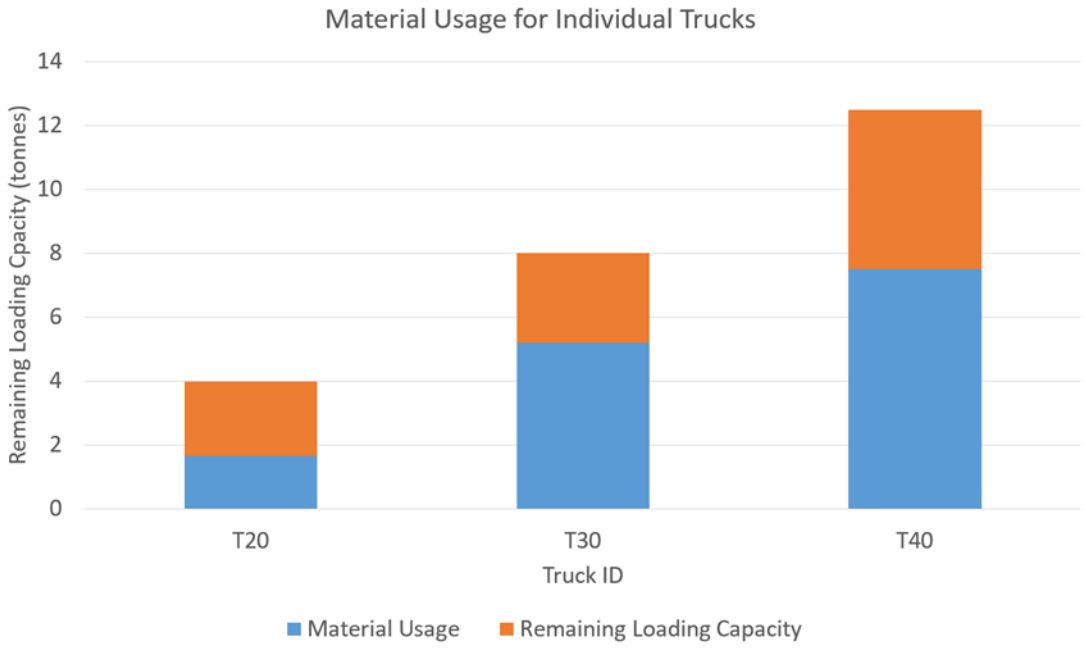
# Case 6: Town of St Marys- Total Operating Distance

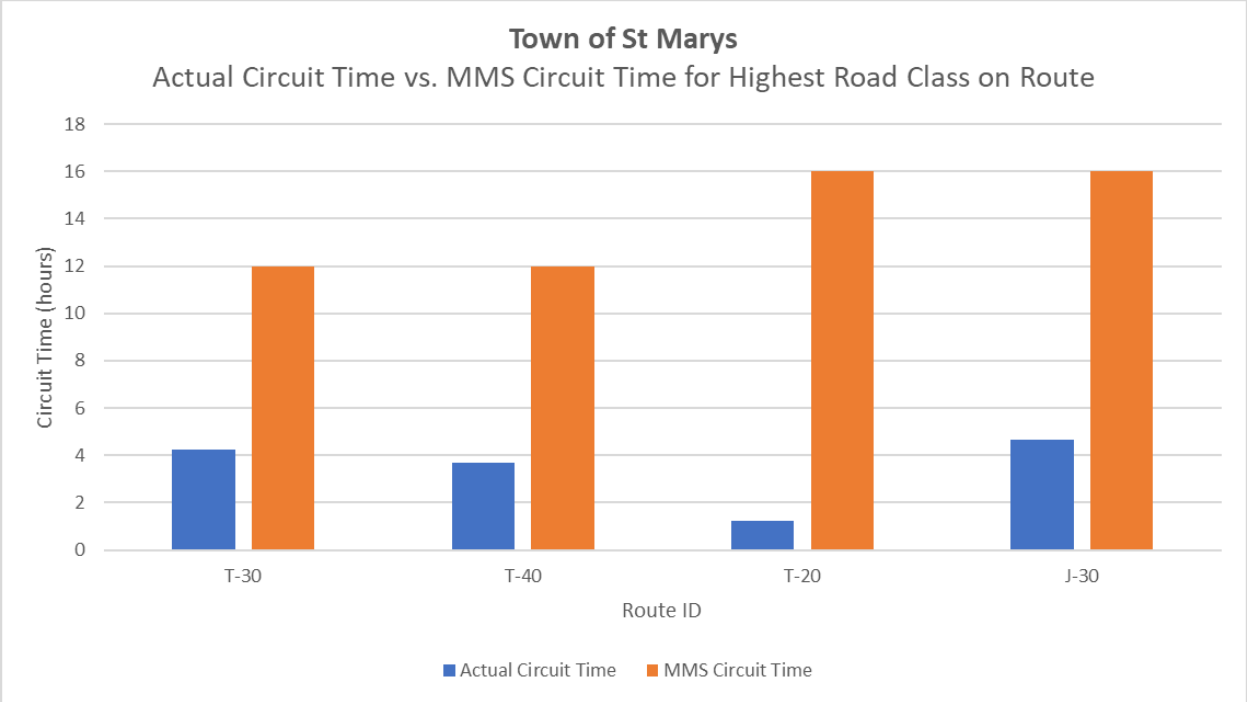



**3 combo unit (out of 4 trucks) are used in optimization process, Total Distance Reduction : 4.86%**

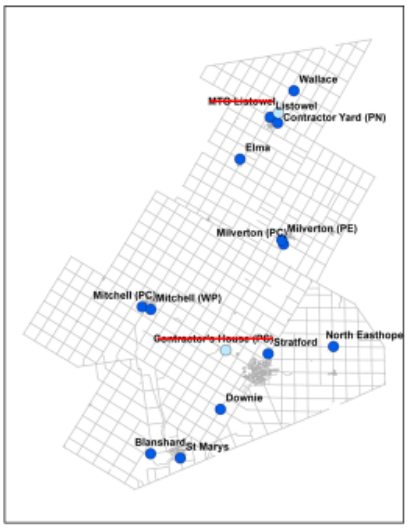
# Case 6: Town of St Marys-Material Usage

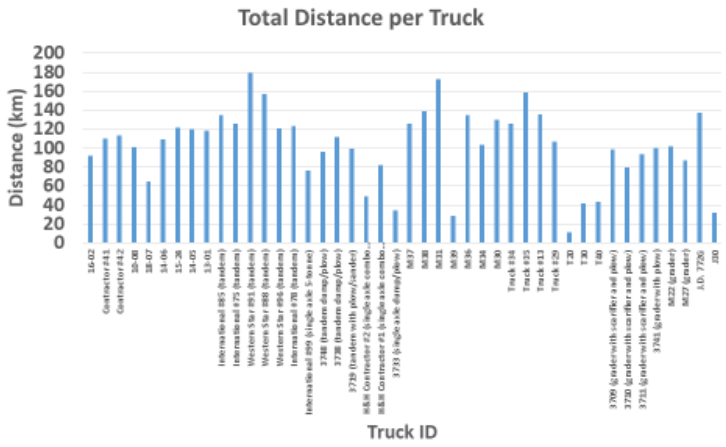



Town of St Marys
Actual Circuit Time vs. MMS Circuit Time for Highest Road Class on Route
Circuit Time (hours)
18
16
14
12
10
8
6
4
2
0
T-30
T-40
T-20
J-30
Route ID
Actual Circuit Time
MMS Circuit Time

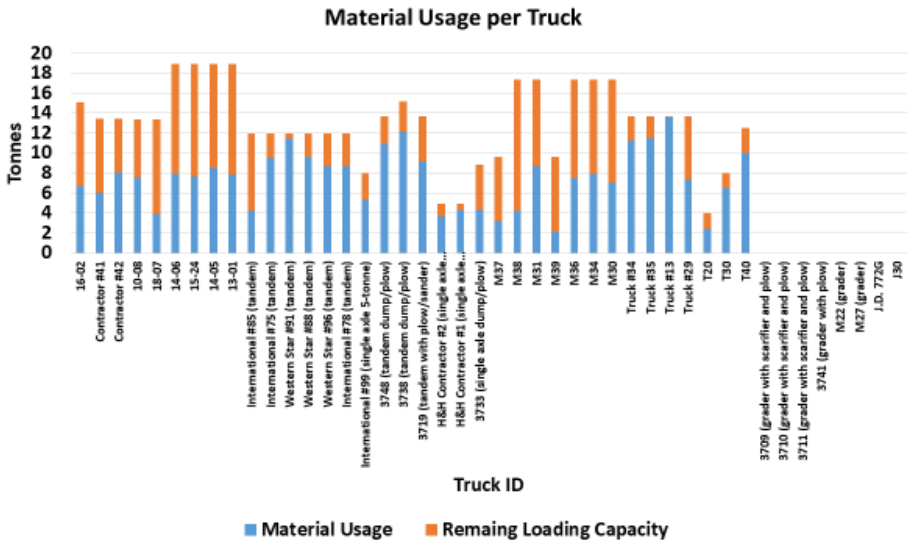
**Appendix E.3: Task 3 Network Integration By Functional Priority of Existing Yards**

## Case 1: 0 Depot Removal-Covered Distance

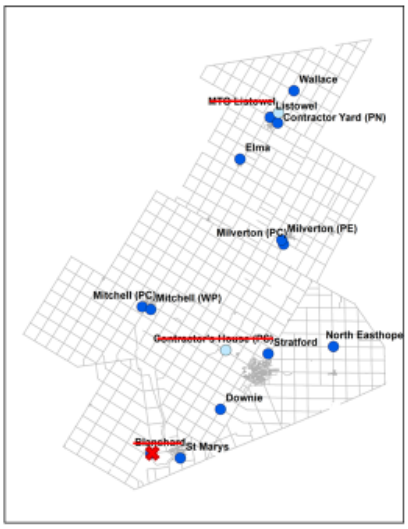


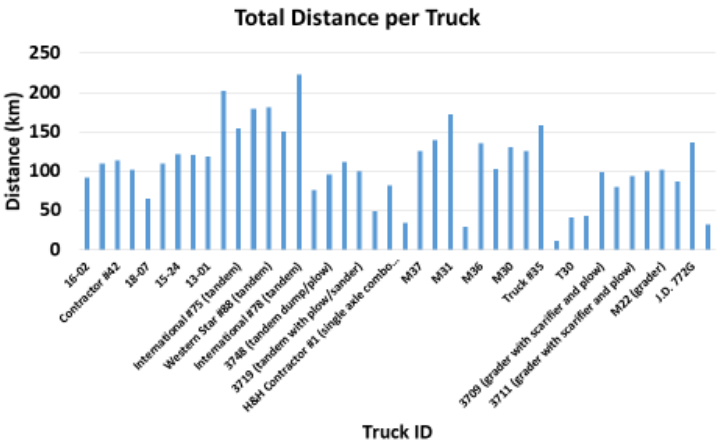




## Case 1: 0 Depot Removal-Material Usage

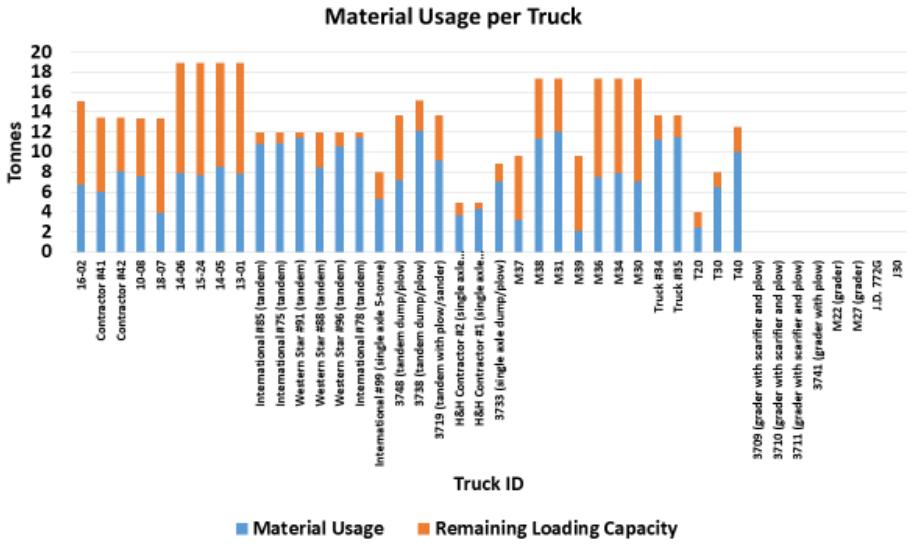


## Case 1: 1 Depot Removal-Covered Distance

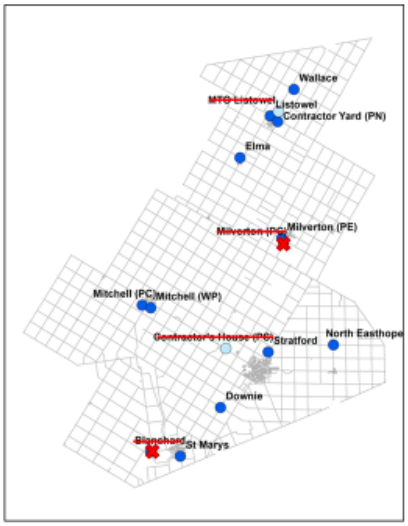


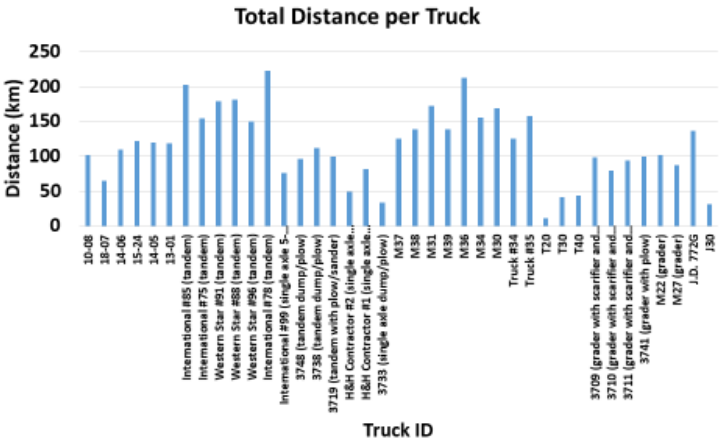




## Case 1: 1 Depot Removal-Material Usage

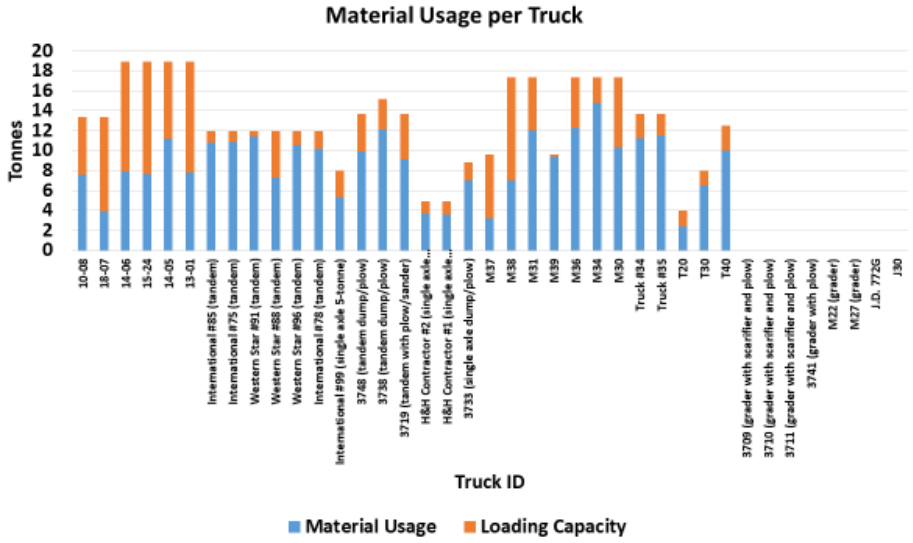


## Case 1: 2 Depots Removal-Covered Distance

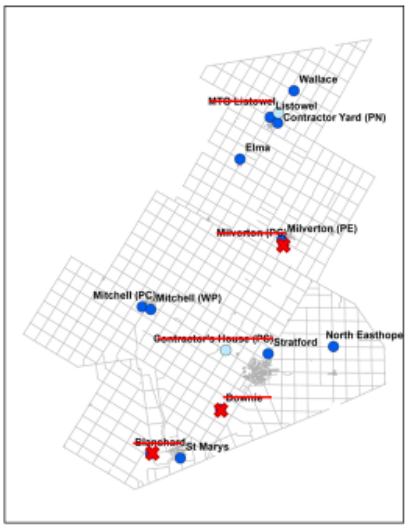


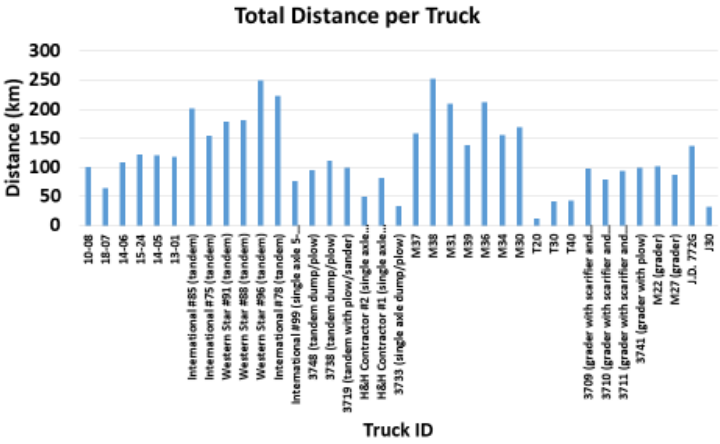




## Case 1: 2 Depots Removal-Material Usage

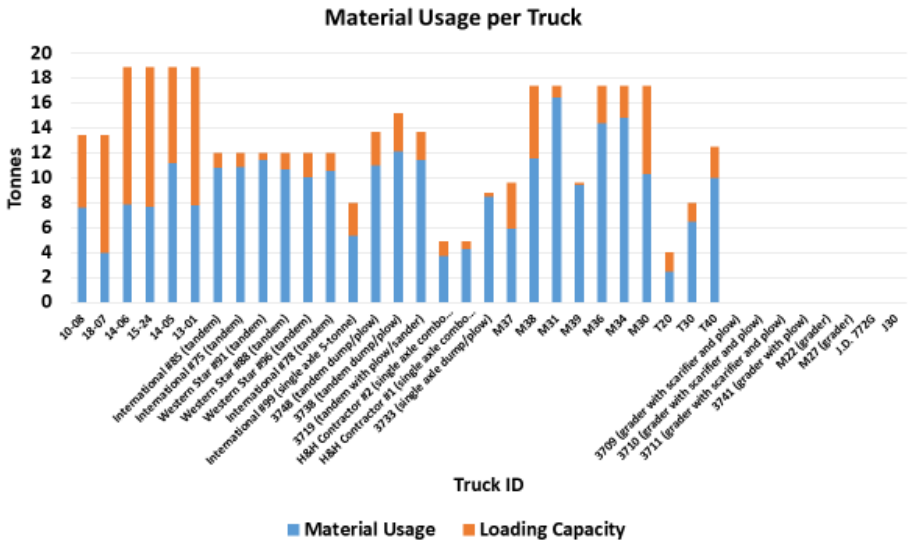


## Case 3: 3 Depots Removal-Covered Distance

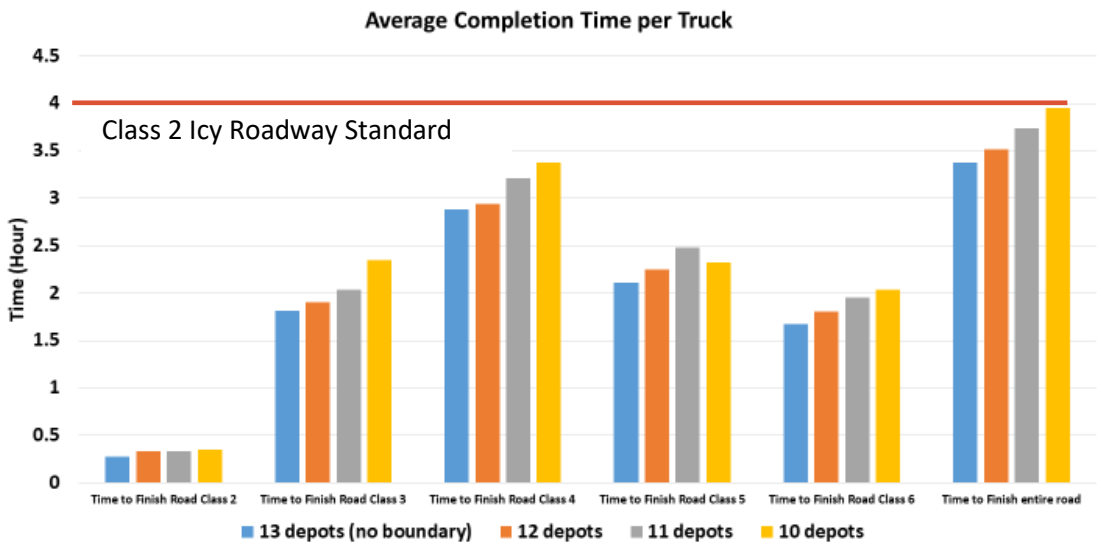


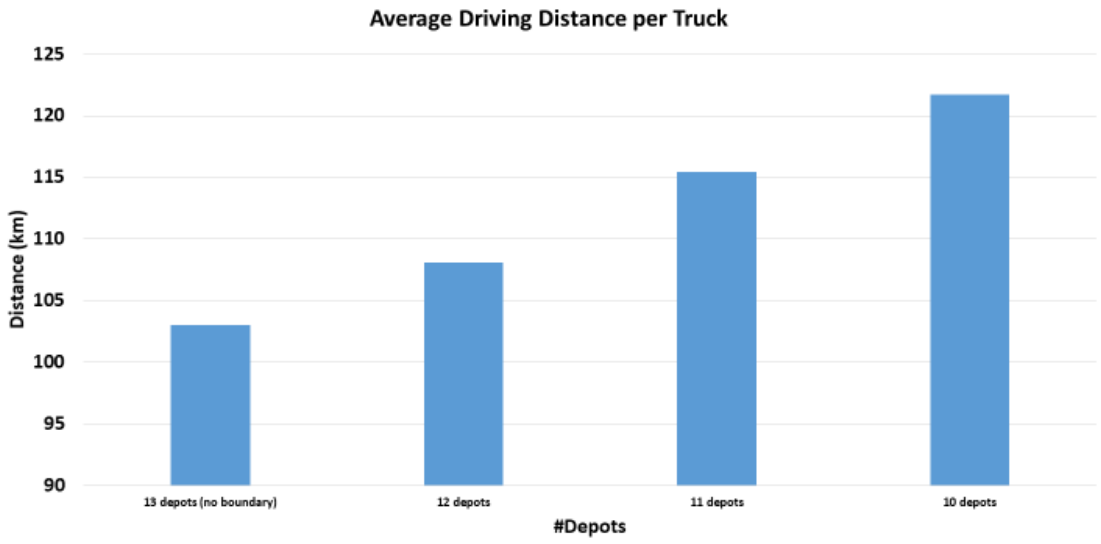

## Case 3: 3 Depot Removal-Material Usage



## Comparison-Average Road Class Finish Time




## Average Total Distance by Truck



## Appendix E.4: Optimized Route Maps for Task 2, 3, and 4

Provided electronically under separate cover.

## Appendix E.5: Network Integration Summary Data

### Task 2 (Existing Routes):

| Truck ID | Calculated Total Distance, Km | Total Service Time (Hour) | Route ID |
|---|---|---|---|
| 16-02 | 101.4531021 | 2.020880897 | #1 |
| Contractor #41 | 101.9758851 | 2.366854904 | #2 |
| Contractor #42 | 93.66893851 | 2.354363988 | #3 |
| 10-08 | 100.9700154 | 1.994166707 | #4 |
| 18-07 | 91.26435114 | 1.725699212 | #5 |
| 14-06 | 109.0620524 | 2.691004936 | #6 |
| 15-24 | 114.2897918 | 2.97599078 | #7 |
| 14-05 | 110.111923 | 2.79024547 | #8 |
| 13-01 | 122.1713538 | 2.728517769 | #9 |
| International #85 (tandem) | 137.5009659 | 3.596715199 | Fullarton South |
| International #75 (tandem) | 157.5196479 | 3.313065714 | Logan South |
| Western Star #91 (tandem) | 146.5957855 | 4.055790041 | Logan North |
| Western Star #88 (tandem) | 161.8175328 | 4.22657688 | Hibbert South |
| Western Star #96 (tandem) | 130.7722603 | 3.246875729 | Fullarton North |
| International #78 (tandem) | 121.698872 | 3.557410264 | Hibbert North |
| International #99 (single axle 5-tonne) | 84.0459147 | 8.954939439 | Mitchell Ward |
| 3733 (single axle dump/plow) | 37.54731634 | 7.401844512 | B |
| H&H Contractor #1 (single axle combo sander/plow) | 91.80753291 | 3.962981122 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | 53.060175 | 6.421622998 | C |
| 3719 (tandem with plow/sander) | 125.6642406 | 2.872110036 | G |
| 3738 (tandem dump/plow) | 96.98928743 | 2.644013201 | H |
| 3748 (tandem dump/plow) | 95.96652248 | 3.0773721 | I |
| M22 (grader) | 115.1076711 | 3.905808496 | 22 |
| M27 (grader) | 118.3032546 | 3.62602763 | 27 |
| M30 | 144.7430371 | 4.043501468 | 30 |
| M31 | 131.0973614 | 2.258454223 | 31 |
| M34 | 135.3287286 | 3.068986132 | 34 |
| M36 | 136.2719966 | 4.272812866 | 36 |
| M37 | 127.4000516 | 4.786000762 | 37 |
| Truck #34 | 132.728106 | 3.114002859 | PR1 |
| Truck #35 | 144.058603 | 3.605000878 | PR2 |
| Truck #13 | 112.7884953 | 3.411307137 | PR3 |
| Truck #29 | 148.0667749 | 2.6058512 | PR4 |
| T20 | 10.436 | 1.251486541 | T-20 |
| T30 | 44.286 | 4.25962024 | T-30 |
| T40 | 48.62 | 3.694785576 | T-40 |
| 3709 (grader with scarifier and plow) | 101.4333721 | 3.257185359 | D |
| 3710 (grader with scarifier and plow) | 90.43257601 | 3.364617147 | E |
| 3711 (grader with scarifier and plow) | 112.8163298 | 2.387952507 | F |
| 3741 (grader with plow) | 101.3596456 | 2.736689925 | J |
| M38 | 145.4240287 | 4.136448914 | 38 |
| M39 | 71.19549895 | 2.98641298 | 39 |
| J.D. 772G | 92.86273476 | 3.256096388 | Logan (Grader) |
| J30 | 31.87466512 | 4.661306724 | J-30 |

**Task 2 (Optimized Routes):**

| Truck ID | Route | Total Distance (Km) | Total Service Time (Hour) | Route ID |
|---|---|---|---|---|
| 16-02 | ['399', '44', | 88.52047737 | 1.962394004 | #1 |
| Contractor #41 | ['399', '44', | 101.9871424 | 2.298355078 | #2 |
| Contractor #42 | ['399', '306', | 100.97795 | 2.286225666 | #3 |
| 10-08 | ['210', '237', | 83.48931455 | 1.936452958 | #4 |
| 18-07 | ['210', '11', | 65.85012969 | 1.675755257 | #5 |
| 14-06 | ['126', '191', | 109.4090835 | 2.613123791 | #6 |
| 15-24 | ['124', '100', | 120.4670653 | 2.889861779 | #7 |
| 14-05 | ['124', '344', | 122.0836433 | 2.709492177 | #8 |
| 13-01 | ['124', '100', | 118.3792091 | 2.649550955 | #9 |
| International #85 (tandem) | ['136', '142', | 135.1592838 | 3.492621635 | Fullarton South |
| International #75 (tandem) | ['136', '137', | 126.1874329 | 3.21718133 | Logan South |
| Western Star #91 (tandem) | ['136', '137', | 155.283753 | 3.938410259 | Logan North |
| Western Star #88 (tandem) | ['136', '142', | 156.0961506 | 4.104254307 | Hibbert South |
| Western Star #96 (tandem) | ['136', '142', | 120.9786818 | 3.152906969 | Fullarton North |
| International #78 (tandem) | ['136', '142', | 123.5206157 | 3.454454235 | Hibbert North |
| International #99 (single axle 5-tonne) | ['136', '137', | 76.27411073 | 8.695771972 | Mitchell Ward |
| 3733 (single axle dump/plow) | ['280', '178', | 81.4892855 | 7.18762561 | B |
| H&H Contractor #1 (single axle combo sander/plow) | ['192', '345', | 33.78384511 | 3.84828735 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | ['192', '168', '5 | 49.24077397 | 6.235772967 | C |
| 3709 (grader with scarifier and plow) | ['167', '189', '1 | 100.8228921 | 2.788987477 | D |
| 3710 (grader with scarifier and plow) | ['167', '158', '1 | 90.53123684 | 2.567492057 | E |
| 3711 (grader with scarifier and plow) | ['167', '189', '1 | 110.7677896 | 2.988308993 | F |
| M22 (grader) | ['210', '219', '2 | 115.1076711 | 3.792769374 | 22 |
| M27 (grader) | ['210', '219', '1 | 118.3032546 | 3.521085726 | 27 |
| M30 | ['383', '1537', | 169.0735317 | 3.926477333 | 30 |
| M31 | ['806', '650', '1 | 99.58549915 | 2.193091652 | 31 |
| M34 | ['383', '2287', | 124.7985135 | 2.980165725 | 34 |
| M36 | ['383', '273', '7 | 132.6012914 | 4.149152165 | 36 |
| M37 | ['806', '463', '1 | 126.8429845 | 4.647487743 | 37 |
| Truck #34 | ['73', '74', ' | 126.1430421 | 3.02387961 | PR1 |
| Truck #35 | ['158', '123', | 158.0425923 | 3.500667515 | PR2 |
| Truck #13 | ['29', '1', '2 | 137.9257161 | 3.31257952 | PR3 |
| Truck #29 | ['29', '63', ' | 104.1765844 | 2.530434514 | PR4 |
| T20 | ['114', '147', '1 | 11.03888885 | 1.21526691 | T-20 |
| T30 | ['114', '147', '1 | 42.09024052 | 4.136341351 | T-30 |
| T40 | ['114', '164', '1 | 43.63561185 | 3.587853728 | T-40 |
| 3719 (tandem with plow/sander) | ['332', '327', | 123.802903 | 3.162918225 | G |
| 3738 (tandem dump/plow) | ['91', '56', ' | 123.3620399 | 3.267240799 | H |
| 3748 (tandem dump/plow) | ['91', '139', | 83.76722138 | 2.31884209 | I |
| 3741 (grader with plow) | ['100', '91', '97 | 101.3043619 | 2.657486598 | J |
| M38 | ['806', '1834', | 157.0900162 | 4.016734761 | 38 |
| M39 | ['383','437', '1 | 66.08563043 | 2.899982346 | 39 |
| J.D. 772G | ['293', '125', '1 | 79.11613989 | 3.16186077 | Logan (Grader) |
| J30 | ['79', '89', '16', | 31.87466512 | 4.526402511 | J-30 |

## Task 3 (No Boundaries):

| Truck ID | Route Sequer | Total Distance (Km) | Total Service Time (Hour) | Route ID |
|---|---|---|---|---|
| 16-02 | ['383', '2287', ' | 92.04117239 | 2.09893511 | #1 |
| Contractor #41 | ['383', '273', '1 | 109.8883946 | 2.731062331 | #2 |
| Contractor #42 | ['383', '437', '2 | 113.888469 | 2.988439143 | #3 |
| 10-08 | ['1697', '106', ' | 101.5457714 | 2.297582094 | #4 |
| 18-07 | ['1697', '94', '1 | 64.84453049 | 1.522875949 | #5 |
| 14-06 | ['396', '1976', ' | 109.4090836 | 2.639935839 | #6 |
| 15-24 | ['900', '1676', ' | 122.0836433 | 2.709492177 | #7 |
| 14-05 | ['900', '838', '1 | 120.4670653 | 2.9205714 | #8 |
| 13-01 | ['900', '838', '1 | 118.3792091 | 2.65255364 | #9 |
| International #85 (tandem) | ['1055', '2032', | 135.1592838 | 3.559288301 | Fullarton South |
| International #75 (tandem) | ['1055', '1803', | 126.1874329 | 3.201969975 | Logan South |
| Western Star #91 (tandem) | ['1055', '1803', | 179.4663822 | 4.214299944 | Logan North |
| Western Star #88 (tandem) | ['1055', '2032', | 156.9400017 | 4.103605778 | Hibbert South |
| Western Star #96 (tandem) | ['1055', '2032', | 120.9786818 | 3.149055922 | Fullarton North |
| International #78 (tandem) | ['1055', '2032', | 123.5206157 | 3.370262017 | Hibbert North |
| International #99 (single axle 5-tonne) | ['1055', '1803', | 76.27411073 | 7.944387546 | Mitchell Ward |
| 3733 (single axle dump/plow) | ['670', '945', '7 | 96.11168035 | 2.699064603 | B |
| H&H Contractor #1 (single axle combo sander/plow) | ['670', '429', '5 | 111.7125542 | 3.034251083 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | ['2469', '1815', | 99.52772062 | 2.72306209 | C |
| 3709 (grader with scarifier and plow) | ['2456', '270', ' | 49.65361941 | 5.572452591 | D |
| 3710 (grader with scarifier and plow) | ['2079', '1199', | 81.88822689 | 7.630199202 | E |
| 3711 (grader with scarifier and plow) | ['2079', '2456', | 34.06352561 | 3.85388096 | F |
| M22 (grader) | ['806', '463', '1 | 125.6085587 | 4.632057422 | 22 |
| M27 (grader) | ['806', '1834', ' | 139.2921798 | 3.586770822 | 27 |
| M30 | ['806', '650', '1 | 172.4230633 | 4.138936484 | 30 |
| M31 | ['383', '437', '1 | 29.03463161 | 2.216078626 | 31 |
| M34 | ['383', '2287', ' | 135.2942277 | 3.158575835 | 34 |
| M36 | ['383', '1537', ' | 103.288693 | 2.363396688 | 36 |
| M37 | ['383', '273', '7 | 130.3425857 | 3.787585011 | 37 |
| Truck #34 | ['97', '1000', '1 | 126.1430421 | 3.02387961 | PR1 |
| Truck #35 | ['97', '470', '17 | 158.447558 | 3.640750278 | PR2 |
| Truck #13 | ['138', '215', '2 | 135.3763084 | 3.190776451 | PR3 |
| Truck #29 | ['138', '1139', ' | 106.9590712 | 2.649317853 | PR4 |
| T20 | ['396', '1528', ' | 11.69066937 | 1.102152232 | T-20 |
| T30 | ['396', '1528', ' | 41.64865711 | 4.083534558 | T-30 |
| T40 | ['396', '1976', ' | 43.63561188 | 3.549671318 | T-40 |
| 3719 (tandem with plow/sander) | ['2469', '1815', | 98.65055798 | 2.752719145 | G |
| 3738 (tandem dump/plow) | ['2469', '2446', | 79.60717397 | 2.097396796 | H |
| 3748 (tandem dump/plow) | ['2469', '2446', | 93.91152134 | 2.517850295 | I |
| 3741 (grader with plow) | ['670', '429', '4 | 100.0474514 | 2.594854983 | J |
| M38 | ['383', '1537', ' | 101.8295835 | 3.260817186 | 38 |
| M39 | ['383', '2287', ' | 87.05916468 | 2.896080246 | 39 |
| J.D. 772G | ['1055', '2032', | 136.9949367 | 5.291153996 | Logan (Grader) |
| J30 | ['396', '1926', ' | 31.87466526 | 4.526402515 | J-30 |

**Task 3 (1 Depot Removal):**

| Truck ID | Route Seq | Total Distance (Km) | Total Service Time (Hour) | Route ID |
|---|---|---|---|---|
| 16-02 | ['383', '228 | 92.04117239 | 2.09893511 | #1 |
| Contractor #41 | ['383', '273 | 109.8883946 | 2.731062331 | #2 |
| Contractor #42 | ['383', '437 | 113.888469 | 2.988439143 | #3 |
| 10-08 | ['1697', '10 | 101.5457714 | 2.297582094 | #4 |
| 18-07 | ['1697', '94 | 64.84453049 | 1.522875949 | #5 |
| 14-06 | ['396', '197 | 109.4090836 | 2.639935839 | #6 |
| 15-24 | ['900', '167 | 122.0836433 | 2.709492177 | #7 |
| 14-05 | ['900', '838 | 120.4670653 | 2.9205714 | #8 |
| 13-01 | ['900', '838 | 118.3792091 | 2.65255364 | #9 |
| International #85 (tandem) | ['1055', '20 | 202.3628564 | 5.11203456 | Fullarton South |
| International #75 (tandem) | ['1055', '18 | 154.9479244 | 3.777179807 | Logan South |
| Western Star #91 (tandem) | ['1055', '18 | 179.4663822 | 4.214299944 | Logan North |
| Western Star #88 (tandem) | ['1055', '20 | 181.7398722 | 4.671557624 | Hibbert South |
| Western Star #96 (tandem) | ['1055', '20 | 150.1364738 | 3.869396143 | Fullarton North |
| International #78 (tandem) | ['1055', '20 | 222.683633 | 5.553522362 | Hibbert North |
| International #99 (single axle 5-tonne) | ['1055', '18 | 76.27411073 | 7.87772088 | Mitchell Ward |
| 3733 (single axle dump/plow) | ['670', '945 | 96.11168035 | 2.699064603 | B |
| H&H Contractor #1 (single axle combo sander/plow) | ['670', '429 | 111.7125542 | 3.034251083 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | ['2469', '18 | 99.52772062 | 2.72306209 | C |
| 3709 (grader with scarifier and plow) | ['2456', '27 | 49.65361941 | 5.639119258 | D |
| 3710 (grader with scarifier and plow) | ['2079', '11 | 81.88822689 | 7.363532535 | E |
| 3711 (grader with scarifier and plow) | ['2079', '24 | 34.06352561 | 3.587214294 | F |
| M22 (grader) | ['806', '463 | 125.6085587 | 4.632057422 | 22 |
| M27 (grader) | ['806', '183 | 139.2921798 | 3.586770822 | 27 |
| M30 | ['806', '650 | 172.4230633 | 4.138936484 | 30 |
| M31 | ['383', '437 | 29.03463161 | 2.216078626 | 31 |
| M34 | ['383', '228 | 135.2942277 | 3.158575835 | 34 |
| M36 | ['383', '153 | 103.288693 | 2.363396688 | 36 |
| M37 | ['383', '273 | 130.3425857 | 3.787585011 | 37 |
| Truck #13 | ['97', '1000 | 126.1430421 | 3.02387961 | PR3 |
| Truck #29 | ['97', '470', | 158.447558 | 3.640750278 | PR4 |
| T20 | ['396', '152 | 11.69066937 | 1.035485566 | T-20 |
| T30 | ['396', '152 | 41.64865711 | 4.083534558 | T-30 |
| T40 | ['396', '197 | 43.63561188 | 3.549671318 | T-40 |
| 3719 (tandem with plow/sander) | ['2469', '18 | 98.65055798 | 2.752719145 | G |
| 3738 (tandem dump/plow) | ['2469', '24 | 79.60717397 | 2.097396796 | H |
| 3748 (tandem dump/plow) | ['2469', '24 | 93.91152134 | 2.517850295 | I |
| 3741 (grader with plow) | ['670', '429 | 100.0474514 | 2.594854983 | J |
| M38 | ['383', '153 | 101.8295835 | 3.260817186 | 38 |
| M39 | ['383', '228 | 87.05916468 | 2.896080246 | 39 |
| J.D. 772G | ['1055', '20 | 136.9949367 | 5.291153996 | Logan (Grader) |
| J30 | ['396', '192 | 31.87466526 | 4.459735849 | J-30 |

**Task 3 (2 Depot Removal):**

| Truck ID | Route Seq | Total Distance (Km) | Total Service Time (Hour) | Route ID |
|---|---|---|---|---|
| 10-08 | ['1697', '10 | 101.5457714 | 2.297582094 | #4 |
| 18-07 | ['1697', '94 | 64.84453049 | 1.522875949 | #5 |
| 14-06 | ['396', '197 | 109.4090836 | 2.639935839 | #6 |
| 15-24 | ['900', '167 | 122.0836433 | 2.709492177 | #7 |
| 14-05 | ['900', '838 | 120.4670653 | 2.9205714 | #8 |
| 13-01 | ['900', '838 | 118.3792091 | 2.65255364 | #9 |
| International #85 (tandem) | ['1055', '20 | 202.3628564 | 5.11203456 | Fullarton South |
| International #75 (tandem) | ['1055', '18 | 154.9479244 | 3.777179807 | Logan South |
| Western Star #91 (tandem) | ['1055', '18 | 179.4663822 | 4.214299944 | Logan North |
| Western Star #88 (tandem) | ['1055', '20 | 181.7398722 | 4.671557624 | Hibbert South |
| Western Star #96 (tandem) | ['1055', '20 | 150.1364738 | 3.869396143 | Fullarton North |
| International #78 (tandem) | ['1055', '20 | 222.683633 | 5.553522362 | Hibbert North |
| International #99 (single axle 5-tonne) | ['1055', '18 | 76.27411073 | 7.944387546 | Mitchell Ward |
| 3733 (single axle dump/plow) | ['670', '945 | 96.11168035 | 2.699064603 | B |
| H&H Contractor #1 (single axle combo sander/plow) | ['670', '429 | 111.7125542 | 3.034251083 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | ['2469', '18 | 99.52772062 | 2.72306209 | C |
| 3709 (grader with scarifier and plow) | ['2456', '27 | 49.65361941 | 5.572452591 | D |
| 3710 (grader with scarifier and plow) | ['2079', '11 | 81.88822689 | 7.230199202 | E |
| 3711 (grader with scarifier and plow) | ['2079', '24 | 34.06352561 | 4.05388096 | F |
| M22 (grader) | ['806', '463 | 125.6085587 | 4.632057422 | 22 |
| M27 (grader) | ['806', '183 | 139.2921798 | 3.586770822 | 27 |
| M30 | ['806', '650 | 172.4230633 | 4.138936484 | 30 |
| M31 | ['383', '437 | 138.649136 | 4.376320366 | 31 |
| M34 | ['383', '228 | 212.9744919 | 4.922367553 | 34 |
| M36 | ['383', '153 | 155.8704522 | 4.254967925 | 36 |
| M37 | ['383', '228 | 169.4772843 | 3.482376819 | 37 |
| Truck #13 | ['97', '1000 | 126.1430421 | 3.02387961 | PR3 |
| Truck #29 | ['97', '470', | 158.447558 | 3.640750278 | PR4 |
| T20 | ['396', '152 | 11.69066937 | 1.035485566 | T-20 |
| T30 | ['396', '152 | 41.64865711 | 4.083534558 | T-30 |
| T40 | ['396', '197 | 43.63561188 | 3.549671318 | T-40 |
| 3719 (tandem with plow/sander) | ['2469', '18 | 98.65055798 | 2.752719145 | G |
| 3738 (tandem dump/plow) | ['2469', '24 | 79.60717397 | 2.097396796 | H |
| 3748 (tandem dump/plow) | ['2469', '24 | 93.91152134 | 2.517850295 | I |
| 3741 (grader with plow) | ['670', '429 | 100.0474514 | 2.594854983 | J |
| M38 | ['383', '153 | 101.8295835 | 3.260817186 | 38 |
| M39 | ['383', '228 | 87.05916468 | 2.896080246 | 39 |
| J.D. 772G | ['1055', '20 | 136.9949367 | 5.291153996 | Logan (Grader) |
| J30 | ['396', '192 | 31.87466526 | 4.459735849 | J-30 |

**Task 3 (3 Depot Removal):**

| Truck ID | Route Seq | Total Distance (Km) | Total Service Time (Hour) | Route ID |
|---|---|---|---|---|
| 10-08 | ['1697', '10 | 101.5457714 | 2.297582094 | #4 |
| 18-07 | ['1697', '94 | 64.84453049 | 1.522875949 | #5 |
| 14-06 | ['396', '197 | 109.4090836 | 2.639935839 | #6 |
| 15-24 | ['900', '167 | 122.0836433 | 2.709492177 | #7 |
| 14-05 | ['900', '838 | 120.4670653 | 2.9205714 | #8 |
| 13-01 | ['900', '838 | 118.3792091 | 2.65255364 | #9 |
| International #85 (tandem) | ['1055', '20 | 202.3628564 | 5.11203456 | Fullarton South |
| International #75 (tandem) | ['1055', '18 | 154.9479244 | 3.777179807 | Logan South |
| Western Star #91 (tandem) | ['1055', '18 | 179.4663822 | 4.214299944 | Logan North |
| Western Star #88 (tandem) | ['1055', '20 | 181.7398722 | 4.671557624 | Hibbert South |
| Western Star #96 (tandem) | ['1055', '20 | 250.7186417 | 6.611529942 | Fullarton North |
| International #78 (tandem) | ['1055', '20 | 222.683633 | 5.553522362 | Hibbert North |
| International #99 (single axle 5-tonne) | ['1055', '18 | 76.27411073 | 7.87772088 | Mitchell Ward |
| 3733 (single axle dump/plow) | ['670', '945 | 96.11168035 | 2.699064603 | B |
| H&H Contractor #1 (single axle combo sander/plow) | ['670', '429 | 111.7125542 | 3.034251083 | A, K |
| H&H Contractor #2 (single axle combo sander/plow) | ['2469', '18 | 99.52772062 | 2.72306209 | C |
| 3709 (grader with scarifier and plow) | ['2456', '27 | 49.65361941 | 5.639119258 | D |
| 3710 (grader with scarifier and plow) | ['2079', '11 | 81.88822689 | 7.563532535 | E |
| 3711 (grader with scarifier and plow) | ['2079', '24 | 34.06352561 | 3.65388096 | F |
| M22 (grader) | ['806', '463 | 158.5591805 | 5.297225742 | 22 |
| M27 (grader) | ['806', '183 | 253.2762416 | 6.419838518 | 27 |
| M30 | ['806', '650 | 209.4102245 | 5.153222535 | 30 |
| M31 | ['383', '437 | 138.649136 | 4.376320366 | 31 |
| M34 | ['383', '228 | 212.9744919 | 4.922367553 | 34 |
| M36 | ['383', '153 | 155.8704522 | 4.254967925 | 36 |
| M37 | ['383', '228 | 169.4772843 | 3.482376819 | 37 |
| T20 | ['396', '152 | 11.69066937 | 1.035485566 | T-20 |
| T30 | ['396', '152 | 41.64865711 | 4.083534558 | T-30 |
| T40 | ['396', '197 | 43.63561188 | 3.549671318 | T-40 |
| 3719 (tandem with plow/sander) | ['2469', '18 | 98.65055798 | 2.752719145 | G |
| 3738 (tandem dump/plow) | ['2469', '24 | 79.60717397 | 2.097396796 | H |
| 3748 (tandem dump/plow) | ['2469', '24 | 93.91152134 | 2.517850295 | I |
| 3741 (grader with plow) | ['670', '429 | 100.0474514 | 2.594854983 | J |
| M38 | ['383', '153 | 101.8295835 | 3.260817186 | 38 |
| M39 | ['383', '228 | 87.05916468 | 2.896080246 | 39 |
| J.D. 772G | ['1055', '20 | 136.9949367 | 5.291153996 | Logan (Grader) |
| J30 | ['396', '192 | 31.87466526 | 4.459735849 | J-30 |

**Task 4:**

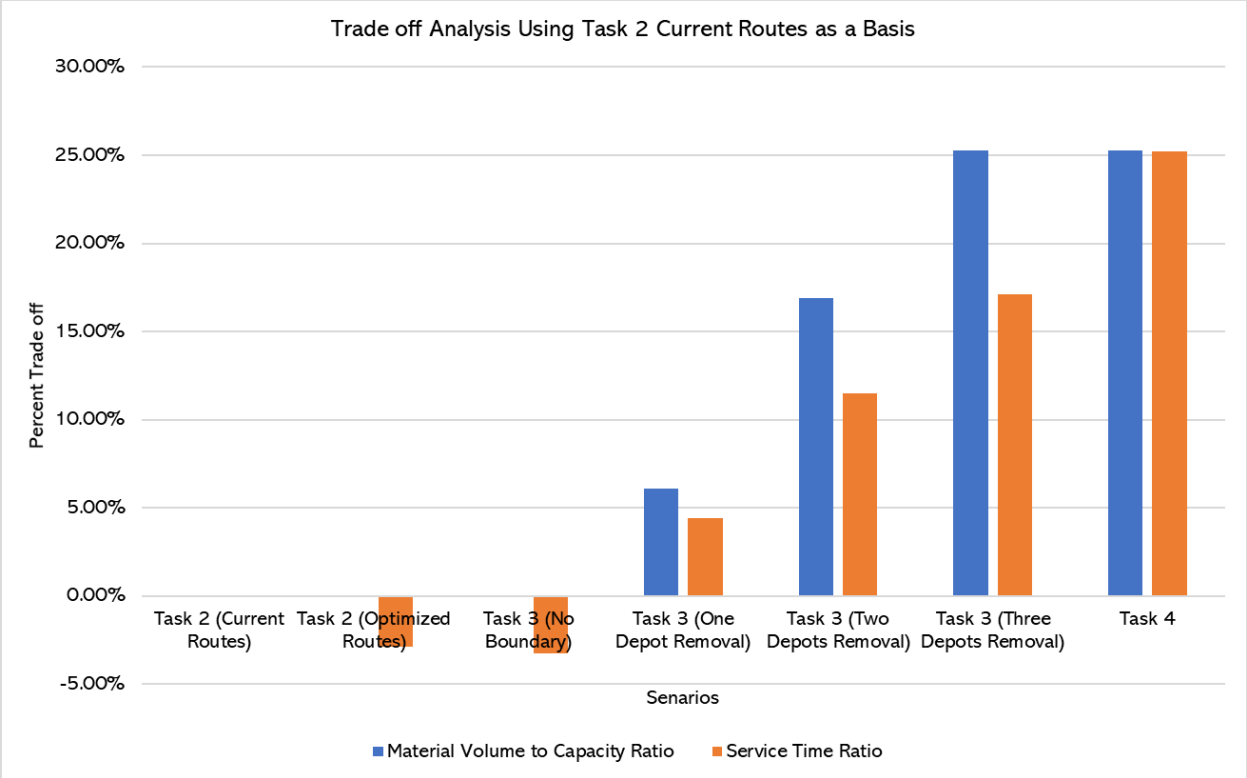
| Truck Type | Route Seq | Total Distance (Km) | Total Service Time (Hour) |
|---|---|---|---|
| Single_Sand | ['1170', '2', | 57.61255603 | 7.740027281 |
| Single_Sand | ['1170', '52 | 61.25340907 | 6.798867223 |
| Single_Sand | ['1170', '52 | 55.49356453 | 3.148168069 |
| Single_Sand | ['2092', '19 | 25.16043156 | 2.292667991 |
| Single_Sand | ['2092', '19 | 37.68662528 | 3.645933278 |
| Grader | ['1170', '52 | 108.2657813 | 2.814545401 |
| Grader | ['26', '1563 | 81.68069729 | 2.202861028 |
| Grader | ['26', '1001 | 117.491948 | 3.007086578 |
| Grader | ['1257', '23 | 167.8646304 | 4.420331885 |
| Grader | ['2092', '19 | 17.13658417 | 2.116447003 |
| Grader | ['2092', '19 | 19.64196562 | 2.02801718 |
| Grader | ['26', '1678 | 108.855122 | 3.101680393 |
| Grader | ['26', '1001 | 142.1287967 | 3.901228942 |
| Single_Salt | ['1257', '23 | 90.37556418 | 8.337484961 |
| Tandem_Salt | ['1170', '59 | 203.7696588 | 5.675393175 |
| Tandem_Salt | ['1170', '52 | 106.7686253 | 2.679982048 |
| Tandem_Salt | ['1257', '16 | 200.6320371 | 4.923836199 |
| Tandem_Salt | ['1257', '17 | 143.78354 | 4.171367465 |
| Tandem_Salt | ['1824', '24 | 183.6644965 | 4.851856489 |
| Tandem_Salt | ['1824', '44 | 176.4074373 | 4.763288098 |
| Tandem_Salt | ['1824', '22 | 216.5942708 | 5.637202476 |
| Tandem_Salt | ['2092', '19 | 121.8770958 | 5.086363689 |
| Tandem_Salt | ['2092', '22 | 232.8078436 | 6.490749762 |
| Tandem_Salt | ['1824', '44 | 106.6418792 | 2.569067534 |
| Tandem_Salt | ['26', '1871 | 245.4635026 | 7.327529606 |
| Tandem_Salt | ['1697', '10 | 222.0698187 | 6.61029857 |
| Tri_Salt | ['1824', '44 | 102.993726 | 2.325975321 |
| Tri_Salt | ['1824', '15 | 69.22551026 | 1.814384063 |
| Tri_Salt | ['2092', '13 | 113.0892019 | 2.718858587 |
| Tri_Salt | ['2092', '10 | 132.1319815 | 3.217546401 |
| Tri_Salt | ['1697', '94 | 112.3452295 | 2.547185279 |
| Tri_Salt | ['1697', '10 | 101.5457714 | 2.269935548 |
| Tri_Sand | ['26', '1871 | 99.25728653 | 3.077860923 |
| Tri_Sand | ['26', '1678 | 115.3255041 | 2.18538434 |
| Tri_Sand | ['1697', '10 | 159.0516565 | 3.773959003 |
| Tri_Sand | ['1697', '10 | 186.0310989 | 4.201566398 |
| Tri_Sand | ['1697', '10 | 145.7591936 | 3.641745692 |

**Service Level Ratios and Trade Off Analysis**

Note: Minus means reduction in service time (i.e. increase in level of service); Plus means increase in service time (i.e. decrease in level of service)

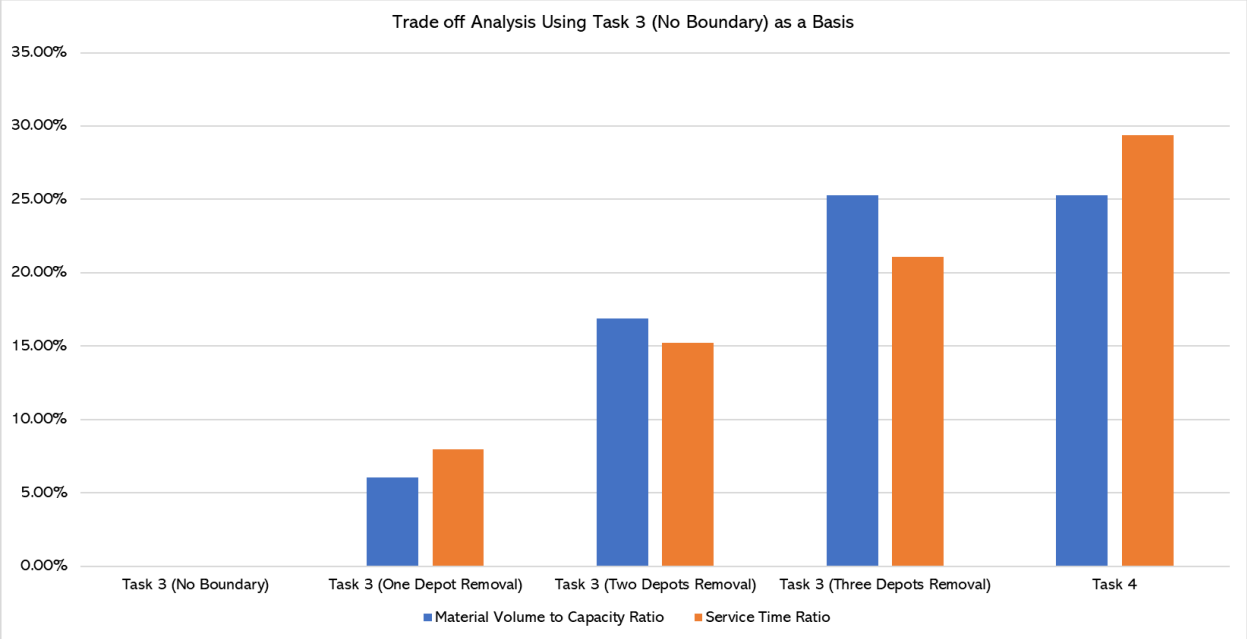
**Using Task 2 (Current Routes) as a Basis**

| | | Material Volume to Capacity Ratio | Service Time Ratio |
|---|---|---|---|
| **Base Cases** | Task 2 (Current Routes) | 0.00% | 0.00% |
| | Task 2 (Optimized Routes) | 0.00% | -2.89% |
| | Task 3 (No Boundary) | 0.00% | -3.24% |
| | Task 3 (One Depot Removal) | 6.07% | 4.44% |
| | Task 3 (Two Depots Removal) | 16.89% | 11.48% |
| | Task 3 (Three Depots Removal) | 25.28% | 17.14% |
| | Task 4 | 25.28% | 25.19% |



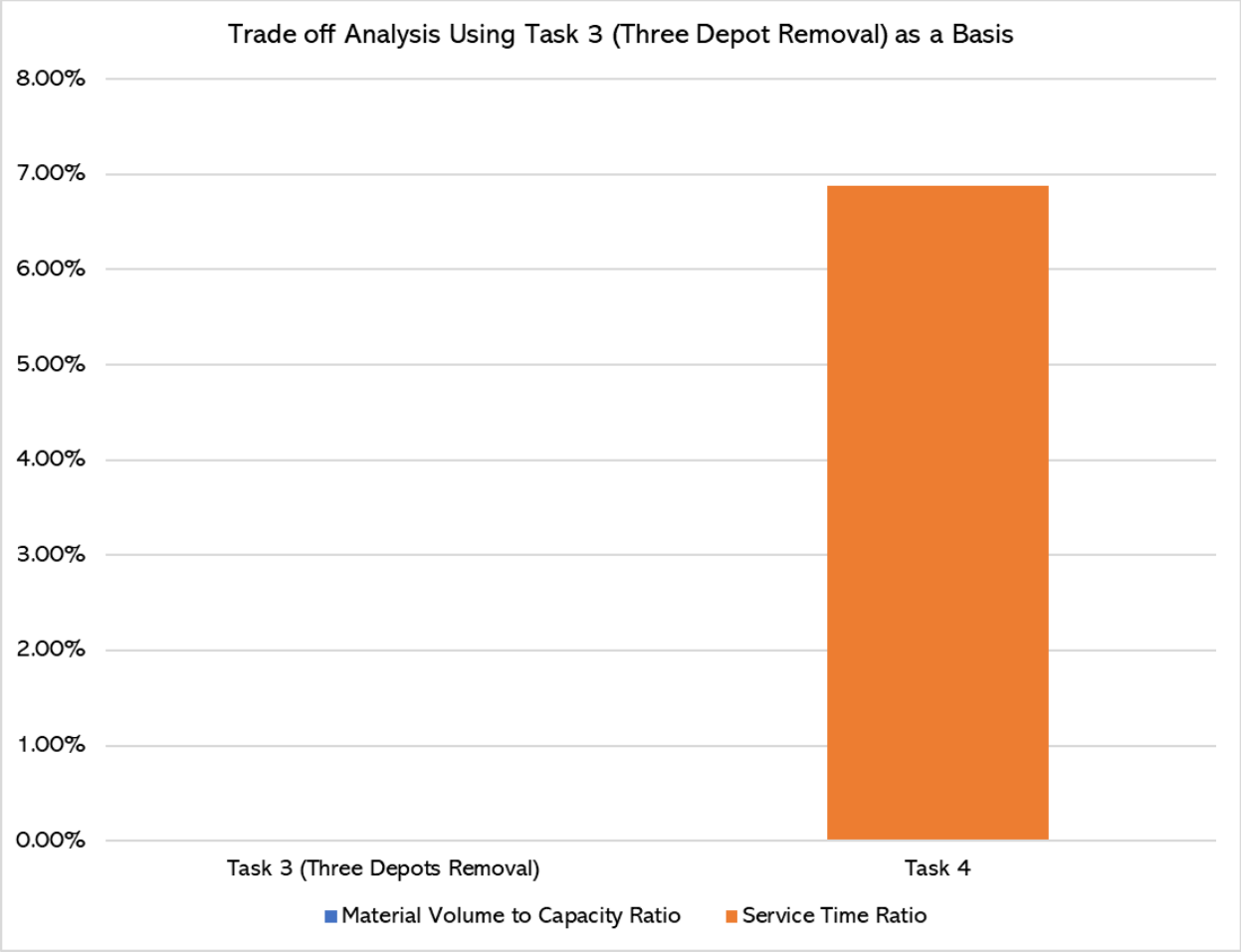
**Using Task 3 (No Boundaries) as a Basis**

| | | Material Volume to Capacity Ratio | Service Time Ratio |
|---|---|---|---|
| **Base Case** | Task 3 (No Boundary) | 0.00% | 0.00% |
| | Task 3 (One Depot Removal) | 6.07% | 7.94% |
| | Task 3 (Two Depots Removal) | 16.89% | 15.22% |
| | Task 3 (Three Depots Removal) | 25.28% | 21.07% |
| | Task 4 | 25.28% | 29.39% |



**Using Task 3 (3 Depot Removal) as Basis**

| | | Material Volume to Capacity Ratio | Service Time Ratio |
|---|---|---|---|
| **Base Case** | Task 3 (Three Depots Removal) | 0.00% | 0.00% |
| | Task 4 | 0.00% | 6.88% |



F

# Appendix F: Animated Map Visualizations of Plow Routes

**Appendix F: Animated Map Visualizations of Plow Routes**

Provided electronically under separate cover.

G

# Appendix G: RWIS Sharing Agreement

**Appendix G: RWIS Sharing Agreement**

## ONTARIO GOOD ROADS ASSOCIATION

## Agreement to Share MTO RWIS Information

**Between:**

**Ontario Good Roads Association [hereinafter referred to as OGRA]**

**And**

**[*Name of Municipality*] [hereinafter referred to as Municipality]**

The Ontario Ministry of Transportation (MTO) wishes to provide municipalities with access to its Road Weather Information System (RWIS) network including data collection, weather and pavement temperature forecasting, data archiving, and web-display services.
MTO and OGRA have entered into an agreement under which OGRA will administer the Municipality's access to MTO's RWIS network.

The purpose of this Agreement is to document the conditions under which OGRA will share access to MTO's Road Weather Information System (RWIS) data with the Municipality. Access to the following aspects of RWIS will be provided:

- observed data
- forecast data: road and atmospheric
- archived data (required for system maintenance contractors, not for general distribution)
- the on-line web-forum on the ARWIS web site.

The Municipality agrees to the following:

1. It is hereby agreed that the data produced by MTO remains the property of MTO. Use of MTO's data for any purposes other than road maintenance will only be by prior written agreement between the Municipality and MTO. This sharing of MTO's data is for road maintenance purposes only, and must not be reproduced or redistributed to any other parties. MTO disclaims all warranties relating to its data, whether express or implied, including without limitation any implied warranties of fitness for a particular purpose. MTO's data is provided as a service and convenience to the Municipality, and MTO does not guarantee the accuracy of its data or that it will be available at any given time during the term of this agreement. The Municipality bears all risk as to the use and application of the data. MTO will not be liable for any damages, howsoever caused, due to the use or misuse of its data.

2. User names and passwords to access MTO's RWIS network will be issued to employees of the Municipality who have completed the Ontario Version of the Anti-Icing/RWIS computer based training program, or an equivalent training program. Proof of training will be required.

3. A one-time activation fee of $100 will be charged for each password. There is no additional fee to change a password.

4. Password account usage will be reviewed annually. Accounts not accessed within the last twelve months will be terminated. Municipalities will need to re-apply to re-instate an account that has been terminated and the municipality will have to pay for the activation fee again.

5. Employees applying for passwords will be bound by all of the conditions of this agreement.

| Name of Head of Public Works | Signature | Date |
|---|---|---|

H

# Appendix H: Staged Implementation of Pre-Treated and Pre-Wet Salt Cost Estimates

# Appendix H: Pre-Treated and Pre-Wet Salt Staged Implementation Cost Estimates

## Perth County Material Costs

| Material Costs (provided by John McClelland) | | |
|---|---|---|
| Conventional Rock Salt | $85 | per tonne |
| Thawrox | $107 | per tonne |
| Sand | $15.00 | per tonne |
| Liquid (applied at 5% by mass) | $0.25 | per litre |

## Phase 1: Transition of all current rock salt procurement to pre-treated salt (pre-wet implementation is maintained at existing level)

| Agency Name | Annual Tonnes of Untreated Salt Purchased or Used | Annual Tonnes of Treated Salt Purchased or Used (30% less than existing annual untreated salt usage for everyone but PC) | Annual Tonnes of Sand Purchased or Used | Annual Litres of Winter Liquids Purchased or Used | Total Cost of Untreated Salt | Total Cost of Treated Salt | Total Cost of Sand | Total Cost of Winter Liquids | Total Future Cost |
|---|---|---|---|---|---|---|---|---|---|
| Perth County | 7570 | 4075 | 6096 | 247,193 | $643,450 | $436,025 | $91,440 | $61,798 | $1,232,713 |
| Town of St Marys | 0 | 1023 | 2560 | 0 | $0 | $109,484 | $38,400 | $0 | $147,884 |
| Perth East | 0 | 1243 | 1000 | 0 | $0 | $132,948 | $15,000 | $0 | $147,948 |
| Perth South | 0 | 245 | 2500 | 0 | $0 | $26,215 | $37,500 | $0 | $63,715 |
| West Perth | 0 | 750 | 1270 | 0 | $0 | $80,198 | $19,050 | $0 | $99,248 |
| North Perth | 0 | 1262 | 2500 | 0 | $0 | $135,045 | $37,500 | $0 | $172,545 |
| | | | | | | | | **TOTAL** | **$1,864,052** |

## Phase 2: 30% increase in pre-wetting and equivalent reduction to pre-treating

| Agency Name | Annual Tonnes of Untreated Salt Purchased or Used (existing value) | Annual Tonnes of Treated Salt Purchased or Used (existing value) | Annual Tonnes of Sand Purchased or Used | Annual Litres of Winter Liquids Purchased or Used | Total Cost of Untreated Salt | Total Cost of Treated Salt | Total Cost of Sand | Total Cost of Winter Liquids | Total Future Cost (materials only) |
|---|---|---|---|---|---|---|---|---|---|
| Perth County | 7570 | 4075 | 6096 | 247,193 | $643,450 | $436,025 | $91,440 | $61,798 | $1,232,713 |
| **Agency Name** | **Annual Tonnes of Untreated Salt to be Used (50% each)** | **Annual Tonnes of Treated Salt/Untreated Salt to be Pre-Wet (30% less than existing annual untreated)** | **Annual Tonnes of Sand Purchased or Used** | **Annual Litres of Winter Liquids to be Purchased or Used** | **Total Cost of Untreated Salt** | **Total Cost of Treated Salt** | **Total Cost of Sand** | **Total Cost of Winter Liquids** | **Total Future Cost (materials only)** |
| St M, PE, PS, WP, NP (Thawrox) | 3230 | 2261 | 9830 | 0 | $0 | $241,945 | $147,450 | $0 | $389,395 |
| St M, PE, PS, WP, NP (Pre-Wet) | 3230 | 2261 | 0 | 79141 | $192,199 | $0 | $0 | $19,785 | $211,984 |
| *to determine the litres of winter liquids used, reduced annual tonnes of untreated salt by 30% because it is being pre-wet. Converted mass in tonnes to kg by multiplying by 1000 and multipled this value by 0.7 due to specific gravity of winter liquid being approximately 1.3 (i.e. 1 L of liquid to 1.3 kg of salt). Lastly, multiplied by 5% (becasue liquid applied to salt at a rate of 5% by mass) | | | | | | | **TOTAL (MATERIALS ONLY)** | | **$1,834,092** |
| **Agency Name** | **Number of combination trucks/spreaders without pre-wet capabilities (50% to be equipped)** | **Cost to equip trucks with pre-wetting (including any spares)** | **Number of yards supplying material without liquid storage (50% to be equipped)** | **Cost to equip yards for pre-wetting (i.e. storage tanks and related equipment)** | **Added Equipment Cost (total)** | **Added Equipment Cost (am. 10 years at 4%)** | | | **Added Equipment Cost (am. 10 years at 4%)** |
| St M, PE, PS, WP, NP (Pre-Wet) | 15 | $290,000 | 4 | $70,000 | $360,000 | $43,738 | | | $43,738 |
| | | | | | | | | **TOTAL** | **$1,877,830** |

## Phase 3: Transition to 95% pre-wetting and reduction in pre-treating

| Agency Name | Annual Tonnes of Untreated Salt Purchased or Used | Annual Tonnes of Treated Salt Purchased or Used | Annual Tonnes of Sand Purchased or Used | Annual Litres of Winter Liquids to be Purchased or Used | Total Cost of Untreated Salt | Total Cost of Treated Salt | Total Cost of Sand | Total Cost of Winter Liquids | Total Future Cost (materials only) |
|---|---|---|---|---|---|---|---|---|---|
| Perth County | 9374 | 0 | 6096 | 389,818 | $796,790 | $0 | $91,440 | $97,455 | $985,685 |
| **Agency Name** | **Annual Tonnes of Untreated Salt to be Used (80% pre-wet, 20% thawrox)** | **Annual Tonnes of Treated Salt/Salt to be Pre-Wet (30% less than existing annual untreated)** | **Annual Tonnes of Sand Purchased or Used** | **Annual Litres of Winter Liquids to be Purchased or Used** | **Total Cost of Untreated Salt** | **Total Cost of Treated Salt** | **Total Cost of Sand** | **Total Cost of Winter Liquids** | **Total Future Cost (materials only)** |
| St M, PE, PS, WP, NP (Thawrox) | 1292 | 904 | 9830 | 0 | $0 | $96,778 | $147,450 | $0 | $244,228 |
| St M, PE, PS, WP, NP (Pre-Wet) | 5168 | 3618 | 0 | 126625 | $307,518 | $0 | $0 | $31,656 | $339,175 |
| *to determine the litres of winter liquids used, reduced annual tonnes of untreated salt by 30% because it is being pre-wet. Converted mass in tonnes to kg by multiplying by 1000 and multipled this value by 0.7 due to specific gravity of winter liquid being approximately 1.3 (i.e. 1 L of liquid to 1.3 kg of salt). Lastly, multiplied by 5% (becasue liquid applied to salt at a rate of 5% by mass) | | | | | | | **TOTAL (MATERIALS ONLY)** | | **$1,569,087** |
| **Agency Name** | **Number of combination trucks/spreaders without pre-wet capabilities (80% to be equipped)** | **Cost to equip trucks with pre-wetting (including any spares)** | **Number of yards supplying material without liquid storage (80% to be equipped)** | **Cost to equip yards for pre-wetting (i.e. storage tanks and related equipment)** | **Added Equipment Cost (total)** | **Added Equipment Cost (am. 10 years at 4%)** | | | **Added Equipment Cost (am. 10 years at 4%)** |
| All Agencies (Pre-Wet) | 26 | $512,000 | 6 | $112,000 | $624,000 | $75,812 | | | $75,812 |
| | | | | | | | | **TOTAL** | **$1,644,899** |

# Appendix I: Network-Wide Fleet, Material, and Yard Cost Estimates

## Appendix I: Network-Wide Fleet, Material, and Yard Cost Estimates

The yard and fleet rental rates used for the following cost estimates were included previously in Appendix C.

### Annual Fleet and Labour Costs (Task 2, Current Routes):

| Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Single Axle | 1 | 68 | 91.81 | 4.0 | 1 | 5 | 337 | 179 | 516 | 40 | 20646 |
| Single Axle | 1 | 68 | 37.55 | 7.4 | 1 | 8 | 571 | 302 | 874 | 40 | 34952 |
| Single Axle | 1 | 68 | 53.06 | 6.4 | 1 | 7 | 505 | 267 | 772 | 40 | 30874 |
| Grader | N/A | 68 | 101.43 | 3.3 | 1 | 4 | 289 | 153 | 443 | 40 | 0 |
| Grader | N/A | 68 | 90.43 | 3.4 | 1 | 4 | 297 | 157 | 454 | 40 | 0 |
| Grader | N/A | 68 | 112.82 | 2.4 | 1 | 3 | 230 | 122 | 352 | 40 | 0 |
| Tandem | 2 | 110 | 125.66 | 2.9 | 1 | 4 | 426 | 139 | 565 | 40 | 22613 |
| Tandem | 2 | 110 | 96.99 | 2.6 | 1 | 4 | 401 | 131 | 532 | 40 | 21281 |
| Tandem | 2 | 110 | 95.97 | 3.1 | 1 | 4 | 449 | 147 | 595 | 40 | 23812 |
| Grader | N/A | 68 | 101.36 | 2.7 | 1 | 4 | 254 | 135 | 389 | 40 | 0 |
| Tandem | 2 | 110 | 101.45 | 2.0 | 1 | 3 | 332 | 109 | 441 | 110 | 48515 |
| Tandem | 2 | 110 | 101.98 | 2.4 | 1 | 3 | 370 | 121 | 492 | 110 | 54072 |
| Tandem | 2 | 110 | 93.67 | 2.4 | 1 | 3 | 369 | 121 | 490 | 110 | 53871 |
| Tri Axle | 3 | 115 | 100.97 | 2.0 | 1 | 3 | 344 | 108 | 452 | 110 | 49733 |
| Tri Axle | 3 | 115 | 91.26 | 1.7 | 1 | 3 | 313 | 98 | 412 | 110 | 45274 |
| Tri Axle | 3 | 115 | 109.06 | 2.7 | 1 | 4 | 424 | 133 | 557 | 110 | 61308 |
| Tri Axle | 3 | 115 | 114.29 | 3.0 | 1 | 4 | 457 | 143 | 600 | 110 | 66041 |
| Tri Axle | 3 | 115 | 110.11 | 2.8 | 1 | 4 | 436 | 136 | 572 | 110 | 62956 |
| Tri Axle | 3 | 115 | 122.17 | 2.7 | 1 | 4 | 429 | 134 | 563 | 110 | 61931 |
| Grader | N/A | 68 | 115.11 | 3.9 | 1 | 5 | 334 | 177 | 510 | 50 | 0 |
| Grader | N/A | 68 | 118.30 | 3.6 | 1 | 5 | 315 | 167 | 481 | 50 | 0 |
| Tri Axle | 3 | 115 | 144.74 | 4.0 | 1 | 5 | 580 | 182 | 762 | 50 | 38078 |
| Tri Axle | 3 | 115 | 131.10 | 2.3 | 1 | 3 | 375 | 117 | 492 | 50 | 24601 |
| Tri Axle | 3 | 115 | 135.33 | 3.1 | 1 | 4 | 468 | 146 | 614 | 50 | 30721 |
| Tri Axle | 3 | 115 | 136.27 | 4.3 | 1 | 5 | 606 | 190 | 796 | 50 | 39810 |
| Tandem | 2 | 110 | 127.40 | 4.8 | 1 | 6 | 636 | 208 | 845 | 50 | 42238 |
| Tri Axle | 3 | 115 | 145.42 | 4.1 | 1 | 5 | 591 | 185 | 776 | 50 | 38780 |
| Tandem | 2 | 110 | 71.20 | 3.0 | 1 | 4 | 439 | 144 | 582 | 50 | 29101 |
| Tandem | 2 | 110 | 132.73 | 3.1 | 1 | 4 | 453 | 148 | 601 | 50 | 30032 |
| Tandem | 2 | 110 | 144.06 | 3.6 | 1 | 5 | 507 | 166 | 672 | 50 | 33617 |
| Tandem | 2 | 110 | 112.79 | 3.4 | 1 | 4 | 485 | 159 | 644 | 50 | 32203 |
| Tandem | 2 | 110 | 148.07 | 2.6 | 1 | 4 | 397 | 130 | 526 | 50 | 26323 |
| Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.7 | 1 | 6 | 283 | 204 | 487 | 85 | 0 |
| Single Axle | 1 | 68 | 10.44 | 1.3 | 1 | 2 | 153 | 81 | 234 | 85 | 19903 |
| Single Axle | 1 | 68 | 44.29 | 4.3 | 1 | 5 | 358 | 189 | 547 | 85 | 46495 |
| Tandem | 2 | 110 | 48.62 | 3.7 | 1 | 5 | 516 | 169 | 685 | 85 | 58262 |
| Tandem | 2 | 110 | 130.77 | 3.2 | 1 | 4 | 467 | 153 | 620 | 65 | 40303 |
| Tandem | 2 | 110 | 137.50 | 3.6 | 1 | 5 | 506 | 165 | 671 | 65 | 43623 |
| Tandem | 2 | 110 | 121.70 | 3.6 | 1 | 5 | 501 | 164 | 665 | 65 | 43250 |
| Tandem | 2 | 110 | 161.82 | 4.2 | 1 | 5 | 575 | 188 | 763 | 65 | 49600 |
| Grader | N/A | 68 | 92.86 | 3.3 | 1 | 4 | 289 | 153 | 443 | 65 | 0 |
| Tandem | 2 | 110 | 146.60 | 4.1 | 1 | 5 | 556 | 182 | 738 | 65 | 47979 |
| Tandem | 2 | 110 | 157.52 | 3.3 | 1 | 4 | 474 | 155 | 630 | 65 | 40931 |
| Single Axle | 1 | 68 | 84.05 | 9.0 | 1 | 10 | 677 | 358 | 1035 | 65 | 67295 |
| | | | 4682.59 | 153.67 | 44.00 | 197.67 | | | | Sum for all Routes (Task 2 Current Routes) | $1,481,023 |

## Annual Fleet and Labour Costs (Task 2, Optimized Routes):

| Maintenance Yard Name | Route ID | Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Perth | Beat A / K | Single Axle | 1 | 68 | 33.78 | 3.8 | 1 | 5 | 330 | 175 | 504 | 40 | 20169 |
| North Perth | Beat B | Single Axle | 1 | 68 | 81.49 | 7.2 | 1 | 8 | 557 | 295 | 852 | 40 | 34061 |
| North Perth | Beat C | Single Axle | 1 | 68 | 49.24 | 6.2 | 1 | 7 | 492 | 260 | 753 | 40 | 30101 |
| North Perth | Beat D | Grader | N/A | 68 | 100.82 | 2.8 | 1 | 4 | 258 | 136 | 394 | 40 | 0 |
| North Perth | Beat E | Grader | N/A | 68 | 90.53 | 2.6 | 1 | 4 | 243 | 128 | 371 | 40 | 0 |
| North Perth | Beat F | Grader | N/A | 68 | 110.77 | 3.0 | 1 | 4 | 271 | 144 | 415 | 40 | 0 |
| North Perth | Beat G | Tandem | 2 | 110 | 123.80 | 3.2 | 1 | 4 | 458 | 150 | 608 | 40 | 24311 |
| North Perth | Beat H | Tandem | 2 | 110 | 123.36 | 3.3 | 1 | 4 | 469 | 154 | 623 | 40 | 24921 |
| North Perth | Beat I | Tandem | 2 | 110 | 83.77 | 2.3 | 1 | 3 | 365 | 119 | 485 | 40 | 19382 |
| North Perth | Beat J | Grader | N/A | 68 | 101.30 | 2.7 | 1 | 4 | 249 | 132 | 380 | 40 | 0 |
| Perth County | Route 1 | Tandem | 2 | 110 | 88.52 | 2.0 | 1 | 3 | 326 | 107 | 433 | 110 | 47576 |
| Perth County | Route 2 | Tandem | 2 | 110 | 101.99 | 2.3 | 1 | 3 | 363 | 119 | 482 | 110 | 52972 |
| Perth County | Route 3 | Tandem | 2 | 110 | 100.98 | 2.3 | 1 | 3 | 361 | 118 | 480 | 110 | 52777 |
| Perth County | Route 4 | Tri Axle | 3 | 115 | 83.49 | 1.9 | 1 | 3 | 338 | 106 | 443 | 110 | 48774 |
| Perth County | Route 5 | Tri Axle | 3 | 115 | 65.85 | 1.7 | 1 | 3 | 308 | 96 | 404 | 110 | 44444 |
| Perth County | Route 6 | Tri Axle | 3 | 115 | 109.41 | 2.6 | 1 | 4 | 416 | 130 | 546 | 110 | 60014 |
| Perth County | Route 7 | Tri Axle | 3 | 115 | 120.47 | 2.9 | 1 | 4 | 447 | 140 | 587 | 110 | 64611 |
| Perth County | Route 8 | Tri Axle | 3 | 115 | 122.08 | 2.7 | 1 | 4 | 427 | 134 | 560 | 110 | 61615 |
| Perth County | Route 9 | Tri Axle | 3 | 115 | 118.38 | 2.6 | 1 | 4 | 420 | 131 | 551 | 110 | 60619 |
| Perth East | M22 | Grader | N/A | 68 | 115.11 | 3.8 | 1 | 5 | 326 | 173 | 498 | 50 | 0 |
| Perth East | M27 | Grader | N/A | 68 | 118.30 | 3.5 | 1 | 5 | 307 | 163 | 470 | 50 | 0 |
| Perth East | M30 | Tri Axle | 3 | 115 | 169.07 | 3.9 | 1 | 5 | 567 | 177 | 744 | 50 | 37195 |
| Perth East | M31 | Tri Axle | 3 | 115 | 99.59 | 2.2 | 1 | 3 | 367 | 115 | 482 | 50 | 24108 |
| Perth East | M34 | Tri Axle | 3 | 115 | 124.80 | 3.0 | 1 | 4 | 458 | 143 | 601 | 50 | 30050 |
| Perth East | M36 | Tri Axle | 3 | 115 | 132.60 | 4.1 | 1 | 5 | 592 | 185 | 778 | 50 | 38876 |
| Perth East | M37 | Tandem | 2 | 110 | 126.84 | 4.6 | 1 | 6 | 621 | 203 | 825 | 50 | 41227 |
| Perth East | M38 | Tri Axle | 3 | 115 | 157.09 | 4.0 | 1 | 5 | 577 | 181 | 758 | 50 | 37876 |
| Perth East | M39 | Tandem | 2 | 110 | 66.09 | 2.9 | 1 | 4 | 429 | 140 | 569 | 50 | 28470 |
| Perth South | PR1 | Tandem | 2 | 110 | 126.14 | 3.0 | 1 | 4 | 443 | 145 | 587 | 50 | 29374 |
| Perth South | PR2 | Tandem | 2 | 110 | 158.04 | 3.5 | 1 | 5 | 495 | 162 | 657 | 50 | 32855 |
| Perth South | PR3 | Tandem | 2 | 110 | 137.93 | 3.3 | 1 | 4 | 474 | 155 | 630 | 50 | 31482 |
| Perth South | PR4 | Tandem | 2 | 110 | 104.18 | 2.5 | 1 | 4 | 388 | 127 | 515 | 50 | 25772 |
| St Marys | J-30 | Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.5 | 1 | 6 | 276 | 199 | 475 | 85 | 0 |
| St Marys | T-20 | Single Axle | 1 | 68 | 11.04 | 1.2 | 1 | 2 | 151 | 80 | 230 | 85 | 19583 |
| St Marys | T-30 | Single Axle | 1 | 68 | 42.09 | 4.1 | 1 | 5 | 349 | 185 | 534 | 85 | 45405 |
| St Marys | T-40 | Tandem | 2 | 110 | 43.64 | 3.6 | 1 | 5 | 505 | 165 | 670 | 85 | 56935 |
| West Perth | Fullerton North | Tandem | 2 | 110 | 120.98 | 3.2 | 1 | 4 | 457 | 150 | 606 | 65 | 39411 |
| West Perth | Fullerton South | Tandem | 2 | 110 | 135.16 | 3.5 | 1 | 4 | 494 | 162 | 656 | 65 | 42635 |
| West Perth | Hibbert North | Tandem | 2 | 110 | 123.52 | 3.5 | 1 | 4 | 490 | 160 | 650 | 65 | 42273 |
| West Perth | Hibbert South | Tandem | 2 | 110 | 156.10 | 4.1 | 1 | 5 | 561 | 184 | 745 | 65 | 48439 |
| West Perth | Logan Grader | Grader | N/A | 68 | 79.12 | 3.2 | 1 | 4 | 283 | 150 | 433 | 65 | 0 |
| West Perth | Logan North | Tandem | 2 | 110 | 155.28 | 3.9 | 1 | 5 | 543 | 178 | 721 | 65 | 46866 |
| West Perth | Logan South | Tandem | 2 | 110 | 126.19 | 3.2 | 1 | 4 | 464 | 152 | 616 | 65 | 40021 |
| West Perth | Mitchell Ward | Single Axle | 1 | 68 | 76.27 | 8.7 | 1 | 10 | 659 | 349 | 1008 | 65 | 65543 |
| | | | | | 4547.07 | 149.22 | 44.00 | 193.22 | | | | **Sum for all Routes (Task 2 Optimized Routes)** | $1,450,743 |

## Annual Fleet and Labour Costs (Task 3, No Boundaries):

| Maintenance Yard Name | Route ID | Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Perth | Beat A / K | Single Axle | 1 | 68 | 111.71 | 3.0 | 1 | 4 | 274 | 145 | 420 | 40 | 16782 |
| North Perth | Beat B | Single Axle | 1 | 68 | 96.11 | 2.7 | 1 | 4 | 252 | 133 | 385 | 40 | 15388 |
| North Perth | Beat C | Single Axle | 1 | 68 | 99.53 | 2.7 | 1 | 4 | 253 | 134 | 387 | 40 | 15488 |
| North Perth | Beat D | Grader | N/A | 68 | 49.65 | 5.6 | 1 | 7 | 447 | 237 | 684 | 40 | 0 |
| North Perth | Beat E | Grader | N/A | 68 | 81.89 | 7.6 | 1 | 9 | 587 | 311 | 898 | 40 | 0 |
| North Perth | Beat F | Grader | N/A | 68 | 34.06 | 3.9 | 1 | 5 | 330 | 175 | 505 | 40 | 0 |
| North Perth | Beat G | Tandem | 2 | 110 | 98.65 | 2.8 | 1 | 4 | 413 | 135 | 548 | 40 | 21916 |
| North Perth | Beat H | Tandem | 2 | 110 | 79.61 | 2.1 | 1 | 3 | 341 | 112 | 452 | 40 | 18089 |
| North Perth | Beat I | Tandem | 2 | 110 | 93.91 | 2.5 | 1 | 4 | 387 | 127 | 514 | 40 | 20544 |
| North Perth | Beat J | Grader | N/A | 68 | 100.05 | 2.6 | 1 | 4 | 244 | 129 | 374 | 40 | 0 |
| Perth County | Route 1 | Tandem | 2 | 110 | 92.04 | 2.1 | 1 | 3 | 341 | 112 | 452 | 110 | 49769 |
| Perth County | Route 2 | Tandem | 2 | 110 | 109.89 | 2.7 | 1 | 4 | 410 | 134 | 545 | 110 | 59921 |
| Perth County | Route 3 | Tandem | 2 | 110 | 113.89 | 3.0 | 1 | 4 | 439 | 144 | 582 | 110 | 64054 |
| Perth County | Route 4 | Tri Axle | 3 | 115 | 101.55 | 2.3 | 1 | 3 | 379 | 119 | 498 | 110 | 54773 |
| Perth County | Route 5 | Tri Axle | 3 | 115 | 64.84 | 1.5 | 1 | 3 | 290 | 91 | 381 | 110 | 41905 |
| Perth County | Route 6 | Tri Axle | 3 | 115 | 109.41 | 2.6 | 1 | 4 | 419 | 131 | 550 | 110 | 60459 |
| Perth County | Route 7 | Tri Axle | 3 | 115 | 122.08 | 2.7 | 1 | 4 | 427 | 134 | 560 | 110 | 61615 |
| Perth County | Route 8 | Tri Axle | 3 | 115 | 120.47 | 2.9 | 1 | 4 | 451 | 141 | 592 | 110 | 65121 |
| Perth County | Route 9 | Tri Axle | 3 | 115 | 118.38 | 2.7 | 1 | 4 | 420 | 131 | 552 | 110 | 60669 |
| Perth East | M22 | Grader | N/A | 68 | 125.61 | 4.6 | 1 | 6 | 383 | 203 | 586 | 50 | 0 |
| Perth East | M27 | Grader | N/A | 68 | 139.29 | 3.6 | 1 | 5 | 312 | 165 | 477 | 50 | 0 |
| Perth East | M30 | Tri Axle | 3 | 115 | 172.42 | 4.1 | 1 | 5 | 591 | 185 | 776 | 50 | 38799 |
| Perth East | M31 | Tri Axle | 3 | 115 | 29.03 | 2.2 | 1 | 3 | 370 | 116 | 486 | 50 | 24281 |
| Perth East | M34 | Tri Axle | 3 | 115 | 135.29 | 3.2 | 1 | 4 | 478 | 150 | 628 | 50 | 31397 |
| Perth East | M36 | Tri Axle | 3 | 115 | 103.29 | 2.4 | 1 | 3 | 387 | 121 | 508 | 50 | 25394 |
| Perth East | M37 | Tandem | 2 | 110 | 130.34 | 3.8 | 1 | 5 | 527 | 172 | 699 | 50 | 34949 |
| Perth East | M38 | Tri Axle | 3 | 115 | 101.83 | 3.3 | 1 | 4 | 490 | 153 | 643 | 50 | 32169 |
| Perth East | M39 | Tandem | 2 | 110 | 87.06 | 2.9 | 1 | 4 | 429 | 140 | 569 | 50 | 28441 |
| Perth South | PR1 | Tandem | 2 | 110 | 126.14 | 3.0 | 1 | 4 | 443 | 145 | 587 | 50 | 29374 |
| Perth South | PR2 | Tandem | 2 | 110 | 158.45 | 3.6 | 1 | 5 | 510 | 167 | 678 | 50 | 33877 |
| Perth South | PR3 | Tandem | 2 | 110 | 135.38 | 3.2 | 1 | 4 | 461 | 151 | 612 | 50 | 30593 |
| Perth South | PR4 | Tandem | 2 | 110 | 106.96 | 2.6 | 1 | 4 | 401 | 131 | 533 | 50 | 26640 |
| St Marys | J-30 | Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.5 | 1 | 6 | 276 | 199 | 475 | 85 | 0 |
| St Marys | T-20 | Single Axle | 1 | 68 | 11.69 | 1.1 | 1 | 2 | 143 | 76 | 219 | 85 | 18583 |
| St Marys | T-30 | Single Axle | 1 | 68 | 41.65 | 4.1 | 1 | 5 | 346 | 183 | 529 | 85 | 44938 |
| St Marys | T-40 | Tandem | 2 | 110 | 43.64 | 3.5 | 1 | 5 | 500 | 164 | 664 | 85 | 56461 |
| West Perth | Fullerton North | Tandem | 2 | 110 | 120.98 | 3.1 | 1 | 4 | 456 | 149 | 606 | 65 | 39375 |
| West Perth | Fullerton South | Tandem | 2 | 110 | 135.16 | 3.6 | 1 | 5 | 502 | 164 | 666 | 65 | 43268 |
| West Perth | Hibbert North | Tandem | 2 | 110 | 123.52 | 3.4 | 1 | 4 | 481 | 157 | 638 | 65 | 41474 |
| West Perth | Hibbert South | Tandem | 2 | 110 | 156.94 | 4.1 | 1 | 5 | 561 | 184 | 745 | 65 | 48433 |
| West Perth | Logan Grader | Grader | N/A | 68 | 136.99 | 5.3 | 1 | 6 | 428 | 226 | 654 | 65 | 0 |
| West Perth | Logan North | Tandem | 2 | 110 | 179.47 | 4.2 | 1 | 5 | 574 | 188 | 761 | 65 | 49484 |
| West Perth | Logan South | Tandem | 2 | 110 | 126.19 | 3.2 | 1 | 4 | 462 | 151 | 613 | 65 | 39877 |
| West Perth | Mitchell Ward | Single Axle | 1 | 68 | 76.27 | 7.9 | 1 | 9 | 608 | 322 | 930 | 65 | 60464 |
| | | | | | 4533.19 | 148.68 | 44.00 | 192.68 | | | | **Sum for all Routes (Task 3, No Boundaries)** | $1,404,765 |

## Annual Fleet and Labour Costs (Task 3, 1 Depot Removal):

| Maintenance Yard Name | Route ID | Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Perth | Beat A / K | Single Axle | 1 | 68 | 111.71 | 3.0 | 1 | 4 | 274 | 145 | 420 | 40 | 16782 |
| North Perth | Beat B | Single Axle | 1 | 68 | 96.11 | 2.7 | 1 | 4 | 252 | 133 | 385 | 40 | 15388 |
| North Perth | Beat C | Single Axle | 1 | 68 | 99.53 | 2.7 | 1 | 4 | 253 | 134 | 387 | 40 | 15488 |
| North Perth | Beat D | Grader | N/A | 68 | 49.65 | 5.6 | 1 | 7 | 451 | 239 | 690 | 40 | 0 |
| North Perth | Beat E | Grader | N/A | 68 | 81.89 | 7.4 | 1 | 8 | 569 | 301 | 870 | 40 | 0 |
| North Perth | Beat F | Grader | N/A | 68 | 34.06 | 3.6 | 1 | 5 | 312 | 165 | 477 | 40 | 0 |
| North Perth | Beat G | Tandem | 2 | 110 | 98.65 | 2.8 | 1 | 4 | 413 | 135 | 548 | 40 | 21916 |
| North Perth | Beat H | Tandem | 2 | 110 | 79.61 | 2.1 | 1 | 3 | 341 | 112 | 452 | 40 | 18089 |
| North Perth | Beat I | Tandem | 2 | 110 | 93.91 | 2.5 | 1 | 4 | 387 | 127 | 514 | 40 | 20544 |
| North Perth | Beat J | Grader | N/A | 68 | 100.05 | 2.6 | 1 | 4 | 244 | 129 | 374 | 40 | 0 |
| Perth County | Route 1 | Tandem | 2 | 110 | 92.04 | 2.1 | 1 | 3 | 341 | 112 | 452 | 110 | 49769 |
| Perth County | Route 2 | Tandem | 2 | 110 | 109.89 | 2.7 | 1 | 4 | 410 | 134 | 545 | 110 | 59921 |
| Perth County | Route 3 | Tandem | 2 | 110 | 113.89 | 3.0 | 1 | 4 | 439 | 144 | 582 | 110 | 64054 |
| Perth County | Route 4 | Tri Axle | 3 | 115 | 101.55 | 2.3 | 1 | 3 | 379 | 119 | 498 | 110 | 54773 |
| Perth County | Route 5 | Tri Axle | 3 | 115 | 64.84 | 1.5 | 1 | 3 | 290 | 91 | 381 | 110 | 41905 |
| Perth County | Route 6 | Tri Axle | 3 | 115 | 109.41 | 2.6 | 1 | 4 | 419 | 131 | 550 | 110 | 60459 |
| Perth County | Route 7 | Tri Axle | 3 | 115 | 122.08 | 2.7 | 1 | 4 | 427 | 134 | 560 | 110 | 61615 |
| Perth County | Route 8 | Tri Axle | 3 | 115 | 120.47 | 2.9 | 1 | 4 | 451 | 141 | 592 | 110 | 65121 |
| Perth County | Route 9 | Tri Axle | 3 | 115 | 118.38 | 2.7 | 1 | 4 | 420 | 131 | 552 | 110 | 60669 |
| Perth East | M22 | Grader | N/A | 68 | 125.61 | 4.6 | 1 | 6 | 383 | 203 | 586 | 50 | 0 |
| Perth East | M27 | Grader | N/A | 68 | 139.29 | 3.6 | 1 | 5 | 312 | 165 | 477 | 50 | 0 |
| Perth East | M30 | Tri Axle | 3 | 115 | 172.42 | 4.1 | 1 | 5 | 591 | 185 | 776 | 50 | 38799 |
| Perth East | M31 | Tri Axle | 3 | 115 | 29.03 | 2.2 | 1 | 3 | 370 | 116 | 486 | 50 | 24281 |
| Perth East | M34 | Tri Axle | 3 | 115 | 135.29 | 3.2 | 1 | 4 | 478 | 150 | 628 | 50 | 31397 |
| Perth East | M36 | Tri Axle | 3 | 115 | 103.29 | 2.4 | 1 | 3 | 387 | 121 | 508 | 50 | 25394 |
| Perth East | M37 | Tandem | 2 | 110 | 130.34 | 3.8 | 1 | 5 | 527 | 172 | 699 | 50 | 34949 |
| Perth East | M38 | Tri Axle | 3 | 115 | 101.83 | 3.3 | 1 | 4 | 490 | 153 | 643 | 50 | 32169 |
| Perth East | M39 | Tandem | 2 | 110 | 87.06 | 2.9 | 1 | 4 | 429 | 140 | 569 | 50 | 28441 |
| Perth South | PR3 | Tandem | 2 | 110 | 126.14 | 3.0 | 1 | 4 | 443 | 145 | 587 | 50 | 29374 |
| Perth South | PR4 | Tandem | 2 | 110 | 158.45 | 3.6 | 1 | 5 | 510 | 167 | 678 | 50 | 33877 |
| St Marys | J-30 | Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.5 | 1 | 5 | 273 | 197 | 470 | 85 | 0 |
| St Marys | T-20 | Single Axle | 1 | 68 | 11.69 | 1.0 | 1 | 2 | 138 | 73 | 212 | 85 | 17994 |
| St Marys | T-30 | Single Axle | 1 | 68 | 41.65 | 4.1 | 1 | 5 | 346 | 183 | 529 | 85 | 44938 |
| St Marys | T-40 | Tandem | 2 | 110 | 43.64 | 3.5 | 1 | 5 | 500 | 164 | 664 | 85 | 56461 |
| West Perth | Fullerton North | Tandem | 2 | 110 | 150.14 | 3.9 | 1 | 5 | 536 | 175 | 711 | 65 | 46211 |
| West Perth | Fullerton South | Tandem | 2 | 110 | 202.36 | 5.1 | 1 | 6 | 672 | 220 | 892 | 65 | 58003 |
| West Perth | Hibbert North | Tandem | 2 | 110 | 222.68 | 5.6 | 1 | 7 | 721 | 236 | 957 | 65 | 62193 |
| West Perth | Hibbert South | Tandem | 2 | 110 | 181.74 | 4.7 | 1 | 6 | 624 | 204 | 828 | 65 | 53823 |
| West Perth | Logan Grader | Grader | N/A | 68 | 136.99 | 5.3 | 1 | 6 | 428 | 226 | 654 | 65 | 0 |
| West Perth | Logan North | Tandem | 2 | 110 | 179.47 | 4.2 | 1 | 5 | 574 | 188 | 761 | 65 | 49484 |
| West Perth | Logan South | Tandem | 2 | 110 | 154.95 | 3.8 | 1 | 5 | 525 | 172 | 697 | 65 | 45335 |
| West Perth | Mitchell Ward | Single Axle | 1 | 68 | 76.27 | 7.9 | 1 | 9 | 604 | 320 | 923 | 65 | 60013 |
| | | | | | 4539.94 | 147.77 | 42.00 | 189.77 | | | | **Sum for all Routes (Task 3, 1 Depot Removal)** | $1,399,632 |

## Annual Fleet and Labour Costs (Task 3, 2 Depot Removal):

| Maintenance Yard Name | Route ID | Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Perth | Beat A / K | Single Axle | 1 | 68 | 111.71 | 3.0 | 1 | 4 | 274 | 145 | 420 | 40 | 16782 |
| North Perth | Beat B | Single Axle | 1 | 68 | 96.11 | 2.7 | 1 | 4 | 252 | 133 | 385 | 40 | 15388 |
| North Perth | Beat C | Single Axle | 1 | 68 | 99.53 | 2.7 | 1 | 4 | 253 | 134 | 387 | 40 | 15488 |
| North Perth | Beat D | Grader | N/A | 68 | 49.65 | 5.6 | 1 | 7 | 447 | 237 | 684 | 40 | 0 |
| North Perth | Beat E | Grader | N/A | 68 | 81.89 | 7.2 | 1 | 8 | 560 | 296 | 856 | 40 | 0 |
| North Perth | Beat F | Grader | N/A | 68 | 34.06 | 4.1 | 1 | 5 | 344 | 182 | 526 | 40 | 0 |
| North Perth | Beat G | Tandem | 2 | 110 | 98.65 | 2.8 | 1 | 4 | 413 | 135 | 548 | 40 | 21916 |
| North Perth | Beat H | Tandem | 2 | 110 | 79.61 | 2.1 | 1 | 3 | 341 | 112 | 452 | 40 | 18089 |
| North Perth | Beat I | Tandem | 2 | 110 | 93.91 | 2.5 | 1 | 4 | 387 | 127 | 514 | 40 | 20544 |
| North Perth | Beat J | Grader | N/A | 68 | 100.05 | 2.6 | 1 | 4 | 244 | 129 | 374 | 40 | 0 |
| Perth County | Route 4 | Tri Axle | 3 | 115 | 101.55 | 2.3 | 1 | 3 | 379 | 119 | 498 | 110 | 54773 |
| Perth County | Route 5 | Tri Axle | 3 | 115 | 64.84 | 1.5 | 1 | 3 | 290 | 91 | 381 | 110 | 41905 |
| Perth County | Route 6 | Tri Axle | 3 | 115 | 109.41 | 2.6 | 1 | 4 | 419 | 131 | 550 | 110 | 60459 |
| Perth County | Route 7 | Tri Axle | 3 | 115 | 122.08 | 2.7 | 1 | 4 | 427 | 134 | 560 | 110 | 61615 |
| Perth County | Route 8 | Tri Axle | 3 | 115 | 120.47 | 2.9 | 1 | 4 | 451 | 141 | 592 | 110 | 65121 |
| Perth County | Route 9 | Tri Axle | 3 | 115 | 118.38 | 2.7 | 1 | 4 | 420 | 131 | 552 | 110 | 60669 |
| Perth East | M22 | Grader | N/A | 68 | 125.61 | 4.6 | 1 | 6 | 383 | 203 | 586 | 50 | 0 |
| Perth East | M27 | Grader | N/A | 68 | 139.29 | 3.6 | 1 | 5 | 312 | 165 | 477 | 50 | 0 |
| Perth East | M30 | Tri Axle | 3 | 115 | 172.42 | 4.1 | 1 | 5 | 591 | 185 | 776 | 50 | 38799 |
| Perth East | M31 | Tri Axle | 3 | 115 | 138.65 | 4.4 | 1 | 5 | 618 | 194 | 812 | 50 | 40591 |
| Perth East | M34 | Tri Axle | 3 | 115 | 212.97 | 4.9 | 1 | 6 | 681 | 213 | 894 | 50 | 44714 |
| Perth East | M36 | Tri Axle | 3 | 115 | 155.87 | 4.3 | 1 | 5 | 604 | 189 | 794 | 50 | 39675 |
| Perth East | M37 | Tandem | 2 | 110 | 169.48 | 3.5 | 1 | 4 | 493 | 161 | 654 | 50 | 32721 |
| Perth East | M38 | Tri Axle | 3 | 115 | 101.83 | 3.3 | 1 | 4 | 490 | 153 | 643 | 50 | 32169 |
| Perth East | M39 | Tandem | 2 | 110 | 87.06 | 2.9 | 1 | 4 | 429 | 140 | 569 | 50 | 28441 |
| Perth South | PR3 | Tandem | 2 | 110 | 126.14 | 3.0 | 1 | 4 | 443 | 145 | 587 | 50 | 29374 |
| Perth South | PR4 | Tandem | 2 | 110 | 158.45 | 3.6 | 1 | 5 | 510 | 167 | 678 | 50 | 33877 |
| St Marys | J-30 | Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.5 | 1 | 5 | 273 | 197 | 470 | 85 | 0 |
| St Marys | T-20 | Single Axle | 1 | 68 | 11.69 | 1.0 | 1 | 2 | 138 | 73 | 212 | 85 | 17994 |
| St Marys | T-30 | Single Axle | 1 | 68 | 41.65 | 4.1 | 1 | 5 | 346 | 183 | 529 | 85 | 44938 |
| St Marys | T-40 | Tandem | 2 | 110 | 43.64 | 3.5 | 1 | 5 | 500 | 164 | 664 | 85 | 56461 |
| West Perth | Fullerton North | Tandem | 2 | 110 | 150.14 | 3.9 | 1 | 5 | 536 | 175 | 711 | 65 | 46211 |
| West Perth | Fullerton South | Tandem | 2 | 110 | 202.36 | 5.1 | 1 | 6 | 672 | 220 | 892 | 65 | 58003 |
| West Perth | Hibbert North | Tandem | 2 | 110 | 222.68 | 5.6 | 1 | 7 | 721 | 236 | 957 | 65 | 62193 |
| West Perth | Hibbert South | Tandem | 2 | 110 | 181.74 | 4.7 | 1 | 6 | 624 | 204 | 828 | 65 | 53823 |
| West Perth | Logan Grader | Grader | N/A | 68 | 136.99 | 5.3 | 1 | 6 | 428 | 226 | 654 | 65 | 0 |
| West Perth | Logan North | Tandem | 2 | 110 | 179.47 | 4.2 | 1 | 5 | 574 | 188 | 761 | 65 | 49484 |
| West Perth | Logan South | Tandem | 2 | 110 | 154.95 | 3.8 | 1 | 5 | 525 | 172 | 697 | 65 | 45335 |
| West Perth | Mitchell Ward | Single Axle | 1 | 68 | 76.27 | 7.9 | 1 | 9 | 608 | 322 | 930 | 65 | 60464 |
| | | | | | 4503.13 | 145.80 | 39.00 | 184.80 | | | | **Sum for all Routes (Task 3, 2 Depot Removal)** | $1,268,018 |

## Annual Fleet and Labour Costs (Task 3, 3 Depot Removal):

| Maintenance Yard Name | Route ID | Truck Type | # of Axles | Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Perth | Beat A / K | Single Axle | 1 | 68 | 111.71 | 3.0 | 1 | 4 | 274 | 145 | 420 | 40 | 16782 |
| North Perth | Beat B | Single Axle | 1 | 68 | 96.11 | 2.7 | 1 | 4 | 252 | 133 | 385 | 40 | 15388 |
| North Perth | Beat C | Single Axle | 1 | 68 | 99.53 | 2.7 | 1 | 4 | 253 | 134 | 387 | 40 | 15488 |
| North Perth | Beat D | Grader | N/A | 68 | 49.65 | 5.6 | 1 | 7 | 451 | 239 | 690 | 40 | 0 |
| North Perth | Beat E | Grader | N/A | 68 | 81.89 | 7.6 | 1 | 9 | 582 | 308 | 891 | 40 | 0 |
| North Perth | Beat F | Grader | N/A | 68 | 34.06 | 3.7 | 1 | 5 | 316 | 168 | 484 | 40 | 0 |
| North Perth | Beat G | Tandem | 2 | 110 | 98.65 | 2.8 | 1 | 4 | 413 | 135 | 548 | 40 | 21916 |
| North Perth | Beat H | Tandem | 2 | 110 | 79.61 | 2.1 | 1 | 3 | 341 | 112 | 452 | 40 | 18089 |
| North Perth | Beat I | Tandem | 2 | 110 | 93.91 | 2.5 | 1 | 4 | 387 | 127 | 514 | 40 | 20544 |
| North Perth | Beat J | Grader | N/A | 68 | 100.05 | 2.6 | 1 | 4 | 244 | 129 | 374 | 40 | 0 |
| Perth County | Route 4 | Tri Axle | 3 | 115 | 101.55 | 2.3 | 1 | 3 | 379 | 119 | 498 | 110 | 54773 |
| Perth County | Route 5 | Tri Axle | 3 | 115 | 64.84 | 1.5 | 1 | 3 | 290 | 91 | 381 | 110 | 41905 |
| Perth County | Route 6 | Tri Axle | 3 | 115 | 109.41 | 2.6 | 1 | 4 | 419 | 131 | 550 | 110 | 60459 |
| Perth County | Route 7 | Tri Axle | 3 | 115 | 122.08 | 2.7 | 1 | 4 | 427 | 134 | 560 | 110 | 61615 |
| Perth County | Route 8 | Tri Axle | 3 | 115 | 120.47 | 2.9 | 1 | 4 | 451 | 141 | 592 | 110 | 65121 |
| Perth County | Route 9 | Tri Axle | 3 | 115 | 118.38 | 2.7 | 1 | 4 | 420 | 131 | 552 | 110 | 60669 |
| Perth East | M22 | Grader | N/A | 68 | 158.56 | 5.3 | 1 | 6 | 428 | 227 | 655 | 50 | 0 |
| Perth East | M27 | Grader | N/A | 68 | 253.28 | 6.4 | 1 | 7 | 505 | 267 | 772 | 50 | 0 |
| Perth East | M30 | Tri Axle | 3 | 115 | 209.41 | 5.2 | 1 | 6 | 708 | 222 | 929 | 50 | 46457 |
| Perth East | M31 | Tri Axle | 3 | 115 | 138.65 | 4.4 | 1 | 5 | 618 | 194 | 812 | 50 | 40591 |
| Perth East | M34 | Tri Axle | 3 | 115 | 212.97 | 4.9 | 1 | 6 | 681 | 213 | 894 | 50 | 44714 |
| Perth East | M36 | Tri Axle | 3 | 115 | 155.87 | 4.3 | 1 | 5 | 604 | 189 | 794 | 50 | 39675 |
| Perth East | M37 | Tandem | 2 | 110 | 169.48 | 3.5 | 1 | 4 | 493 | 161 | 654 | 50 | 32721 |
| Perth East | M38 | Tri Axle | 3 | 115 | 101.83 | 3.3 | 1 | 4 | 490 | 153 | 643 | 50 | 32169 |
| Perth East | M39 | Tandem | 2 | 110 | 87.06 | 2.9 | 1 | 4 | 429 | 140 | 569 | 50 | 28441 |
| St Marys | J-30 | Parking Lot Type Vehicle | N/A | 50 | 31.87 | 4.5 | 1 | 5 | 273 | 197 | 470 | 85 | 0 |
| St Marys | T-20 | Single Axle | 1 | 68 | 11.69 | 1.0 | 1 | 2 | 138 | 73 | 212 | 85 | 17994 |
| St Marys | T-30 | Single Axle | 1 | 68 | 41.65 | 4.1 | 1 | 5 | 346 | 183 | 529 | 85 | 44938 |
| St Marys | T-40 | Tandem | 2 | 110 | 43.64 | 3.5 | 1 | 5 | 500 | 164 | 664 | 85 | 56461 |
| West Perth | Fullerton North | Tandem | 2 | 110 | 250.72 | 6.6 | 1 | 8 | 837 | 274 | 1111 | 65 | 72233 |
| West Perth | Fullerton South | Tandem | 2 | 110 | 202.36 | 5.1 | 1 | 6 | 672 | 220 | 892 | 65 | 58003 |
| West Perth | Hibbert North | Tandem | 2 | 110 | 222.68 | 5.6 | 1 | 7 | 721 | 236 | 957 | 65 | 62193 |
| West Perth | Hibbert South | Tandem | 2 | 110 | 181.74 | 4.7 | 1 | 6 | 624 | 204 | 828 | 65 | 53823 |
| West Perth | Logan Grader | Grader | N/A | 68 | 136.99 | 5.3 | 1 | 6 | 428 | 226 | 654 | 65 | 0 |
| West Perth | Logan North | Tandem | 2 | 110 | 179.47 | 4.2 | 1 | 5 | 574 | 188 | 761 | 65 | 49484 |
| West Perth | Logan South | Tandem | 2 | 110 | 154.95 | 3.8 | 1 | 5 | 525 | 172 | 697 | 65 | 45335 |
| West Perth | Mitchell Ward | Single Axle | 1 | 68 | 76.27 | 7.9 | 1 | 9 | 604 | 320 | 923 | 65 | 60013 |
| | | | | | 4503.05 | 146.32 | 37.00 | 183.32 | | | | **Sum for all Routes (Task 3, 3 Depot Removal)** | $1,237,996 |

## Annual Fleet and Labour Costs (Task 4, Clean Slate Optimization with 6 Depots)

| Truck Rental Rate/Hour | Route Length (Single Lane km) | Time to Cover Route (Hour) | Preparation, Loading, Clean up time per Deployment | Total Hours per Deployment | Truck Rent per Deployment | Labour per Deployment | Total $ per Deployment | Assumed Annual Deployment | Annual Truck Rent and Labour |
|---|---|---|---|---|---|---|---|---|---|
| 68 | 57.61 | 7.7 | 1 | 9 | 594 | 315 | 909 | 40 | 36359 |
| 68 | 61.25 | 6.8 | 1 | 8 | 530 | 281 | 811 | 40 | 32443 |
| 68 | 55.49 | 3.1 | 1 | 4 | 282 | 149 | 431 | 40 | 17256 |
| 68 | 25.16 | 2.3 | 1 | 3 | 224 | 119 | 342 | 85 | 0 |
| 68 | 37.69 | 3.6 | 1 | 5 | 316 | 167 | 483 | 85 | 0 |
| 68 | 108.27 | 2.8 | 1 | 4 | 259 | 137 | 397 | 40 | 0 |
| 68 | 81.68 | 2.2 | 1 | 3 | 218 | 115 | 333 | 50 | 16655 |
| 68 | 117.49 | 3.0 | 1 | 4 | 272 | 144 | 417 | 50 | 20837 |
| 68 | 167.86 | 4.4 | 1 | 5 | 369 | 195 | 564 | 65 | 36641 |
| 68 | 17.14 | 2.1 | 1 | 3 | 212 | 112 | 324 | 85 | 0 |
| 68 | 19.64 | 2.0 | 1 | 3 | 206 | 109 | 315 | 85 | 26768 |
| 68 | 108.86 | 3.1 | 1 | 4 | 279 | 148 | 427 | 50 | 21329 |
| 68 | 142.13 | 3.9 | 1 | 5 | 333 | 176 | 510 | 50 | 25486 |
| 68 | 90.38 | 8.3 | 1 | 9 | 635 | 336 | 971 | 65 | 63121 |
| 110 | 203.77 | 5.7 | 1 | 7 | 734 | 240 | 975 | 40 | 38984 |
| 110 | 106.77 | 2.7 | 1 | 4 | 405 | 132 | 537 | 40 | 21491 |
| 110 | 200.63 | 4.9 | 1 | 6 | 652 | 213 | 865 | 65 | 0 |
| 110 | 143.78 | 4.2 | 1 | 5 | 569 | 186 | 755 | 65 | 0 |
| 110 | 183.66 | 4.9 | 1 | 6 | 644 | 211 | 854 | 65 | 55534 |
| 110 | 176.41 | 4.8 | 1 | 6 | 634 | 207 | 841 | 65 | 54694 |
| 110 | 216.59 | 5.6 | 1 | 7 | 730 | 239 | 969 | 65 | 62987 |
| 110 | 121.88 | 5.1 | 1 | 6 | 670 | 219 | 889 | 85 | 75532 |
| 110 | 232.81 | 6.5 | 1 | 7 | 824 | 270 | 1094 | 85 | 92960 |
| 110 | 106.64 | 2.6 | 1 | 4 | 393 | 128 | 521 | 65 | 33870 |
| 110 | 245.46 | 7.3 | 1 | 8 | 916 | 300 | 1216 | 50 | 60791 |
| 110 | 222.07 | 6.6 | 1 | 8 | 837 | 274 | 1111 | 110 | 0 |
| 115 | 102.99 | 2.3 | 1 | 3 | 382 | 120 | 502 | 65 | 32644 |
| 115 | 69.23 | 1.8 | 1 | 3 | 324 | 101 | 425 | 65 | 27623 |
| 115 | 113.09 | 2.7 | 1 | 4 | 428 | 134 | 562 | 85 | 47732 |
| 115 | 132.13 | 3.2 | 1 | 4 | 485 | 152 | 637 | 85 | 54132 |
| 115 | 112.35 | 2.5 | 1 | 4 | 408 | 128 | 536 | 110 | 58919 |
| 115 | 101.55 | 2.3 | 1 | 3 | 376 | 118 | 494 | 110 | 54314 |
| 115 | 99.26 | 3.1 | 1 | 4 | 469 | 147 | 616 | 110 | 67733 |
| 115 | 115.33 | 2.2 | 1 | 3 | 366 | 115 | 481 | 110 | 0 |
| 115 | 159.05 | 3.8 | 1 | 5 | 549 | 172 | 721 | 110 | 79295 |
| 115 | 186.03 | 4.2 | 1 | 5 | 598 | 187 | 785 | 110 | 86398 |
| 115 | 145.76 | 3.6 | 1 | 5 | 534 | 167 | 701 | 110 | 77099 |
| | 4587.88 | 148.12 | 37.00 | 185.12 | | | | **Sum for all Routes (Task 4)** | $1,379,629 |

## Perth County Material Costs

| Material Costs (provided by John McClelland) | | |
|---|---|---|
| Conventional Rock Salt | $85 | per tonne |
| Thawrox | $107 | per tonne |
| Sand | $15.00 | per tonne |
| Liquid (applied at 5% by mass) | $0.25 | per litre |

## Annual Material and Spreading Costs

| Agency Name | Annual Tonnes of Salt Purchased or Used | Annual Tonnes of Treated Salt Purchased or Used | Annual Litres of Anti-icing Liquid Purchased or Used | Annual Tonnes of Winter Sand Purchased or Used | simple untreated salt $ | simple treated salt $ | simple liquid $ | $ total salt cost (includes winter liquids) | simple sand $ | spreading salt km | spreading sand km | salt spread time @40 kph | sand spread time @ 40 kph | $ salt spread @ $146/hour | $ sand spread @ $146/hour | all material+ spreading | all material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Perth County | 7570 | 4075 | 247193 | 6096 | $643,450 | $436,025 | $61,798 | $1,141,273 | $91,440 | 155267 | 30480 | 3882 | 762 | $566,723 | $111,252 | $1,474,664 | $796,688 |
| Town of St Marys | 1462 | 0 | 0 | 2560 | $124,247 | $0 | $0 | $124,247 | $38,400 | 19490 | 12800 | 487 | 320 | $71,138 | $46,720 | $280,505 | $162,647 |
| Perth East | 1775 | 0 | 0 | 1000 | $150,875 | $0 | $0 | $150,875 | $15,000 | 23667 | 5000 | 592 | 125 | $86,383 | $18,250 | $270,508 | $165,875 |
| Perth South | 350 | 0 | 0 | 2500 | $29,750 | $0 | $0 | $29,750 | $37,500 | 4667 | 12500 | 117 | 313 | $17,033 | $45,625 | $129,908 | $67,250 |
| West Perth | 1071 | 0 | 0 | 1270 | $91,013 | $0 | $0 | $91,013 | $19,050 | 14277 | 6350 | 357 | 159 | $52,109 | $23,178 | $185,350 | $110,063 |
| North Perth | 1803 | 0 | 0 | 2500 | $153,255 | $0 | $0 | $153,255 | $37,500 | 24040 | 12500 | 601 | 313 | $87,746 | $45,625 | $324,126 | $190,755 |
| | 14030 | 4075 | 247193 | 15926 | $1,192,590 | $436,025 | $61,798 | $1,690,413 | $238,890 | $241,406 | $79,630 | 6035 | 1991 | $881,133 | $290,650 | **$3,101,086** | **$1,929,303** |

## Maintenance Yard Rental Costs

| Maintenance Yard Name | Yard Area (sq ft) | Building Area (sq ft) | Building Annual Rental Rate per sq ft | Total Annual Rental |
|---|---|---|---|---|
| Mitchell (PC) | 31487 | 16000 | $6 | $96,000 |
| Stratford | 37781 | 16800 | $6 | $100,800 |
| Milverton (PC) | 12128 | 3000 | $6 | $18,000 |
| St. Marys | 63023 | 23680 | $6 | $142,080 |
| Milverton (PE) | 107639 | 19300 | $6 | $115,800 |
| North Easthope | 32292 | 5000 | $6 | $30,000 |
| Downie | 0 | 4600 | $6 | $27,600 |
| Blanshard | 23000 | 5300 | $6 | $31,800 |
| Mitchell (WP) | 60000 | 12000 | $6 | $72,000 |
| Elma (Atwood) | 3714 | 5920 | $6 | $35,521 |
| Listowel | 20236 | 5059 | $6 | $30,354 |
| Wallace (Gowanstown) | 1292 | 9688 | $6 | $58,125 |
| MTO Listowel (Storage Only) - 245 McDonald Street East | 21600 | 2581 | $6 | $15,486 |
| | | | **Total** | $773,566 |

J

# Appendix J: Equipment List

**Appendix J: Equipment List**

| Agency | Truck ID | Truck Type | Number of Axles | Spreader Capacity (tonnes) |
|---|---|---|---|---|
| **North Perth** | H&H Contractor #1 | Single Axle | 1 | 4.895 |
| **North Perth** | 3733 | Single Axle | 1 | 8.811 |
| **North Perth** | H&H Contractor #2 | Single Axle | 1 | 4.895 |
| **North Perth** | 3719 | Tandem | 2 | 13.706 |
| **North Perth** | 3738 | Tandem | 2 | 15.175 |
| **North Perth** | 3748 | Tandem | 2 | 13.706 |
| **North Perth** | 3729 | Single Axle | 1 | 2.937 |
| **North Perth** | 3745 | Tandem | 2 | 13.706 |
| **Perth County** | 16 02 | Tandem | 2 | 15.07 |
| **Perth County** | Contractor #41 | Tandem | 2 | 13.42 |
| **Perth County** | Contractor #42 | Tandem | 2 | 13.42 |
| **Perth County** | 10 08 | Tri Axle | 3 | 13.41 |
| **Perth County** | 18 07 | Tri Axle | 3 | 13.41 |
| **Perth County** | 14 06 | Tri Axle | 3 | 18.89 |
| **Perth County** | 15 24 | Tri Axle | 3 | 18.89 |
| **Perth County** | 14 05 | Tri Axle | 3 | 18.89 |
| **Perth County** | 13 01 | Tri Axle | 3 | 18.89 |
| **Perth County** | 09 09 | Tandem | 2 | 13.41 |

| Agency | Truck ID | Truck Type | Number of Axles | Spreader Capacity (tonnes) |
|---|---|---|---|---|
| **Perth County** | 07 29 | Tandem | 2 | 13.41 |
| **Perth East** | M11 | Parking Lot Type Vehicle | N/A | 1.958 |
| **Perth East** | M30 | Tri Axle | 3 | 17.4 |
| **Perth East** | M31 | Tri Axle | 3 | 17.4 |
| **Perth East** | M34 | Tri Axle | 3 | 17.4 |
| **Perth East** | M36 | Tri Axle | 3 | 17.4 |
| **Perth East** | M37 | Tandem | 2 | 9.6 |
| **Perth East** | M38 | Tri Axle | 3 | 17.4 |
| **Perth East** | M39 | Tandem | 2 | 9.6 |
| **Perth South** | Truck #34 | Tandem | 2 | 13.706 (16.643 tonnes with 10" sideboards) |
| **Perth South** | Truck #35 | Tandem | 2 | 13.706 (16.643 tonnes with 10" sideboards) |
| **Perth South** | Truck #13 | Tandem | 2 | 13.706 (16.643 tonnes with 10" sideboards) |
| **Perth South** | Truck #29 | Tandem | 2 | 13.706 (16.643 tonnes with 10" sideboards) |
| **Perth South** | Pickup #45 | Parking Lot Type Vehicle | N/A | 1.469 |
| **St Marys** | T20 | Single Axle | 1 | 4 |
| **St Marys** | T30 | Single Axle | 1 | 8 |
| **St Marys** | T40 | Tandem | 2 | 12.5 |
| **St Marys** | T60 | Parking Lot Type Vehicle | N/A | 2.448 |
| **St Marys** | T10 | Parking Lot Type Vehicle | N/A | 2.448 |

| Agency | Truck ID | Truck Type | Number of Axles | Spreader Capacity (tonnes) |
|---|---|---|---|---|
| **West Perth** | Western Star #96 | Tandem | 2 | 12 |
| **West Perth** | International #85 | Tandem | 2 | 12 |
| **West Perth** | International #78 | Tandem | 2 | 12 |
| **West Perth** | Western Star #88 | Tandem | 2 | 12 |
| **West Perth** | Western Star #91 | Tandem | 2 | 12 |
| **West Perth** | International #75 | Tandem | 2 | 12 |
| **West Perth** | International #99 | Single Axle | 1 | 8 |

K

# Appendix K: Spreader Calibration

**Appendix K: Spreader Calibration**

Salt and sand spreading equipment includes mechanical, hydraulic and electrical components that control the of flow of solid and liquid material (if equipped) from a storage container on the truck to a discharge point onto the road. Typical components requiring adjustment includes a gate and auger or chain and spinner (for solids) or pump and nozzles (for liquids). The system requires adjustment to account for material properties such as solid grain size and weight; liquid viscosity; temperature effects on electrical or hydraulic motors, and; normal wear of mechanical parts through a season.[64][65]

The calibration procedure is a manual, trial-and-error process which can attain precision of approximately 5%. [66] Precision is limited by natural variations in the winter materials as well as precision of equipment function and the manual process. In practical experience, imprecision in spreading rates can be in the order of 30%. This impacts on material management, ability to complete a prescribed spreading route without reloading, and material management and accounting.

Spreader calibration is not required by MMS but is included in the TAC Code of Practice which recommends that spreaders should be calibrated at least annually at the start of winter season, for each material and application rate that is included in an agency's rules of practice. Lack of documented spreader calibration to an agency's defined material application rates can also impact defense of claims.

The cost of calibration for one spreader vehicle is ½ to 1-day vehicle rental and labour for an operator and calibration technician and requires a plywood box or bucket, stopwatch, and spring scale (**Figure K**).


**Figure K: Spreader Calibration Equipment (Clear Roads**

[64] http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Calibration-Guide.pdf
[65] https://clearroads.org/project/calibration-accuracy-of-manual-and-ground-speed-control-spreaders/
[66] MTO Maintenance Management Office, 2001, internal report, Tolerance of Spreader Calibrations

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