Salt Management Plans
"Braving Winter's Cold Shoulder in Renfrew County"

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ABSTRACT

The County of Renfrew recognized that a piece-wise approach to salt management would not work. Its efforts needed to be part of a bigger salt management plan that included proper diagnostic tools, detailed documentation of treatments, and education and training for its personnel. Such a plan would also need constant monitoring and updating as feedback was provided for operational staff. Starting in 2001, Renfrew embarked on an initiative to update its entire winter maintenance approach. At the same time, County road administrators began implementing some early winner projects. The approach worked. There were many benefits seen, including early improvements in salt consumption.

The County learned that planning and forecasting tools alone were not enough to achieve reductions in salt. Changes in approach and application were needed. The path to improved salt consumption involved many stages; these stages are discussed in this paper and are specific to the County of Renfrew.

The implementation of the County of Renfrew's Salt Management Plan encompassed eight stages that were executed between 2001 and 2003. Details of this plan are discussed in Section 4. Details of the benefits achieved by implementing this plan, including reduction in salt usage, winter maintenance costs, collisions, and fuel costs, are reviewed in this paper.

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Salt Management Plans – "Braving Winter's Cold Shoulder"

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1. Salt Management

In Canada, over $1 billion is spent annually on winter maintenance to keep roads safe and passable. In the County of Renfrew over $2-3 million is spent annually on winter maintenance. Snow and ice control is the key part of winter maintenance operations. Because of their cost, effectiveness, and ease of handling, road salts, particularly sodium chloride, are the preferred de-icing/anti-icing chemicals for maintaining winter roadway safety.

In the past, winter maintenance operators reacted to snow and ice by applying road salts after an event had occurred. This meant that the bond had already formed and additional salt was required. More and more, operators are proactively treating road surfaces prior to snow and ice events. This prevents the bond from forming and simplifies the mechanical removal.

The benefits of using salt on roadways have always outweighed the damaging effects to vehicles and roadside vegetation. As with all things, salt must be used in moderation. When used in excess, the potential side effects can harm the people and the very things it is trying to protect. Salt use should be carefully controlled and used as part of a larger plan. This plan should include proper tools and proven guidelines. Just as a doctor diagnoses a health problem, winter maintenance operators identify road problems caused by winter weather and develop appropriate treatments to remedy the situation. It is often helpful to use diagnostic tools and follow proven guidelines to ensure that the treatment is appropriate for the problem. For example, more salt being poured on a winter road will not make it safer. The first step to safer winter roads is an effective Salt Management Plan (SMP).

The road to success has been well mapped. TAC has been the leader in responding to Environment Canada (EC) requests for improved environmental stewardship. EC, together with TAC, assembled a task force that has developed, by consensus, a suitable and approved process for management of road salt.

TAC has, in turn, published numerous documents to assist road authorities in their winter maintenance efforts. The *Road Salt Snow and Ice Control Primer* provides an executive summary of the TAC project which was written for the public and underlines the significant role that salt plays in the provision of safe roads. The *Salt Management Guide (1999)* is the comprehensive reference guide providing details on all facets of Road Salt.

The *Syntheses of Best Practices for Road Salt Management* is a series of nine guidance documents related to management of road salts. As suggested in the Environment Canada *Code of Practice for the Environmental Management of Road Salts*, the approved guidelines for Salt Management, the syntheses deal with:

- Salt Management Plans,
- Training,
- Road and Bridge Design,
- Drainage and Storm Water Management,
- Pavements and Salt Management,
- Vegetation Management,
- Design and Operation of Road Maintenance Yards,
- Snow Storage and Disposal, and
- Winter Maintenance Equipment and Technologies.

2. County of Renfrew

2.1. Background

The County of Renfrew was formed in 1861 and is made up of 17 lower-tier municipalities. The County of Renfrew currently has its headquarters in the City of Pembroke.

The County of Renfrew is the largest County in Ontario, covering a total land area of 7,645.7 square kilometres. The County stretches from Ottawa westward along the Ottawa River to the northern tip of Algonquin Park. It is situated in the centre of the Ottawa Valley, a long trench formed during the last ice age along the Ottawa River between Quebec and Ontario. Because of how it was formed, Renfrew County can count among its physical features the Opeongo Hills, the Madawaska Highlands, deep valleys, limestone canyons, and over three hundred pristine lakes and four major river systems. Meteorology in the County is affected by the topography (rolling hills, mountains, deserted zones) and diverse vegetation.

The County is responsible for the winter maintenance of 812 km of roadway located within its boundary. The County is not responsible for the maintenance of local roads, sidewalks or parking lots within its boundary. As population increased, there was a greater need for quicker response to conditions caused during adverse winter weather. The initial response to this growing need caused a steady increase in salt consumption through the late 1990s. This increase raised budgetary and environmental concerns since much of the County relied on wells for domestic water consumption.

To address these issues, Renfrew County intended to adopt a salt management policy which committed the County to measurable improvements in its salt management practices.

2.2. Existing Conditions

Prior to the commencement of their salt management efforts, Renfrew County had prepared a well documented and approved set of guidelines which laid out their standard operating practices. The practices were as follows:

- Winter maintenance decisions were made based on observed conditions and publicly available forecasts from Environment Canada
- Winter maintenance procedures were based on the Minimum Maintenance Standards and Levels of Service as defined by provincial Ministry of Transportation. These guidelines included strict direction to not apply salt prior to an accumulation of ice on the roadway.

A summary of the average winter maintenance operations costs and values for the period prior to SMP commencement is provided in Table ١.

Table ١: County of Renfrew Pre-SMP Condition Summary

Annual Condition	**Average Annual Values (2000/2001 to 2002/2003)**
Collision Statistics (not including those involving animals)	214
Mass of Salt Used	12,900 tons
Mass of Sand Used	8,000 tons
Total Winter Maintenance Costs	$ 2,360,000
Time to Mobilize	Data not available
Greenhouse Gas Contribution	432,000 kg

3. Salt Management Initiatives

3.1. MFPA and the County of Renfrew

In 2000, the County of Renfrew recognized that pending legislated changes in environmental requirements for controlling road sale use were inevitable. They had also noticed a trend indicating increased salt use during winter maintenance. The Public Works Department pro-actively retained Mark F. Pinet & Associates Limited (MFPA) to review their winter maintenance activities and develop an appropriate strategy for addressing the salt consumption. This strategy became the County of Renfrew's Salt Management Plan.

The SMP set out a policy and procedural framework for ensuring that the County continuously improved its management of road salt. It also defined goals that would improve the County's salt management practices. The goals were as follows:

- Reduce salt consumption by up to 20-30% (EC),
- Lower collision rates by up to 75% (AASHTON), and
- Use money saved to reinvest in local infrastructure.

In addition to these goals, an important criterion stated that any modifications to the winter maintenance activities had to ensure that roadway safety and public mobility was not compromised. This dictated that monitoring would be a key part of their plan and, consequently, a Road Weather Information System (RWIS) was implemented. The purpose of the RWIS was to:

- Remotely monitor atmospheric and pavement conditions,
- Facilitate forecasting of pavement conditions, and
- Document the application and effectiveness of de-icing chemicals.

To secure funding for the RWIS implementation, the County submitted an application to the Federation of Canadian Municipalities' (FCM) "Municipal Green Enabling Fund" program. The FCM recognized the importance of monitoring performance improvements and conditionally granted the funding. The condition was that the County provide analysis and reports of a range of appropriate benchmark measures. The benchmark process and situational analysis employed in the SMP is outlined in *TAC's Salt Management Guide-1999*.

With the RWIS system in place, and a working SMP, the County was able to continue providing winter driving conditions consistent with the needs of the road system. At the same time, the County was minimizing the adverse effects of road salts on the environment. To meet these commitments, the County:

- Met and adhered to the guidelines contained within the SMP;
- Strived to review and upgrade, as necessary, the standards contained in the SMP on an annual basis to take into account new technologies and developments; and
- Worked with Environment Canada, other transportation agencies, and environmental groups to upgrade best winter practices, and commit to on-going staff training and education.

It was recognized that the delivered SMP would be a living thing. The principals that would guide the ongoing process to upgrade the SMP included:

- Periodic Review and Analysis of Industry Practices,
- Implementation and Documentation of the Plan,

- Education and Training of Staff,
- Monitoring and Analysis,
- Management Review,
- Environmental Review, and
- Practices and Policy Revision.

As anticipated, a review and update of the SMP was required in 2003 as a result of the EC *Code of Practice for the Environmental Management of Road Salts*. The main recommendations to the Code were:

- The development and implementation of Road Salt Management Plans which take into consideration all activities that potentially result in the release of road salts into the environment, such as storage, application of salt on roads, and disposal of snow containing road salts;
- The implementation of Best Management Practices related to these activities to protect the environment;
- The establishment of procedures to monitor and report on progress accomplished; and
- A review after 5 years to consider the level of implementation of Best Management Practices and to determine if other steps are needed to further prevent or reduce negative impacts of road salts on the environment.

In addition to allowing for changes to the Code, the 2003 SMP was able to build on the significant changes in approach and technology adopted by the County of Renfrew. Both the 2001 and 2003 SMP recommend that practices focus on improved handing, storage, and use. Both SMP's also developed strategic action plans that consisted of specific tasks and initiatives. However, in the 2003 SMP, operations monitoring played a larger role. In order to assess the effectiveness of the new approach, and to demonstrate the value of the investment, it was necessary to track salt improvements and ensure that the expected benefits were being achieved. This was to be done without compromising the other benchmark parameters.

3.2. Measurement and Performance Monitoring

Once in place, best management practices required road maintainers to tightly control and monitor salt use. RWIS technology had been recognized as a fundamental tool in managing road salt and providing maximum safety with minimum environmental impact.

To analyze the effectiveness of their salt management efforts, County road managers reviewed their year-to-year performance in salt consumption, winter maintenance costs, number of collisions, and fuel consumption. This analysis was then used to address funding questions from FCM.

The results of the SMP's implementation were highly anticipated. However, it was difficult to determine whether the performance had improved since every winter has a different severity. The weather is the primary factor affecting salt consumption, making yearly monitoring a challenge. Some municipalities use a five year rolling budget instead of a yearly one; this method does not reduce the challenge associated with winter maintenance costs.

The effects of global warming and changes in incident numbers and precipitation types and volumes do not help the municipalities in their winter maintenance cost performance reviews. The deployment of RWIS across Renfrew has helped reduce this challenge.

3.3. Winter Severity Index

Winter severity and, more importantly, the requirement to de-ice the roads is dependant on a number of factors. These include:

- The type, duration, and rate of precipitation;
- Moisture present, which could result in frost; and
- Pavement temperature fluctuations during the day which are influenced by:
    - cloud cover (which determines if road temperatures will rise above zero),
    - ground temperatures,
    - pavement temperatures, and
    - air temperatures.

RWIS provides continuous long term monitoring of these parameters. Without which Environment Canada data is of limited value in rationalizing salt consumption and year to year changes since it tracks a limited number of parameters. Sources of winter severity based data included:

Environment Canada

- Snowfall
- Daily mean temperature
- Daily max temperature
- Total precipitation (snow, rain, etc.)
- Relative humidity

County Records

- Salt purchased (annual, monthly, by district, by vehicle/storm patrol)
- Sand/salt used (annual, monthly, by district, by vehicle/storm patrol)
- Hours of operation
- Patrol records (start/stop of operations, type of weather, type of treatment)
- RWIS (only partial records for the period in question)
- Collision statistics

While the Renfrew salt management planning process was underway, TAC initiated a project to develop an appropriate Winter Severity Index. The TAC study team determined that a good measure of the winter severity was the salt consumption (i.e. the amount of salt used).

The initial review of the Renfrew data during the study revealed that salt consumption alone would not be a good indicator of winter severity since substantial changes were being made in the operations which would inevitably effect salt consumption.

4. Salt Management Plan

4.1. Phased Approach

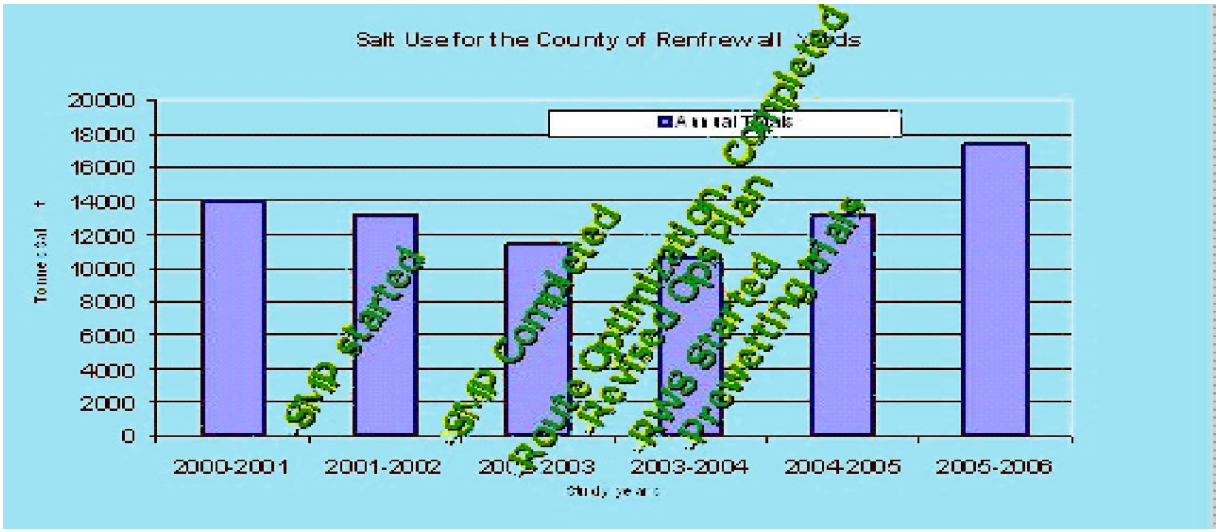
The general steps that MFPA undertook in creating the SMP for Renfrew County are as follows:

- Consulted management and staff and conducted field visits to perform audits (vehicles, patrol yards, consumption records, road tour);
- Completed gap analysis;
- Identified areas that were deemed to be deficient;
- Identified tasks to remedy the deficiencies in the identified areas;
- Established priorities to yield the maximum return on investment;
- Identified and prioritized specific projects requiring capital funding were identified and prioritized;
- Sought funding from Council, as well as, other sources (i.e. FCM);
- Presented plan to Management, Council, and staff for reviews and edits; and
- Finalized plan upon completion of revisions made by Council.

Updates to the best management practices as outlined in the April 4, 2004 publication of "*The Code of Practice for the Environmental Management of Road Salts"* and the September 2004 *"Implementation Guide for the Code of Practice for the Environmental Management of Road Salts"*, required the County of Renfrew to reemploy the services of Mark F. Pinet & Associates Limited. MFPA provided the County with an updated report detailing the new County of Renfrew Salt Management Plan.

Chronologically the Planning and Implementation of the County's strategy took place in a phased approach.

Stage 1	Salt Management Plan	2001-2002
Stage 2	Training	2001-2002
Stage 3	Winter Roads Condition Model	2001-2002
Stage 4	Route Optimization	2002
Stage 5	Road Weather Information System: 2 of 4 sites operating	2003
Stage 6	Pre-wetting started	2003-2004
Stage 7	Updated Salt Management Plan	2003
Stage 8	Revised Operational Plan	2003



4.2. Salt Management Training

The SMP, winter maintenance model, and RWIS site selection was completed with input from County management and staff. All field staff and management were provided with a basic Salt Management introduction to start off the planning for each stage. As each phase of the salt management implementation was commenced, affected field and management staff were provided with general salt management training in which the specific phase was described in the context of the overall plan. This training aided the staff participating in the planning and made them aware of the important parameters, and allowed MFPA to benefit from their field expertise. The presentations to staff provided background information in salt science, meteorology, sources of salt contamination, and reinforced the advantages of improved salt sensitive, proactive operational planning, and decision-support systems.

Management and staff were surprised that, even before the SMP was completed, and the measures implemented, initial successes were being seen in the County operations.

The ongoing phasing-in of the plan's tasks and the resulting presentations built on the information provided to the management and staff. As the plan evolved, so did the knowledge and understanding of the staff. It was because of these on going presentations, and the resulting change in approach by staff, that initial "early-winner" results were observed.

4.3. Winter Maintenance Road Model

The County of Renfrew had limited resources to allocate towards patrolling roads and towards winter maintenance decision making. Staff confirmed that they were regularly challenged in completing their duties. This was because there are numerous microclimates which exist in the County and weather patterns which are regularly different across the region. As such, a problem existed: how to determine the number of RWIS sites and ensure that they were representative of larger areas?

MFPA developed a GIS Winter Maintenance Road Model that allowed the team to determine the number of RWIS sites needed. It also determined which roads shared similar winter conditions and which required the same maintenance treatments. The primary objective in developing the County's Winter Road Model was to use it as a tool for selecting RWIS site locations; however, it was recognized that it could be used in the future for other purposes.

In order to develop an effective and representative model, a GIS model was developed. It illustrated all the roads in the area, road classification, and jurisdiction, as well as the topography of the total area. From this, and in conjunction with County staff, the typical weather patterns of a number of sub areas were determined. Once the GIS model had been completed, MFPA established representative zones based on a correlation of microclimates, representative roadways, and topography and superimposed the existing RWIS sites within the County and in the adjacent municipalities. They then superimposed data collection boundary limits and identified the need and general location of required RWIS sites

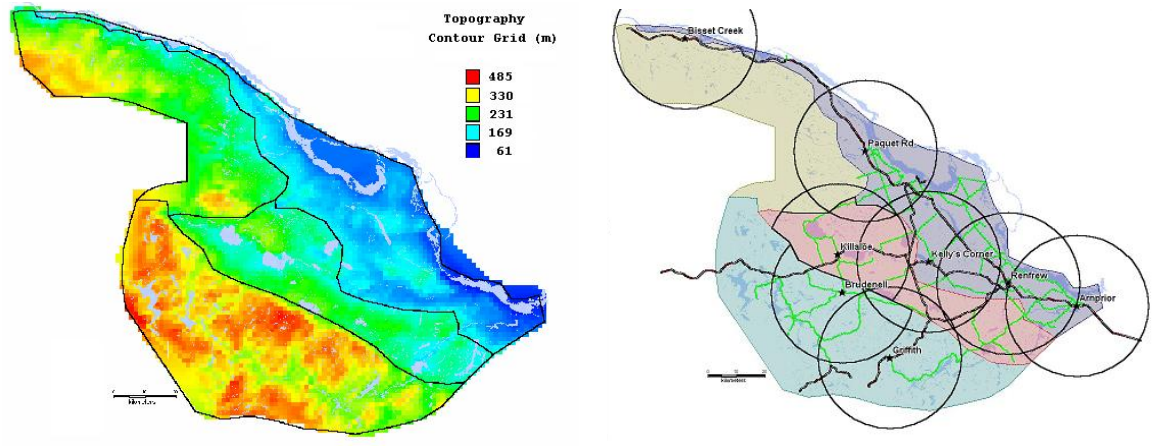


Figure ٢: Winter Maintenance Road Model – GIS Model and Radiuses

This model could be further built upon to analyze the effectiveness of winter maintenance activities and assess the specific risks associated with particular segments by importing other relevant data sets such as collisions statistics.

4.4. Route Modelling and Optimization

The County is continually challenged to reduce costs. Winter maintenance costs represent the larger portion of their maintenance costs which are made up of labour, material, and equipment. It is recognized in the industry that equipment costs represent one of the larger fixed costs and, because equipment must be regularly replaced, is an ongoing issue.

In an effort to reduce vehicle costs the County looked at the opportunity to better balance their route plowing and salting beats; however, they recognized that savings would only be achieved if vehicle numbers could be reduced from the fleet. The County had noticed that there was a significant disparity amongst the routes in terms of the route lengths and time to complete.

As a primary objective, the County first requested that the route lengths be balanced in terms of the time to complete. The second exercise was to look at the number of vehicles which were actually required to meet the County's minimum maintenance standards in terms of cycle time.

A route modelling and optimization application was developed as an add-on to the previously developed GIS Winter Maintenance Road Model.

The algorithms and processes were developed specifically for winter maintenance applications. Off-the-shelf Road Optimization software was not an option because it was

based on a courier pick-up model which could not optimize all points or segments along routes being serviced in both directions.

Existing routes and levels of service were first overlaid onto the County Road network. The optimization model was calibrated against existing route times and then the new routes were tested based on one two criteria: balancing route times or minimizing the number of routes while meeting minimum maintenance requirements.

Friction factors and delay times were developed to address signalized intersections. Intersections and interchanges were required where there were specific, customized, maintenance services.

The information from the maintenance road model allowed municipal staff to develop a new route model or optimize their existing model. The route model allowed staff to make decisions regarding the most cost effective manner in which to deploy their vehicles and to confirm the location of the patrol yards and material depots.

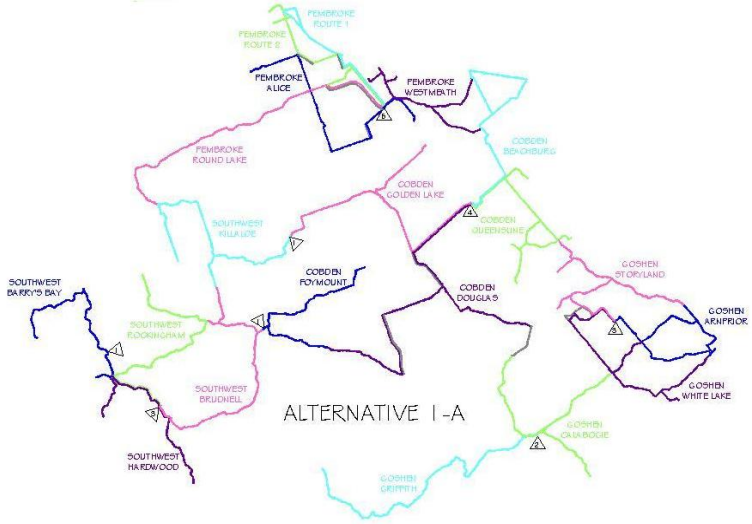


Figure ٣: Route Optimization Model

Several scenarios for optimizing the beats were able to be developed from the route model and three options were presented to the County.

Alternative 1	Balanced Runs (2-4 hours) resulted in reduction of longest run by 64 minutes
Alternative 2	Balanced runs eliminated 2/20 trucks and reduced dead head by 73 km
Alternative 3	Eliminated 3/20 vehicles, maintained council LOS objectives, and reduced dead head by 96 km

The theoretical best alternative (alternative 3) allowed reduction of the County fleet size by 15% while maintaining the same level of service permitted by council.

4.5. RWIS Deployment

The County undertook a strategic RWIS network planning exercise that combined information from the winter maintenance model and route optimization. Each segment of the road network was then assigned to a specific RWIS site. The design took into account RWIS data available from neighbouring jurisdictions. Information from the RWIS network enabled a more accurate forecasting of pavement conditions. This was necessary for proactive decision-making, as well as, supporting decisions related to more advanced technology, and approaches (i.e. pre-wetting) and MDSS. The plan specified the installation of four additional RWIS sites to address information requirements based on the identified meteorological zones. Two of the four sites were installed and operational in early 2003. Pavement-condition forecasts were available starting that year to assist the maintenance staff.

4.6. Pre-wetting

In the 1990's, Renfrew County staff experimented with pre-wetting. Unfortunately, the County did not have access to a great deal of information related to the material properties of de-icing chemicals. Nor did they have accurate forecasts of the pavement conditions. The trial results were unsettling and the County abandoned the trial. The following year all pre-wetting equipment was removed from the trucks.

After the trial all units were fitted with computerized spreader controls to regulate solid material application rates. These units are capable of being retrofitted for pre-wetting.

In the winter of 2003/2004, the County undertook a second pre-wetting trial. They had more confidence in their ability to obtain pavement conditions forecasts and a better knowledge of the pre-wetting approach, maternal science, technology, and knowledge as to effect of the weather on the chemical suitability. The trial involved a single-route controlled-trial on the Round Lake Beat. For this trial the County purchased one tandem combination truck and specified it to be fit up for pre-wetting. The County gathered data on the trial and hoped that the results would support and justify a larger scale deployment. This has been the case and they have expanded the project to fit up equipment on most of the vehicles and routes. In 2004, the County had retrofit ten of their tandem combination trucks to accommodate pre-wetting. Since 2003/2004 the County has completed the implementation of the Pre-wetting to their entire fleet.

4.7. Updated Salt Management Plan

In 2001 the County made their first attempt at completing a salt management plan based on the best available information from Environment Canada and the available mitigating measures and best practices prepared by TAC. Based on the finalized 2003 Environment Canada Road Salts Code of Practice, the County undertook an update of the previously completed salt management plan. This required minor changes and additions to the first plan to meet the new requirements.

The primary changes included developing a process to identify salt vulnerable areas and adding a dimension for monitoring and reporting results. The new report provided the County with an opportunity to document the work completed to date and, based on the previously identified priorities, review and outline the next steps.

The net effect was a plan, similar to the original, along with updated recommendations to ensure that the County of Renfrew would continue to move ahead and achieve success in their Winter Maintenance activities. The recommendations suggested that the County of Renfrew update its multi-year Action Plan.

4.8. Revised Operational Plan

As mentioned previously, planning alone is not enough to achieve salt reductions. Prior to embarking on the salt management process the County's council approved guidelines and processes which dictated the manner in which staff would approach storms. It provided details relating to mechanisms for detecting storms, reacting to storms, and reporting activities.

The previous operation plan was well documented, but as described in the following text and listed in Table ٢ (Appendix I), was reactive and mandated that personnel wait for precipitation before beginning treatment.

The previous guidelines were as follows:

Operational Planning

With regards to materials and equipment, the County had in place materials management, budget, and guideline information related to winter maintenance activities. This, in combination with staff knowledge and experience, provided for adequate winter planning in the pre-season from a material and equipment perspective. Material consumed and network expansions were tracked from year to year from a historical perspective and these records were used to perform macro level benchmarking of performance.

With regard to balancing route times, meeting prescribed levels of service, and ensuring coverage, staff was deployed from patrol yards located around the County. At several

locations, where necessary and practical, other jurisdictions or contractors maintained sections of the County network. The operators ensured that appropriate rates were programmed into the spreader control computers and that the chutes gates were appropriately set. The vehicle operators then set out and followed their prescribed routes.

The County employed Roadway Service Standards and a County GIS database to aid in operations planning.

Operational Control

The supervisors held the majority of control with regards to winter maintenance operations as they were the main decision-makers. On roads where the County provided the maintenance services, the County supervisors directed the approach and material application rates based on approved guidelines, communicating the information to the equipment operators; however, the spreader operators did have the capability to adjust and override application rates to respond to specific conditions in the field at the time of arrival.

Decision Making

Day-to-day decision making took place at the supervisor level. Supervisors made decisions based on the County's approved guidelines and procedures, which were laid out on the basis of existing pavement and forecast atmospheric conditions. Senior Management were available to assist. Patrol Supervisors monitored weather reports and atmospheric forecasts based on the available media, which included a customized Environment Canada Website.

Patrolling the road network was required, when warranted, to physically observe conditions. Based on the supervisor's observations, forecasts, and their joint experience the call would be made to mobilize or not. For the most part, infrared pavement temperatures sensors were not extensively employed.

Updated Operational Plan

The existing operational plan, although well documented, was premised on the basis of reacting to existing storm conditions and precipitation of events. This approach was now outdated. Council needed to be aware of and approve the staff's new approach to winter maintenance. It was necessary for staff to update the existing guidelines to reflect the changes in approach and to exploit the opportunities of new information and technology which had been advocated under the salt management plan. The new guideline was developed to take advantage of opportunities presented by pavement conditions forecasts and a new pre-emptive approach including treatments such as pre-wetting. The council approved guidelines and staff proceeded to implement their new mandate across the County.

The new operational plan took advantage of the new tools available.

Pavement temperature forecasts and trends based on RWIS data outputs also provided new and important decision-making support. Infrared sensors were fitted to monitor existing conditions on the patrol supervisors' vehicles.

The new guidelines were proactive and were specifically designed to take advantage of opportunities of new information and technology, such as, pavement condition forecasts. Suggestions for how to improve the previous guidelines were made and later became the new operational guidelines.

5. Results

The County of Renfrew implemented a Salt Management Plan but did it in conjunction with Staff Training, Winter Maintenance Road and Route Optimization models, as well as, revised Operations Guidelines.

The net results of these changes are listed below. Graphs illustrating these results, as well as, additional data are illustrated in **Appendix II**.

The tally is as follows:

Table٣: Material Use Trends for the Entire County of Renfrew (2000 to 2004)

Annual Condition	Average Annual Values (2000/2001 to 2002/2003)	Average Annual Values (2000/2001 to 2005/2006)
Collision Statistics (not including those involving animals)	214	210
Mass of Salt Used	12,900 tons	13,296 tons
Mass of Sand Used	8,000 tons	8,103 tons
Total Winter Maintenance Costs	$ 2,360,000	$ 2,412,895
Time to Mobilize	Data not available	Data not available
Greenhouse Gas Contribution	432,000 kg	Data not available

Initial results indicated that the County of Renfrew's Salt Management Plan was a success and would drastically improve their Winter Maintenance Operations.

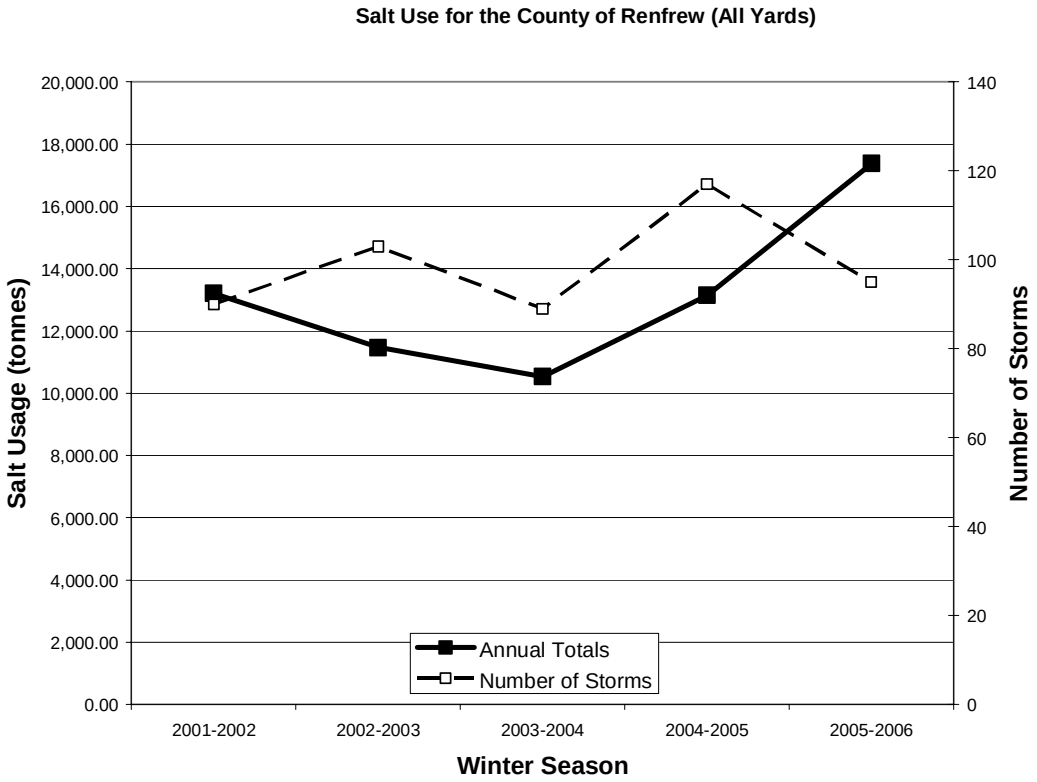


Figure 1: Salt Use for the County of Renfrew, all yards.

2001 – 2002 through 2003 – 2004

During the first three years the SMP was in effect, the County was making significant changes in its approach to salt management. This meant that the first three years of data can be used to determine general trends in the effectiveness of the SMP.

The number of storms in the 2001-2002 and 2003-2004 seasons was roughly equal. As seen in the above figure, the amount of salt used in 2003-2004 was significantly less than the salt used in 2001-2002. This trend supports the SMP.

2004-2005

2004/2005 was a more severe winter than had been encountered in the previous three years. The number of storms observed during this winter season was much higher, approximately 77% (117 storms), than those observed in the previous year (90 storms).As such, the salt consumption, which serves as an indicator of winter severity, increased as expected. The increase was more or less proportional to the increase in the number of storms; an indication that the practices outlined in Salt Management Plan were being properly followed.

2005-2006

At a glance, the winter season of 2005/2006, based on the number storms, should have had a winter severity consistent with the winter severity of first three winter seasons (2001/2002, 2002/2003, and 2003/2004) that were initially studied. However in reviewing the salt consumption for the winter season, there is a marked **increase** in volume of salt consumed relative to all previous years even though the previous years had seen a trend towards year-to-year reductions.

All things being equal (as they were without changes in approach) we would have expected salt consumption consistent with 2003-2004 and perhaps slightly above.

In looking at the records and discussing with staff, however, it was made clear that the winter weather during this season presented a significant challenge to maintenance staff. Although they were not plagued by an inordinate number of storms, the types of storms, the types of precipitation, and the temperature tracks through the storms presented a significant issue in terms of their ability to de-ice the roads.

The County staff indicated that it was indeed a severe winter in terms of the way that the storms occurred. They indicate that they had significant freezing rain events which were not observed in the surrounding areas (even in areas as close as Ottawa, only a couple of hours away). Storms typically started off warm and wet and then progressed to freezing rain followed by snow then a flash freeze. This resulted in significant consumption of salt to de-ice the hard pack which inevitably occurred.

This being the case it would be desirable to run the winter severity index for all five years to illustrate how it is a good indicator of winter severity.

6. Conclusions

Maintenance Decision Support Systems

The results are in! The investments made by Renfrew County have resulted in significant and measurable reductions in salt consumption, as well as numerous other benefits.

Salt Management Planning Makes a Difference

A comprehensive SMP increased the likelihood for success in the agency's effort to upgrade their winter operations. Tracking the year-to-year results using the supporting technology assisted in rationalization of the observed variances in salt consumption (i.e. winter severity). The overall reductions in usages and collisions in the County of Renfrew are testimony that an integrated approach to investing in upgraded winter maintenance can pay rich dividends.

Appendix I

Additional Tables

Table ٢: Guide of operations utilized for a typical storm

LEVEL OF SERVICE	CLASS I	CLASS II	CLASS III	CLASS IV
Primary Objective	Bare Pavement	Essentially Bare Pavement	Centre Bare Pavement	Snow Pack
Time to meet Primary Objective as soon as possible after the storm, not exceeding.	8 hours	16 hours	Centre Bare within 24 hours and essentially bare pavement when conditions permit.	24 hours
Salting				
Begin Salting when snow accumulation…	<0.5 cm	<0.5 cm	<0.5 cm	N/A
**Follow-up Salting	When Required	When Required	When Required	N/A
Plowing				
***Begin Plowing when snow accumulation…	<2 cm	<2 cm	<2 cm	<2 cm
Maximum single lane km/plow.	75 km	120 km	206 km	336 km
*****Maximum allowable accumulation.	<2.5 cm	<4.0 cm	<5.0 cm	<7.0 cm
Sanding	Slippery Condition	Slippery Condition	Slippery Condition	Slippery Condition
Begin Sanding…	When Required	When Required	When Required	When Required
**Follow-up Sanding	****	****	****	8 hours

Appendix II

Additional Figures

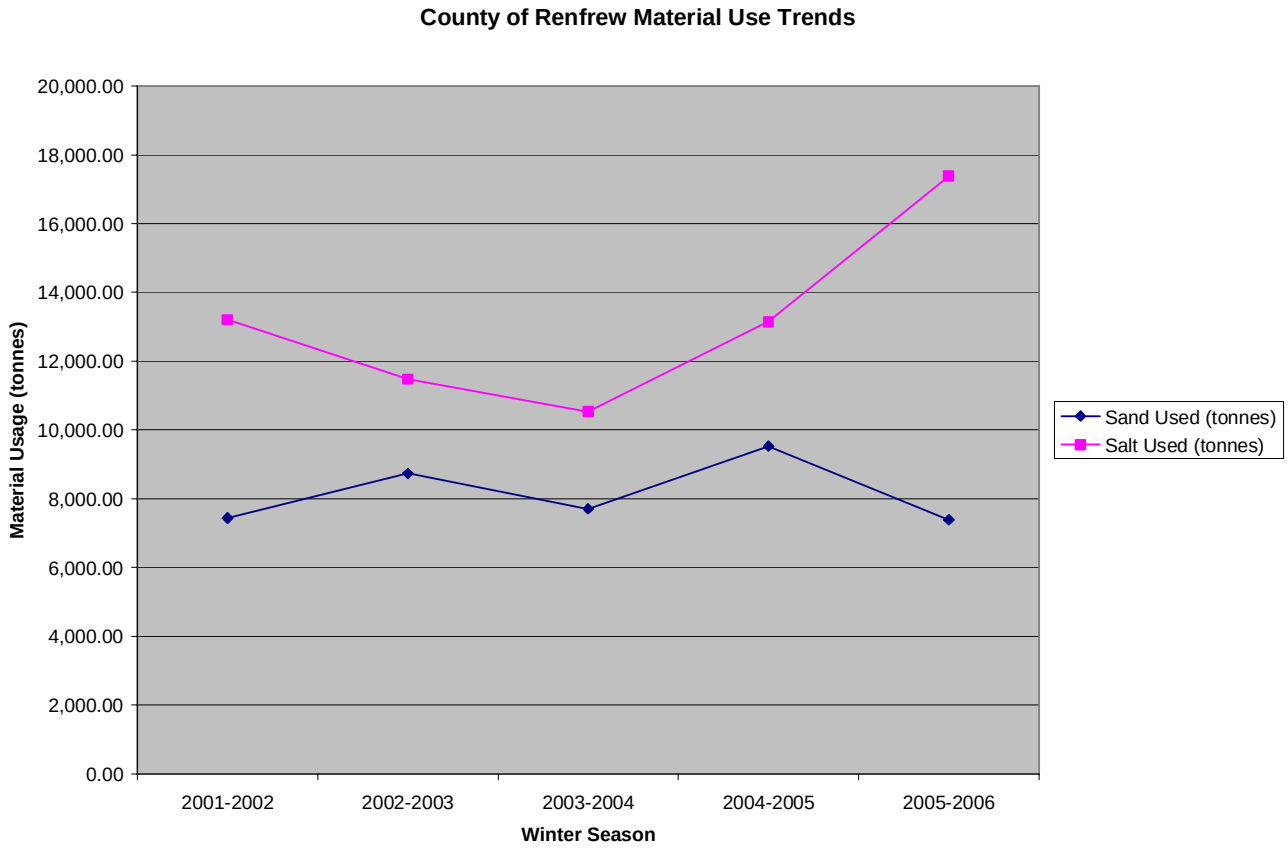


Figure ۴: Winter road material use trends for the County of Renfrew for the winter seasons 2000-2001 to 2003-2004.

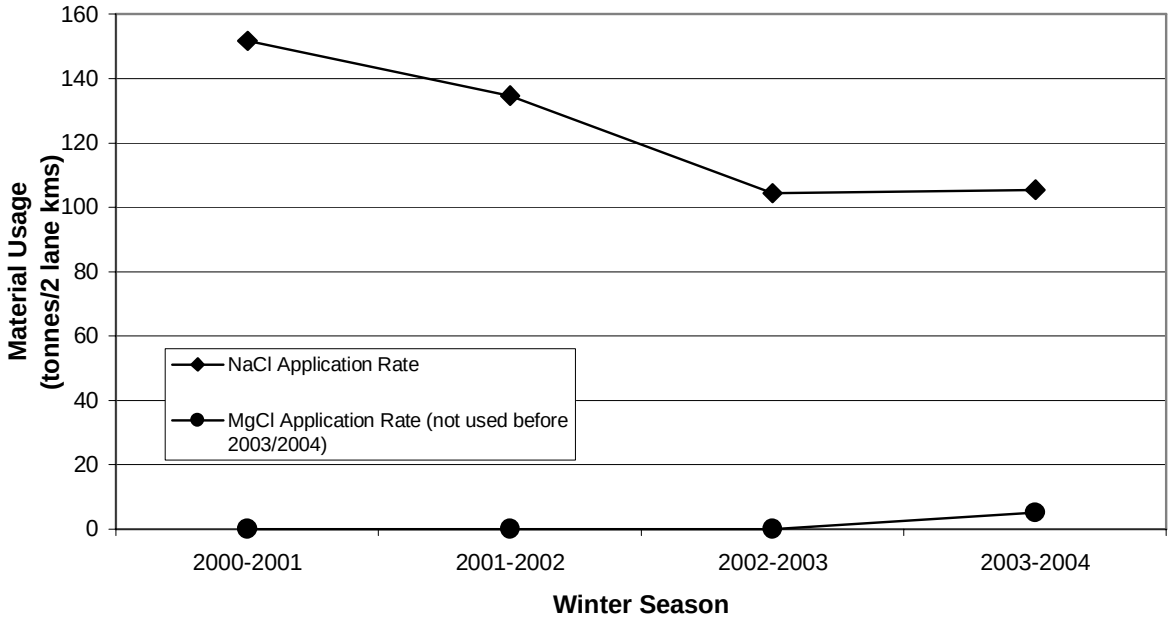


Figure ٥: County of Renfrew road salt application rates for the winter seasons of 2000-2001 to 2003-2004.

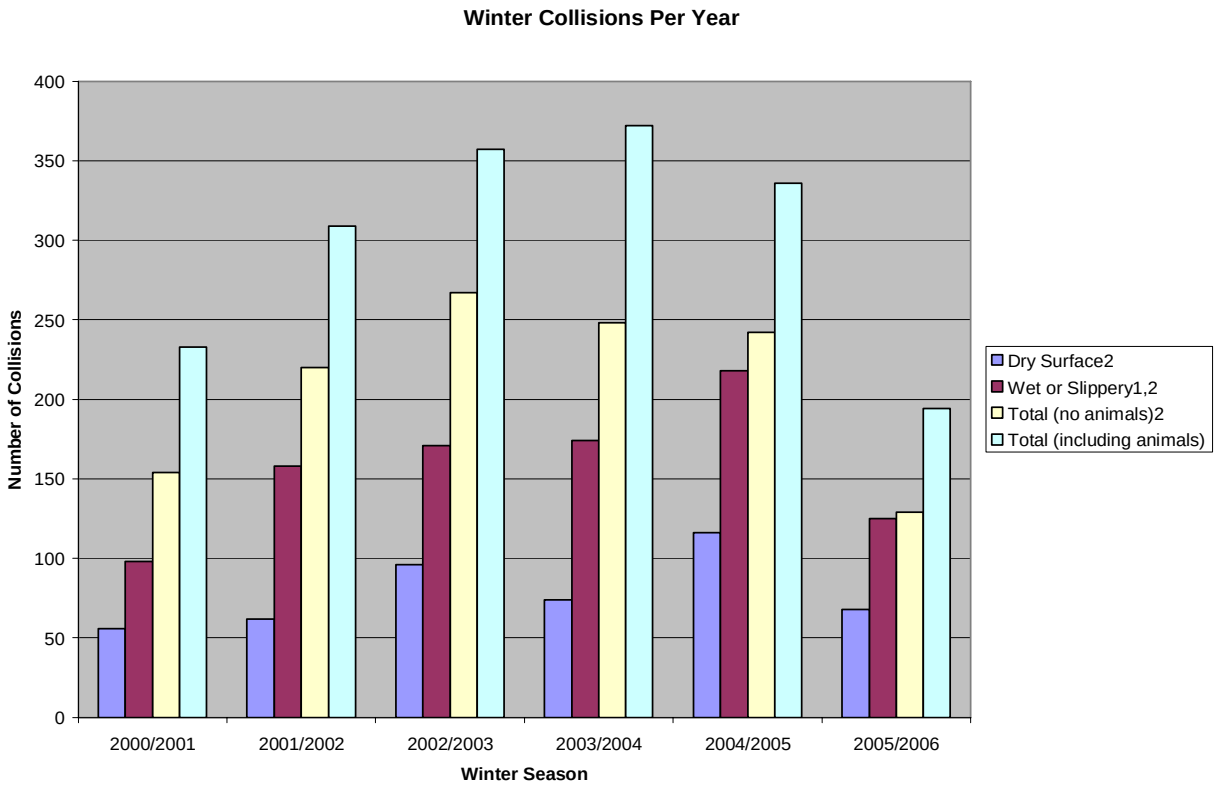


Figure 6: County of Renfrew Winter Season Collisions for 2000-2001 to 2005-2006

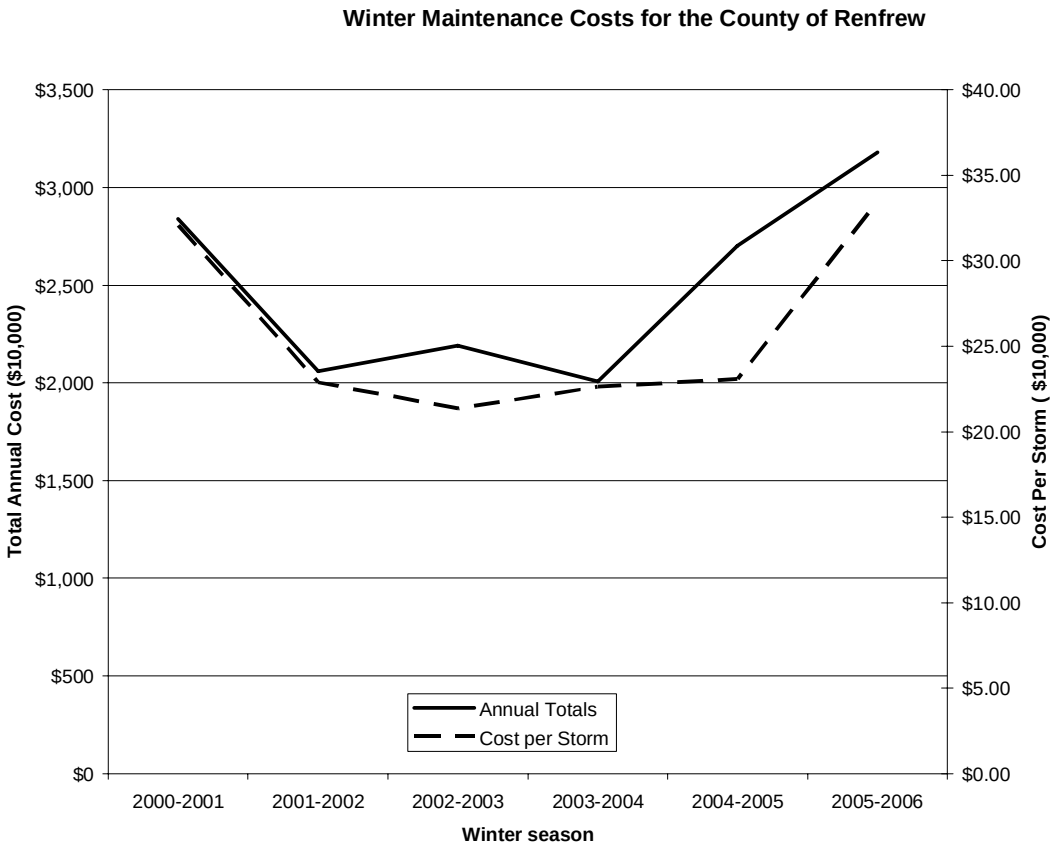


Figure V: County of Renfrew Winter Maintenance Costs 2000-2001 to 2005-2006

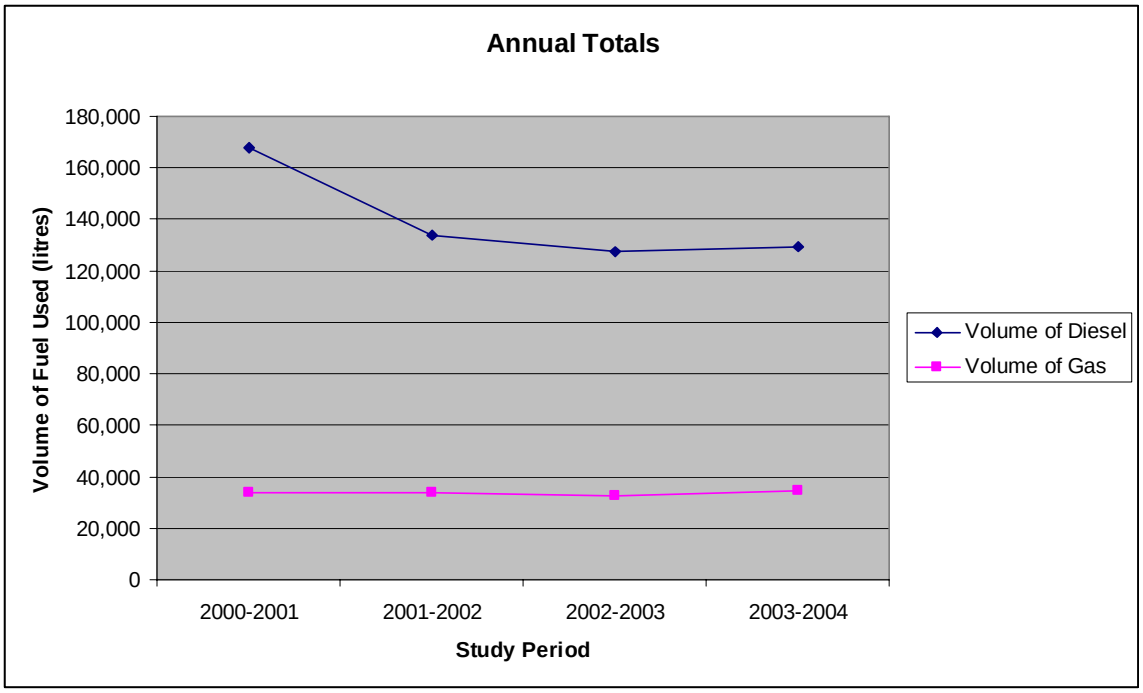


Figure ٨: County of Renfrew Winter Maintenance Fuel Consumption for 2000-2001 to 2003-2004

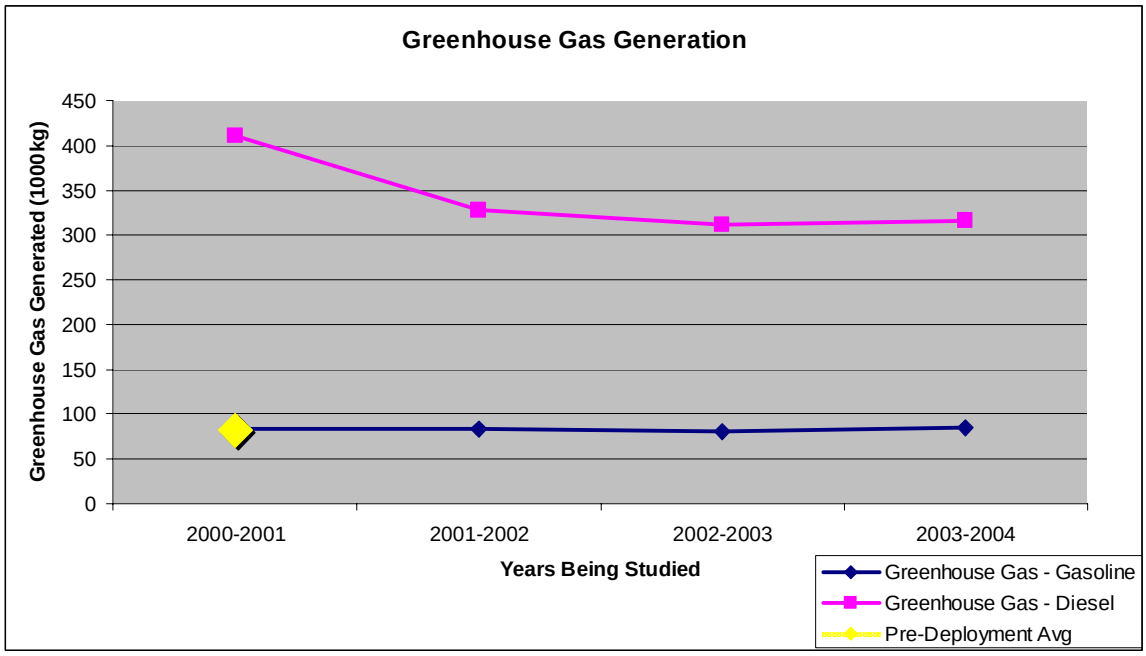


Figure ٩: County of Renfrew Winter Maintenance Greenhouse Gas Generated for 2000-2001 to 2003-2004