Pothole Study - Patching Methods and the All-In-One Pothole Patching Machine Update

Presented To:	Operations Committee
Meeting Date:	December 11, 2023
Type:	Correspondence for Information Only
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Report Summary

This report provides information regarding the final phase of the pothole study and the utilization of the All-In-One Pothole patching machine.

Relationship to the Strategic Plan, Health Impact Assessment and Community Energy & Emissions Plan (CEEP)

This report is consistent with Council's Strategic Plan with respect to the goal of conducting research, benchmarking and experimentation to ensure road maintenance practices reflect appropriate best practices.

Financial Implications

There are no financial implications associated with this report.

Background

Potholes create challenges for all communities across North America. If left unmanaged, potholes could lead to costly impacts for motorists and road authorities. The City of Greater Sudbury (CGS) has been continually looking for solutions to mitigate the pothole problem. The most recent such endeavour was initiated following a harsh winter season in 2018/2019, that realized the number of potholes rise sharply as compared to that of an average winter season. Pothole generation in Greater Sudbury generally increases during the winter months when conditions are ideal for pothole formation due to cold, wet weather and numerous freeze / thaw cycles. Table 1 provides an approximate quantity of potholes patched over the past six winter seasons.

Table 1

Winter Season	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023
Potholes Patched	103,450	161,500	104,700	70,700	132,550	106,700

Potholes typically form when the asphalt pavement is weakened through pavement age, damage and exposure to a combination of freeze / thaw cycles and traffic loading. Road construction projects completed in the summer months can largely resolve pothole generation. To bridge the time between a deteriorating pavement surface and a road construction project, the CGS takes a threefold approach of maintaining its road network. This is achieved by conducting Preventive Maintenance (ex. crack sealing), Holding Maintenance (ex. large spreader laid patches) and Corrective Maintenance (ex. pothole patching).

The CGS patches potholes in accordance with Ontario Regulation 239/02, commonly referred to as the Minimum Maintenance Standards (MMS). The MMS prescribes minimum requirements for pothole patching based on road class. Higher class roads such as Paris Street or Falconbridge Road require patching more frequently than lower class roads such as Robinson Drive or Jeanne D'Arc Street, Hanmer. This patching standard is a requirement regardless of weather conditions or resource availability.

Although pothole patching only provides temporary relief to a distressed pavement surface, there are three main components to the patching operation that can provide maximum longevity of a patch. Namely, using the ideal type of patching material, equipment and methodology. Focusing on winter patching operations, staff began a series of informal studies that reviewed each of these pothole patching components. A presentation to Operations Committee on June 15, 2020, entitled "Pothole Repair Study - Material Testing", indicated that the most cost-effective material available to the CGS during the winter months was recycled asphalt pavement (commonly referred to as RAP) produced at the City's Frobisher Depot. A subsequent report presented to Operations Committee on August 10, 2020, entitled "Pothole Patching Equipment Report", reviewed the various types of equipment (including the All-In-One Pothole Patching Machine) available for the pothole patching operation.

This report provides a conclusion to the CGS's informal pothole study by reviewing the most effective pothole patching methodologies used in Greater Sudbury and comparing them to other municipalities across Canada. The report also provides an overview of the CGS owned All-In-One Pothole Patching Machine (APPM).

Winter Pothole Patching Methods

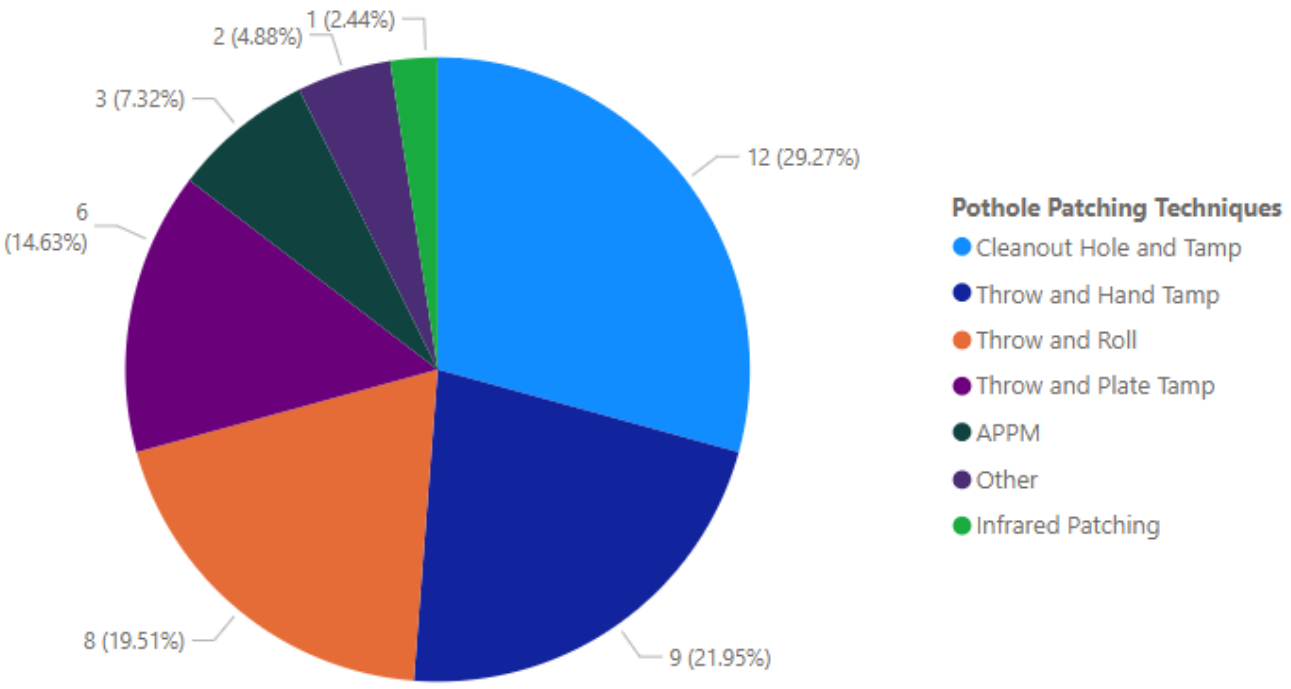
Pothole Patching Survey

The CGS recently conducted a survey of pothole patching methodologies used by 15 Canadian Municipalities (listed in Table 2), including some from Northern Ontario (Timmins, Sault Ste. Marie, Thunder Bay and North Bay). Similar to the CGS, the results indicate that all surveyed municipalities use multiple different patching methods to repair potholes. This is indicative of varying winter weather and resource availability. As depicted in Figure 1, all surveyed municipalities use manual patching crews, 50% of which utilize the "Clean and Tamp" and "Throw and Tamp" methodologies. Both of these methods are also commonly utilized within the CGS.

Table 2 - List of Participating Municipalities

Greater Sudbury	Niagara Region	Halifax, NS
Timmins	Waterloo	St. Johns, NL
North Bay	Windsor	Regina, SK
Thunder Bay	York Region	Edmonton, AB
Sault Ste. Marie	Durham Region	Hamilton

Figure 1 - Common Municipal Patching Techniques



Clean and Tamp Method

The “Clean and Tamp” method typically involves a three to five-person crew using a heated material transportation device (more commonly known as a hot box) or flatbed truck to transport patching material from a maintenance depot to a road where potholes need patching. Using a broom, the crew will first sweep away loose particles then fill the pothole with patching material and compact it with either a plate tamper or hand tamper. Depending on the size of the pothole, it may take anywhere from one to five minutes to complete a patch using this method.

Figure 2a – Clean Pothole with Broom

Figure 2b – Unload Patching Material from Hot Box

Figure 2c – Place and Shape Material

2d – Compact Material

This is the most common patching method utilized in Greater Sudbury. Cleaning the pothole prior to placing and compacting patching material maximizes the bond between the pothole and the patching material which leads to greater longevity of the patch. However, this technique is most suitable when conditions are dry.

Throw and Tamp Method

The “Throw and Tamp” method typically involves a three to five-person crew using a hot box or flatbed truck to transport patching material from a maintenance depot to a road where potholes need patching. The crew will fill the potholes with patching material and compact it with a plate tamper or hand tamper (used if plate tamper is not available or for small patches). Depending on the size of the pothole, it may take anywhere from one to five minutes to complete a patch using this method.

This method is typically utilized when the road is wet and where adequate cleaning of a pothole is not possible (ex. difficult to keep water and debris away from potholes). Rather, water is displaced by applying patching material to the pothole. Not cleaning a pothole reduces the bond between the pothole and patching material, which reduces the longevity of the patch. Although it is clearly less effective than the “Clean and Tamp” method, its utilization is sometimes necessary to meet the MMS and maintain safe motor vehicle passage during inclement weather conditions (ex. snow, rain and ponding).

Figure 3a – Patching in a Wet Environments

Figure 3b – Patching in a Wet Environments

Throw and Roll Method

The “Throw and Roll” method (sometimes referred to as “Throw and Go”) typically involves a three to five-person crew using a hot box or flatbed truck to transport patching material from a maintenance depot to a road where potholes need patching. The crew will fill the potholes with patching material, level / shape it with a shovel and use the tires of the transport vehicle to compact the material rather than using a plate or hand tamping device. The method also partially relies on vehicular traffic to provide some of the compaction effort. Because truck tires do not apply adequate / uniform compaction to patches, partial failure of patches commence relatively quickly. Therefore, patch longevity is typically minimal with this method, especially in a wet environment with multiple freeze / thaw cycles. For these reasons, the City rarely utilizes this method for pothole patching. However, this method has been used with moderate success in areas where favourable weather conditions are common and when treating small potholes.

Figure 4a – Throw and Roll Patching

Figure 4b – Partial Failure of Patches

Infrared Patching

Infrared Patching typically involves a three-person crew utilizing an infrared attachment on a municipal tractor to heat a small section (ex. 4 feet x 6 feet) of damaged pavement such that the pavement material becomes malleable. Additional material is added (as necessary) to the malleable pavement, spread and compacted with a plate tamper or asphalt roller to complete the patch. Although deemed to be effective for pothole patching, this method is extremely time and energy consuming. A typical patch requires more than 30 minutes depending on the size of pothole and ambient temperature. Therefore, the City does not utilize this method for winter pothole patching. Rather, this method is used in the summer months to repair pavement damage surrounding maintenance holes and catch basins.

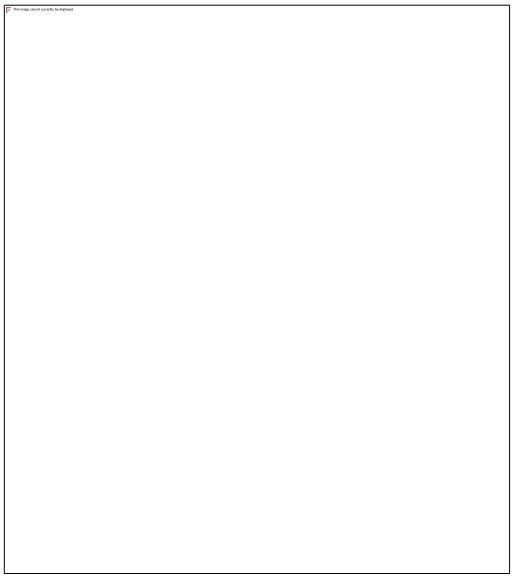
Figure 5 – Infrared Patching in Summer

Patching with the All-In-One Pothole Patching Machine (APPM)

The APPM can dispense a variety of different types of materials to patch potholes. The unit only requires a single operator for its function. Depending on road configuration, additional traffic control personnel and safety devices are required. It can carry about 5 metric tonnes (MT) of patching material and keep it warm (similar to a hot box) throughout the patching operation which maximizes the materials effectiveness. It uses compressed air to clean debris from potholes, applies patching material via a telescoping boom, shapes the patch with an onboard raking mechanism and compacts the material with a hydraulic roller.

Patches completed by the APPM have generally demonstrated greater longevity than other pothole patching methods used by the City but is a significantly slower operation. A more detailed overview of the APPM is provided further in this report.

Figure 6 – CGS Owned APPM



Pothole Study – Patching Methods

The objective of the pothole study – patching methods, was to determine the most effective pothole patching methods available for use in Greater Sudbury during the winter months. For the purpose of this report, only the “Clean and Tamp” (further separated into “Clean and Plate Tamp” and “Clean and Hand Tamp”) and APPM patching methods were analyzed as they are known to produce the most favourable pothole patching results. Although applicable under certain circumstances, all other methods described above are known to produce less favourable results during winter operations and therefore were not included in this study.

Patch Testing Parameters

The pothole patching study was completed during the 2022/2023 winter season in general accordance with the Transportation Association of Canada (TAC) “Best Practices for Pothole Repairs in Canada”. The test strip comprised of a series of large potholes located on the northbound lanes of the Paris Street Bridge. The potholes varied in size (average of 9 feet x 2 feet x 2 Inches deep) and were deemed to have resulted from delamination (separation of the surface and base layers of asphalt) occurring on the wheel path close to the longitudinal pavement joint. The APPM, a manual labour crew with a plate tamper and a hand tamper was used to patch potholes in this study with recycled asphalt pavement (RAP) produced at the Frobisher Depot.

The patches were observed over the course of a two-week period in March of 2023. This is typically deemed to be the height of the pothole season in Greater Sudbury. Environment Canada data indicated that Greater Sudbury received approximately 5.5 mm of rain, 24.6 cm of snow and 5 days of freeze / thaw cycles during the observation period (March 8 – 22, 2023).

Findings of the Study

At the conclusion of the two-week observation period, all three patching techniques utilized resulted in less than 30% of the patching material being lost. The deterioration was largely found along the edges of the patches where bonding is expectedly minimal (difficult to compact new malleable material against existing hard pavement). As shown in Table 3 below, the APPM had the least amount of material loss with the manual labour crew using a plate tamper and hand tamper having increased amounts of material loss.

Table 3

Patching Method	**Performance Description**	**Percent of Material Loss**
APPM	Very slight material loss at edges	10%
Manual Crew with Plate Tamper	Slight material loss at edges	15%
Manual Crew with Hand Tamper	Moderate material loss at edges	30%

Patch deterioration is largely dependent on weather (ex. precipitation and freeze / thaw events) and road conditions (ex. pavement age, existence of standing water and traffic volume). In general, the combination of weather and road conditions present during the observation period was deemed highly conducive to patch deterioration and pothole formation. Still, all three patching methodologies performed reasonably well. In fact, from a depth of pothole perspective, the observed deterioration did not reach a state, as outlined in the MMS, that would warrant an immediate repair of the patches.

Throughout the observation period, patch deterioration was deemed to be gradual. Assuming that patches have to be repaired once a material loss of 30% has been reached, through linear interpolation of the results, patch longevity the APPM, manual crew with a plate tamper and hand tamper would have lasted for six weeks, four weeks and two weeks respectively. Therefore, APPM patches were deemed to have a longevity of 1/3 (33%) more than the most effective manual patching methodology used in the study.

However, the relative success of all the patch methodologies can be attributed to the lack of standing water (commonly referred to as ponding) within the test strip. Ponding would have expedited the freeze / thaw process and provided less favourable results under the same remaining conditions. A similar interpolation (as noted above) of patch longevity would not necessarily apply if ponding was present. In this instance, the absence of ponding is indicative of good roadside drainage due to adequate crossfall of the road surface and open catch basins. A series of documented photographs in Figures 7 through 9 depict the before and after condition of the patches completed by the APPM and the manual patching crew using a plate tamper and hand tamper.

Figure 7 – Patching with the APPM

Prior to Patching

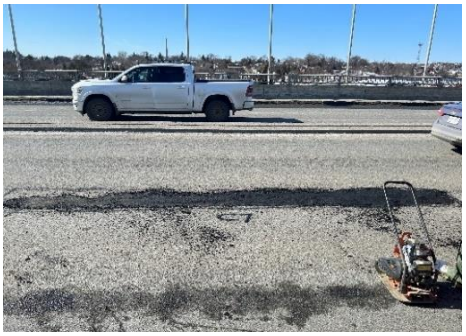
Day of Patching

2 Weeks after Patching

Figure 8 – Manual Labour Crew Patching with Plate Tamper

Prior to Patching

Day of Patching



2 Weeks after Patching

Figure 9 – Manual Labour Crew Patching with Hand Tamper

Prior to Patching

Day of Patching

2 Weeks after Patching

Given that all patches within the test strip were subject to the same general conditions (ex. same patching material used under the same weather and traffic conditions), it is concluded that the only variable with the application of patching material was the compaction effort. Greater compaction resulted in greater longevity of patches. The APPM provided the greatest compaction (weight of the machine's frontend applied to patch), followed by the manual crew using a plate tamper (approx. weight of 120 pounds / 55 Kg applied to patch) and hand tamper (approx. weight of 16 pounds / 7 Kg applied to patch), respectively. The compaction methods used are depicted in Figure 10.

Figure 10a – APPM Roller

Figure 10b – Plate Tamper

Figure 10c – Hand Tamper

All-In-One Pothole Patching Machine Overview

On March 11, 2021, the Finance and Administration Committee (Resolution FA2021-24-A21) approved a business case entitled “Purchase of All-in-One Automated Pothole Patching Machine” (APPM). Soon after delivery in December of 2021, the APPM was deployed for service in January of 2022. It has now been in operation for nearly two years. As noted in the report, the APPM completes higher quality patches compared to other pothole patching methods. In addition, staff have identified benefits and areas for improvement with the APPM which are categorized into four headings below.

Impacts of Weather

Although able to work in all seasons, the APPM’s best performance was observed during the summer months. Because it utilizes several critical fluids (ex. lubricants sprayed on belt and roller components to prevent material sticking / clumping) that begin to gel or freeze during extreme cold conditions, it was determined that the APPM requires more cleaning and maintenance when temperatures are colder than -10 degrees Celsius. As is the case with all pothole patching methods, the APPM is not utilized during snow, rain or ice related events. Pothole patching is ineffective under these weather conditions and crews typically address other maintenance activities during this time. Over the course of ownership, there were approximately 128 days when temperatures were too cold and / or too wet for the APPM’s optimal use.

Operational Challenges and Opportunities

Similar to the vactor, paint truck and street sweeper, the APPM is a highly specialized and complex piece of equipment which requires a great deal of operator expertise for optimal use. However, operator longevity on the APPM has been somewhat inconsistent, partly due to few employees being comfortable operating the unit in live traffic while using sophisticated controls. Operation of the APPM by less experienced operators has led to improper patching (ex. creation of bumps and excess material being left on road), reduced productivity and equipment downtime due to improper cleaning and operation of the equipment.

The APPM was also found to be susceptible to damage when traveling long distances. At the outset of its use, the APPM was deployed to the outlying areas of Greater Sudbury (ex. Capreol, Azilda and Chelmsford). However, it often resulted in various mechanical issues by traveling long distances at posted speed limits. To mitigate this situation, the travel speed of the unit was reduced, and its operation limited to the city core.

Commencing in the spring of 2024, staff will seek out dedicated operators for the APPM. Understanding that the unit requires a high degree of skill and experience for optimal operation, a dedicated operator is expected to reduce operator errors and increase familiarity which is anticipated to result in less equipment downtime and increased utilization and productivity. Staff will also explore opportunities to float or trailer the APPM to the outlying areas to further increase utilization of the unit.

Servicing Challenges and Opportunities

The APPM has been out of service due to mechanical reasons for approximately 127 days over the course of 21 months (January 1, 2022 – September 30, 2023) of ownership. A large portion of that downtime was spent waiting for parts from the manufacturer which is largely attributable to widespread supply-chain delays experienced by the industry in recent times and exacerbated by the fact that the APPM is a proprietary machine and it is not easy to find replacement parts elsewhere. To improve this situation, Fleet Services have recently procured the services of local vendors to fabricate custom parts to expedite repairs to the APPM. Notable repairs to date included the exhaust, suspension, brakes, hydraulics, front conveyor belt and electrical components.

Recent communications with the supplier of the APPM have increased staff’s confidence that the supplier is committed to improving support services as well as to investigate and upgrade equipment concerns raised over the course of ownership. Staff have already implemented better tracking of equipment downtime related to weather and servicing delays which should expedite troubleshooting necessary to optimize the APPM’s utilization.

Summer Operations

When operational, the APPM performed admirably during the summer months. Locally available hot mix asphalt was exclusively used in the summertime operations. All patches completed in the summer provided significantly more longevity than those completed during the winter months. This is mainly due to the availability of hot mix asphalt and operation under ideal weather conditions.

The APPM was utilized on all maintenance road classifications throughout the summer months. An objective of summer operations was to determine how to maximize the units' utilization. In addition to its standard pothole patching operation, trials were conducted to use the APPM with a small grinder crew, conduct shoulder edging and asphalt overlays. Some of these alternate applications are depicted below.

Figure 11a – Paving behind "Small Grinder" Crew

Figure 11b – Asphalt Overlay

Comparison with the Other Northern Municipalities

The City of Timmins (ownership since 2021) and the City of Thunder Bay (ownership since 2017) have also made investments in APPM machines. The CGS has collaborated with both municipalities over the past few years to compare and learn from each other on how to optimize the APPM's performance. Table 4 provides a municipal summary of the APPM's performance in 2023 (Data gathered for the Period of Jan. 1 – Sep. 30, 2023).

Table 4

Municipality	No. of Units Owned	Years in Use	Days Used in 2023	Approx. Utilization Rate in 2023 (%)	Quantity of Material Placed in 2023 (MT)	Production Rate in 2023 (MT/Day)	Primary Winter Patching Material	Primary Summer Patching Material
CGS	1	2	42	59%	95	2.0	RAP	Hotmix
Timmins[1]	1	3	65	70%	100	1.5	Coldmix	Hotmix
Thunder Bay	1	6	120	63%	350	2.9	Coldmix	Hotmix

[1] Stats provided are only for the summer months.

During the winter months, the City of Timmins utilizes their APPM only during mild and dry days. Understanding the importance of operator familiarity and the daily maintenance and cleaning requirements needed for optimal operation, Timmins assigns two dedicated operators to their APPM.

Much like the CGS, the City of Thunder Bay utilizes their APPM on a year-round basis, except during inclement weather. However, unlike the CGS, only cold mix products are utilized during the winter months.

Thunder Bay assigns two to three experienced operators for regular use of their APPM. Staff familiarity with the maintenance and cleaning requirements has led to improvements in utilization and productivity. They noted that most mechanical issues related to their APPM was a result of operator error.

During the course of ownership (January 1st, 2022, to September 30th, 2023) the City's APPM was utilized on 126 days. This equates to a utilization rate of approximately 70% of the time it was available for use, which is generally consistent with reports from Timmins and Thunder Bay. However, because CGS crews attended to greater than normal flood mitigation and street sweeping activities in 2023, utilization of the City's APPM decreased to just 59% in 2023 (January 1st to September 30th, 2023).

There was a total of 459 days when the APPM was not utilized due to inclement weather, equipment downtime and scheduled days off. Table 5 provides a summary of the APPM's utilization over the course of ownership.

Table 5

		Period of Ownership	
CGS APPM's Availability for Use	**Reason**	**Total[1]**	**2023[2]**
Available	Days Worked	126	46
	Days not Worked (ex. crews addressing flooding, sweeping and other priorities)	53	32
	Total Days Available	**179**	**78**
Unavailable	Days not Worked - Inclement Weather	128	60
	Days not Worked - Repairs and Parts Delay	127	49
	Days not Worked - Weekends and Holidays	204	86
	Total Days Unavailable	**459**	**195**

[1] Refers to the period between January 1st, 2022 and September 30th, 2023.
[2] Refers to the period between January 1st and September 30th, 2023.

As with the City, both Timmins and Thunder Bay have experienced significant delays in parts delivery. However, for the most part, the equipment vendor has been attentive to troubleshooting issues as they arise. All three municipalities have noted the importance of extensive operator training, machine cleaning and maintenance as crucial components to the successful operation of the APPM. It is estimated, that during an eight hour shift, approximately 1.5 to 2 hours of daily cleaning is required for optimal operation of the unit.

Overall, daily production rates for CGS are comparable to those of the City of Timmins and the City of Thunder Bay, who have had ownership of their respective APPM's for a longer duration. Through lessons learned from our northern neighbours and planned improvements identified within, it is staff's expectation that APPM production rates can be increased.

Conclusion

A pothole study completed last winter reviewed the most effective pothole patching methodologies used in Greater Sudbury. From a longevity perspective, potholes patched under similar conditions using the All-In-One Pothole Patching Machine (APPM) outperformed the most effective manual patching crew by approximately 33%. It was determined that the APPM's ability to apply better compaction to patches, as compared to a manual patching crew using a plate tamper and hand tamper, was attributable to its better performance.

However, manual patching crews are far less costly (approximately $700/MT) as compared to the APPM (approximately $1,500/MT), over the course of ownership. The high operating cost of the APPM is due in large part to significant periods of downtime (nearly 500 days over the course of 21 months) associated with inclement weather, repairs, service delays, scheduled days off for staff and staff addressing other maintenance priorities such as flood mitigation and street sweeping. When considering performance and operating costs together, the APPM is approximately 40% less cost effective than a manual patching crew.

Therefore, the APPM would have to apply an additional 100 MT of patching material (approximately 220 MT in total) compared to its current annual average output of 120 MT, to be cost effectively equivalent to a manual patching crew. Increasing utilization through lessons learned from within and through our northern Ontario municipal partners should improve material output by the APPM. However, until such time that the cost effectiveness of the APPM is deemed to be equivalent to a manual patching crew, it is not recommended that the City invest in additional APPM units.

Potholes form through a combination of weather and road conditions which vary from year-to-year. To adapt to the peaks and valleys of pothole formation, the City has developed a robust pothole patching program that includes a variety of patching methodologies completed through manual crews (including on-demand contract services) and the recently acquired APPM. The manual patching crew's cost effectiveness and versatility is deemed crucial for managing potholes in Greater Sudbury as it is in other municipalities across Canada. Staff will continue to use professional judgement, investigate and consider new technologies and methods for pothole patching as appropriate. This includes exploring ways to increase utilization and productivity of the City owned All-In-One Pothole Patching Machine.

Resources Cited

Report presented to City Council on September 14, 2021, entitled “Tender ISD 21-149 for All-In-One Automated Pothole Patching Machine”: https://pub-greatersudbury.escribemeetings.com/filestream.ashx?DocumentId=41792

Report presented to Operations Committee on August 10, 2020, entitled “Pothole Patching Equipment Report”: https://pub-greatersudbury.escribemeetings.com/filestream.ashx?documentid=39458

Presentation to Operations Committee on June 15, 2020, entitled “Pothole Repair Study - Material Testing”: PowerPoint Presentation (escribemeetings.com)

Minimum Maintenance Standards: https://www.ontario.ca/laws/regulation/020239

Transportation Association of Canada (TAC) – “Best Practices for Pothole Repairs in Canada”, July 2019