Promoting Sustainability in Infrastructure Through Quantifying Reclaimed Asphalt Pavement – An Ontario Municipal Case Study

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Abstract

More than 6.5 million tonnes of asphalt is used annually in the maintenance and construction of new roads in Ontario municipalities. The use of reclaimed asphalt pavement (RAP) in road construction, has been proven to provide sustainable structures without affecting the integrity of virgin materials. Currently, in Ontario, only two-thirds of municipalities allow the use of RAP in the mix design of asphalt pavements, and most of those municipalities only use it in the base course layer. Promoting such sustainable approaches to infrastructure would lead to cost-effective spending on infrastructure, sustaining resources of virgin materials and would also result in limiting greenhouse gas emissions through reducing asphalt consumption and through utilizing locally available recycled materials. This paper aims to provide quantification of the current amount of RAP available in the province of Ontario, as well as provide trends of RAP consumption.

An environmental scan of the province was conducted to obtain a database of RAP stockpile locations across Ontario. Volume measurements were conducted by using Google Earth Pro Software package. Additional calculations were conducted to estimate tonnage quantities of RAP. The RAP inventory and the trends of RAP consumption resulted from this study would help in the decision making for steering the infrastructure towards more sustainable use of available materials.

Introduction:

Each year the milling and rehabilitation of asphalt pavements generate large quantities of waste materials. Those materials are then reclaimed, processed and reused in the maintenance and construction of new pavements. These recycled materials are referred to as reclaimed asphalt pavement or RAP. The processed RAP is used in different aspects of road building and maintenance activities, but RAP's recycling value would only be maximized when it used in hot mixes where the properties of the recycled aggregates as well as the asphalt cement are effectively utilized. Use of RAP in infrastructure include:

- New road construction
- Rehabilitation
- Road shoulders
- Granular base/subbase layers
- Stabilized base/subbase layers
- Gravel roads
- Embankments and fill materials

The earliest efforts in recycling asphalt concrete into new pavement constructions consisted of pulverization of existing pavement to use in new subbase layers. Earliest records of this recycling practice were in the 1960s in Nevada as well as Ontario, and 1975 in Texas (Clark et al., 1978; McLuckie et al., 1987). Since then, the use of recycled hot mix asphalt (RMH) was introduced to the infrastructure industry and gained widespread acceptance in North America. In 1979, the Ministry of Transportation Ontario (MTO) implemented its first efforts to adopt recycled hot mix asphalt as a standard pavement recycling alternative (McLuckie et al., 1987). The use of RAP in hot mix continued to gain acceptance and shortly became adopted in all 50 states of the USA in 1982. Currently, in the United States, an approximate 98% of all milled pavements were reclaimed, and 96 million tonnes of RAP were used and in 2017, making RAP the most recycled material in North America (Williams et al., 2018).

In the past years, there has been a growing awareness towards sustaining aggregate resources (EBA Engineering, 2013; Ministry of Natural Resources Ontario, 2010). According to The Ontario Aggregate Resource Corporation (2014), approximately 153 million tonnes of aggregates are produced each year in Ontario, out of which, 50% is used in the maintenance and construction of infrastructure in Ontario. This gives RAP the potential to be a significant contributor to aggregate sustainability. In addition to saving valuable diminishing aggregate resources, using RAP in infrastructure contributes to the following:

- Recovering non-renewable petrochemical resources
- Reducing road building costs
- Diverting large amount of solid waste from landfills
- Reducing greenhouse gases emissions

This paper aims to provide quantification of the current amount of RAP available in the province of Ontario, as well as historical trends of RAP consumption. Such information may be used to facilitate decision making and strategic planning towards sustainability in infrastructure which falls within the government's mandate to manage Ontario's natural resources and ensure they are available for the use of current and future generations.

Methodology:

Quantification of current available unprocessed RAP in Ontario, as well as the percent change in RAP quantities over 10 years, were conducted using Google Earth Pro software package. Mention of RAP in the methodology and results sections refer to unprocessed RAP. The following points are a breakdown of the methodology used in this study.

A. Environmental Scan

RAP is mostly stored in stockpiles located near asphalt plants. The *Producers & AC Suppliers* publicly available list compiled by the Ontario Asphalt Pavement Council (OAPC) was used to trace all possible storage locations of RAP stockpiles in Ontario. A database of RAP stockpile locations and company names was created.

RAP stockpiles were located visually using Google Earth Pro. A general understanding of the process of reclaiming, storing, and processing of asphalt pavement was found to provide valuable insights in identifying stockpile from satellite images. Such insights are shown in **Figure 1** and listed in the following points:

- In locations where a quarry is part of the plant, RAP stockpile is usually located close to the asphalt mixing plant for logistics.
- RAP stockpiles tend to be flat on the top with paths of dump trucks vs. pyramid shaped stockpiles of virgin materials and processed RAP.
- Unprocessed RAP stockpile (before crushing) has inconsistent black colour and is located near smaller stockpiles of processed RAP with more consistent black colour

B. Measurements and Estimation

Volume measurements of RAP stockpiles were conducted by measuring the base area of the stockpile and multiplying it by the average elevation height of the stockpile. The 3D Polygon tool in Google Earth Pro was used to measure the base area to an accuracy of $1m^2$. To measure the elevation of the stockpile, a grid was generated using the software's Path tool to allow for capturing the elevation profile of the stockpile and obtaining the average height. This method provides an approximate volume measurement for RAP stockpiles, **Figure 2**.

Due to lack of literature on the density of unprocessed RAP, we relied on field expert input from the Ontario Good Roads Association's Hot Mix Liaison Committee where the assumed density of 2,200 kg/m^3 was used in this study to estimate the quantity of RAP (in tonnes) in a given stockpile.

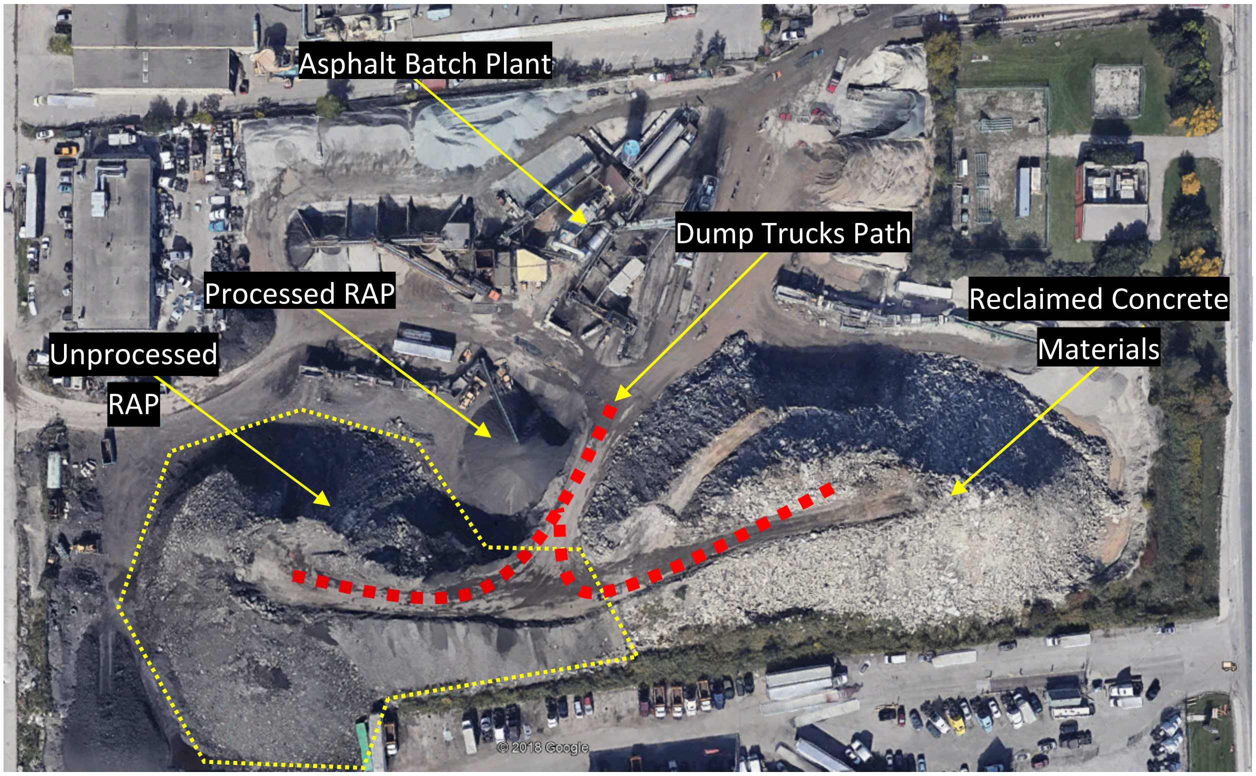

Figure 1 Satellite image illustrating means to visually identify unprocessed RAP stockpile (Furfari Paving Plant #2, 5830 Dixie Road, Mississauga, ON L4W-1E7).

A. Historical Progression of RAP Quantities

The progression of RAP quantities over 10 years was captured indirectly by measuring the stockpile's base area in four different years. Percent change in the base area of each stockpile was calculated to capture the historical progress of RAP quantities in the desired locations. Measuring quantity progression in tonnage was not possible since direct measurements of elevation were only accurate in the most current time period in Google Earth Pro. In other words, elevation can be accurately obtained for the most recent (2018) satellite images only.

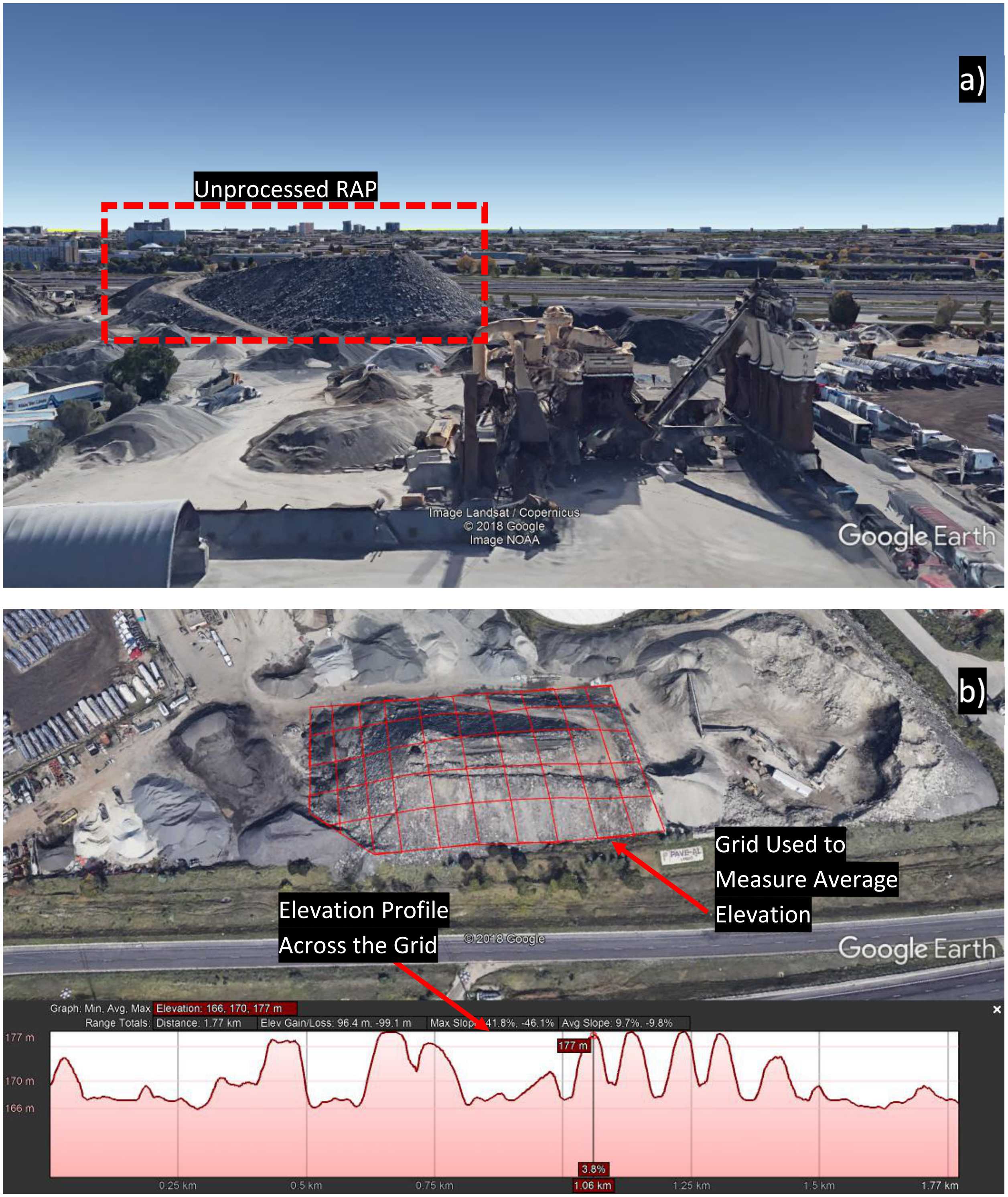

Figure 2 Pave-Al Ltd. Asphalt Plant, a) Side view of unprocessed RAP stockpile, b) Top view of unprocessed RAP showing measurement grid and elevation profile.

Results and Discussion:

A. Environmental Scan:

In this study, Ontario was divided into five zones (Northern, Southeast, Southwest, and Central) as presented in **Figure 3**. The scan resulted in identifying 114 potential RAP storage locations in 78 different municipalities in Ontario. Locations with poor data were also identified as a limitation in this study. 25% of the sites identified in this study were found to have poor data which comprised of irregularities in elevation information in the software or low-quality satellite images where accurate measurements were not attainable.

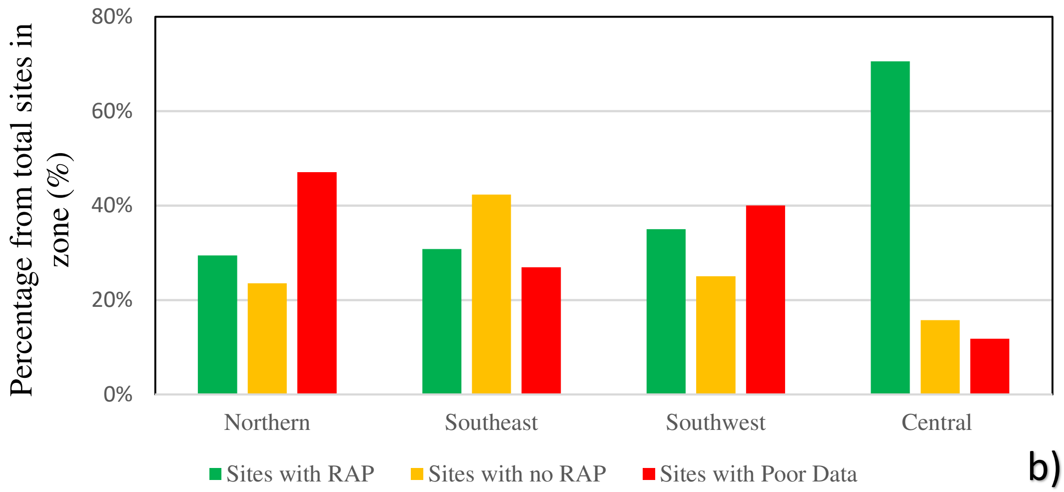

Figure *4* presents the breakdown of RAP data in Ontario.

Figure 3 Ontario zone breakdown

Table 1 and **Figure 4** display the breakdown of RAP data according to in the regional zones recognized in this study. The central zone accounted for the majority of sites which contain RAP stockpiles. Specifically, out of the total of 56 sites containing RAP stockpiles in Ontario, 36 were located in the central zone. 47% of identified locations in the northern zone contained poor data, which is the highest percentage compared to the other three zones. This may be a result of the low population concentration in municipalities located in the northern zone, which may be a factor in Google's prioritization of image quality and data gathering. It was also noted that the percentage of sites containing no RAP was consistent between all zones except for the southeastern zone. 42% of all sites located in the southeastern zone contained no RAP.

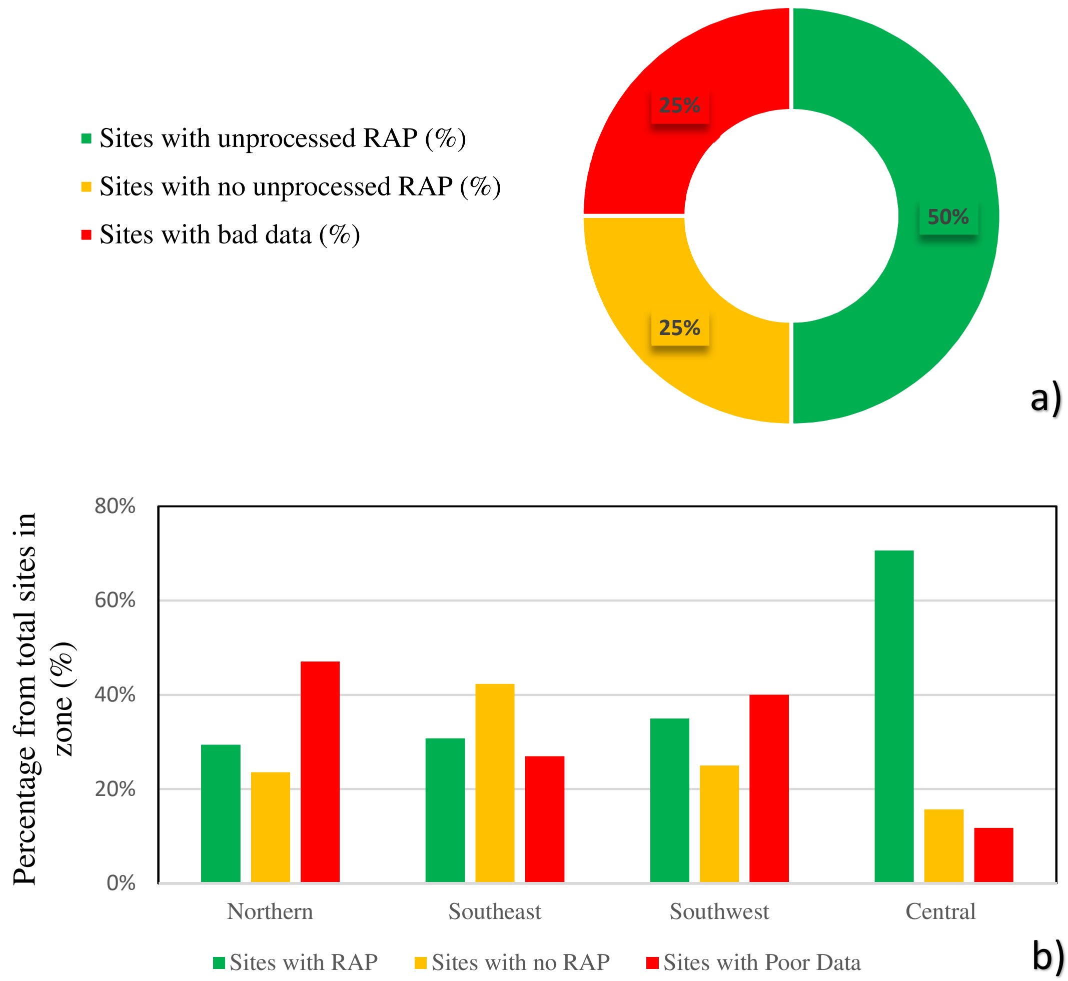

Figure 4 Breakdown of data collected through Google Earth Pro software. a) Breakdown of collected data over the entire province, b) Breakdown of the collected data according to the geographical zones recognized in this study

Table 1 Breakdown of data collected by geographic zones

	Northern	Southeast	Southwest	Central	Province Wide
Identified Sites (site)	17	26	20	51	114
Sites with RAP (%)	29	31	35	72	50
Sites with no RAP (%)	24	42	25	16	25
Sites with poor data (%)	47	27	40	12	25

B. Measurements and Estimation:

Volume measurements for each stockpile were multiplied by the assumed RAP density (2,200 kg/m^3) to estimate the available RAP quantity. The estimated RAP tonnage in Ontario in 2018 was

4.3 Million Tonnes. This value is an underestimate since missing data was accounted for 25% of the total identified sites in this study. **Table 2** and **Figure 5** present the breakdown of available RAP in Ontario.

It was noted that two-thirds of Ontario's available RAP were located in the central zone, while the northern zone contained the lowest percentage of Ontario's available RAP (4%). These values can be explained by the difference in population density between the two zones, which affects road construction and therefore, pavement reclamation. Population density of the four zones is graphically presented in **Figure 6**.

Table 2 Breakdown of available RAP according to geographical zones

	Northern	Southeast	Southwest	Central
Available RAP (Tonnes x 10^6)	0.19	0.75	0.57	2.79
Percentage from Total RAP in Ontario (%)	4.4	17.5	13.2	64.9

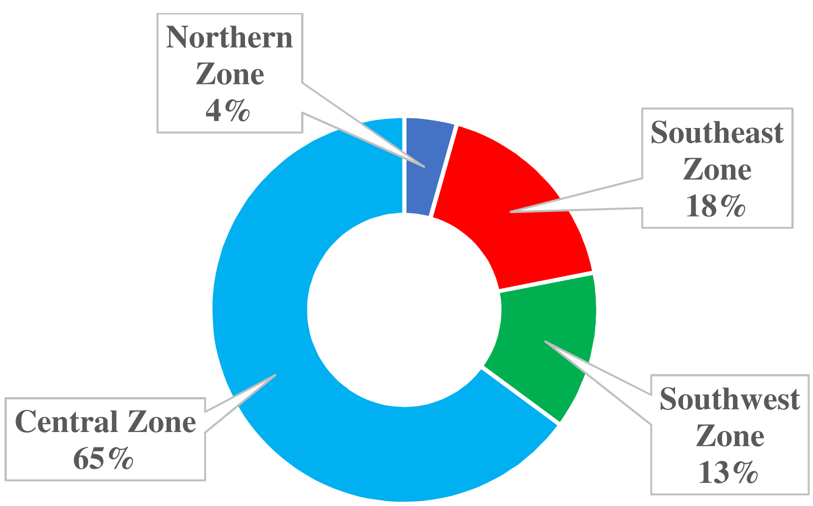

Figure 5 Percentages of total available RAP in Ontario located in each zone

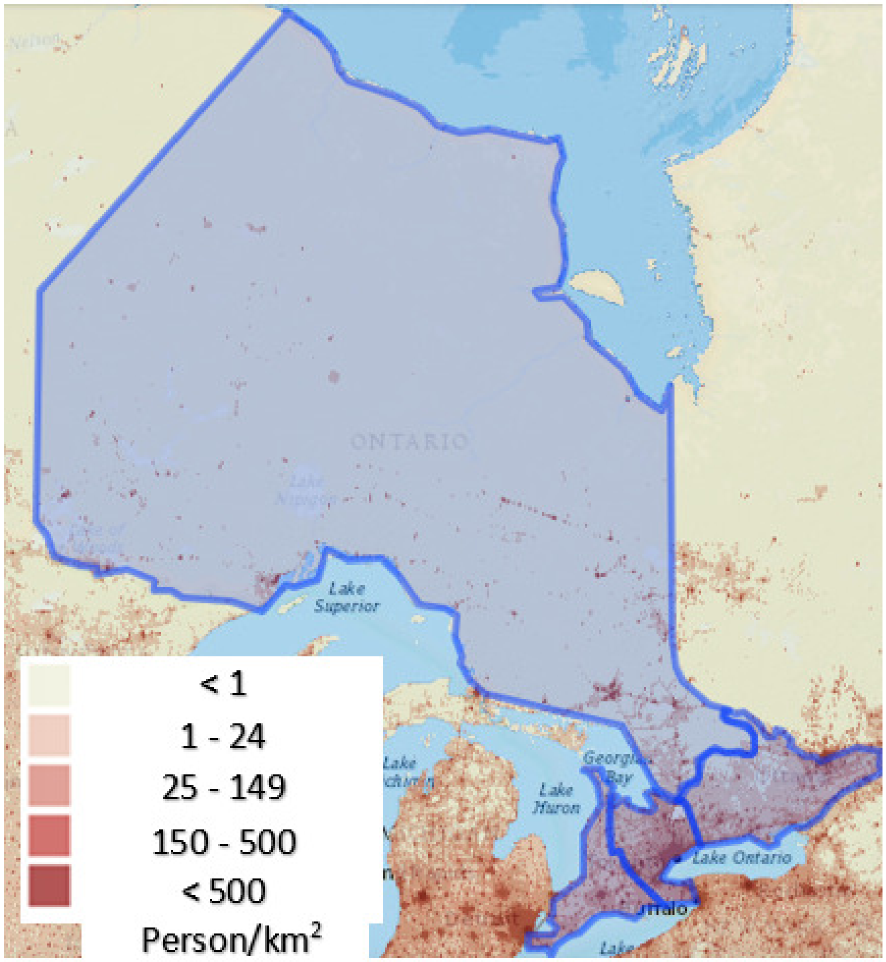

Figure 6 Population density map showing higher density in Central Zone compared to Northern Zone. Data retrieved from Oak Ridge National Laboratory, (2017)

C. Historical Progression of RAP Quantities:

Contrary to Ashtiani et al., (2019), it was found that Google Earth Pro had limitation in its measurements tools when attempting to obtain historical data. Therefore, an indirect method was followed to quantify percent change in RAP. The percent change was captured through measurements of percent change in stockpile base area over four different time periods (2018, 2016, 2013, and 2009). To validate the accuracy of this method, we plotted the 2018 measurements of stockpile base area against tonnage which showed a high correlation between the two metrics. The high correlation suggests that we can make observations of RAP quantity based on the base area of the stockpile.

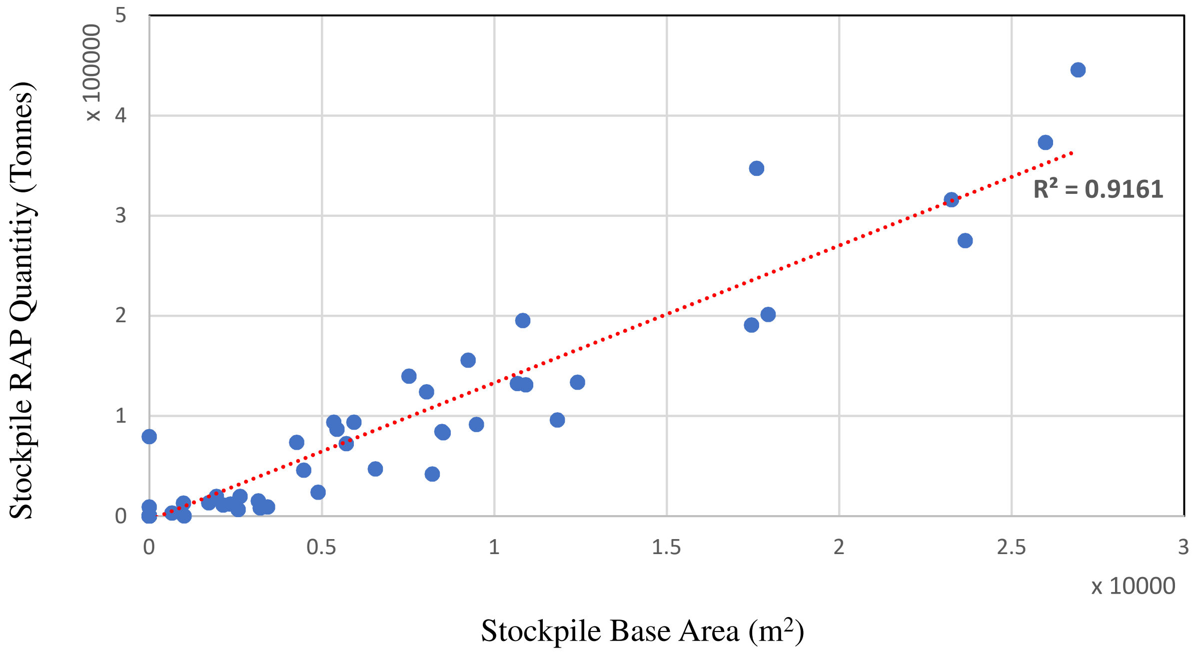

Figure 7 Correlation between stockpile's RAP quantity and its base area

One geographical zone was selected for this part of the study (Southwest Zone). 20 sites were identified in the Southwest Zone. Based on the historical data, an upward trend of 91% increase in stored RAP was observed over the past ten years in the southwest zone of Ontario. The upward trend was also true for individual municipalities along the southwest zone except for two townships, **Figure 9**. Town of Putnam and Town of St. Jacobs experienced downward trends in RAP quantities since 2013 (decrease of 46% and 25%, respectively). Such downward trends may suggest an increase in RAP usage in the area.

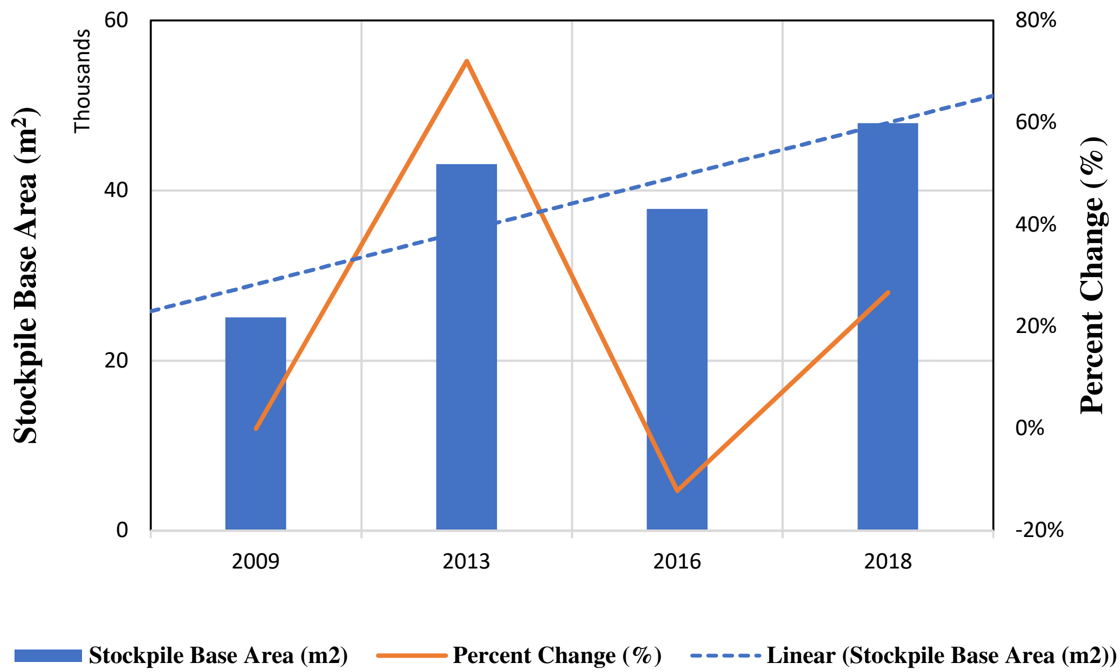

Figure 8 Historical trends in RAP quantities in southwest Ontario

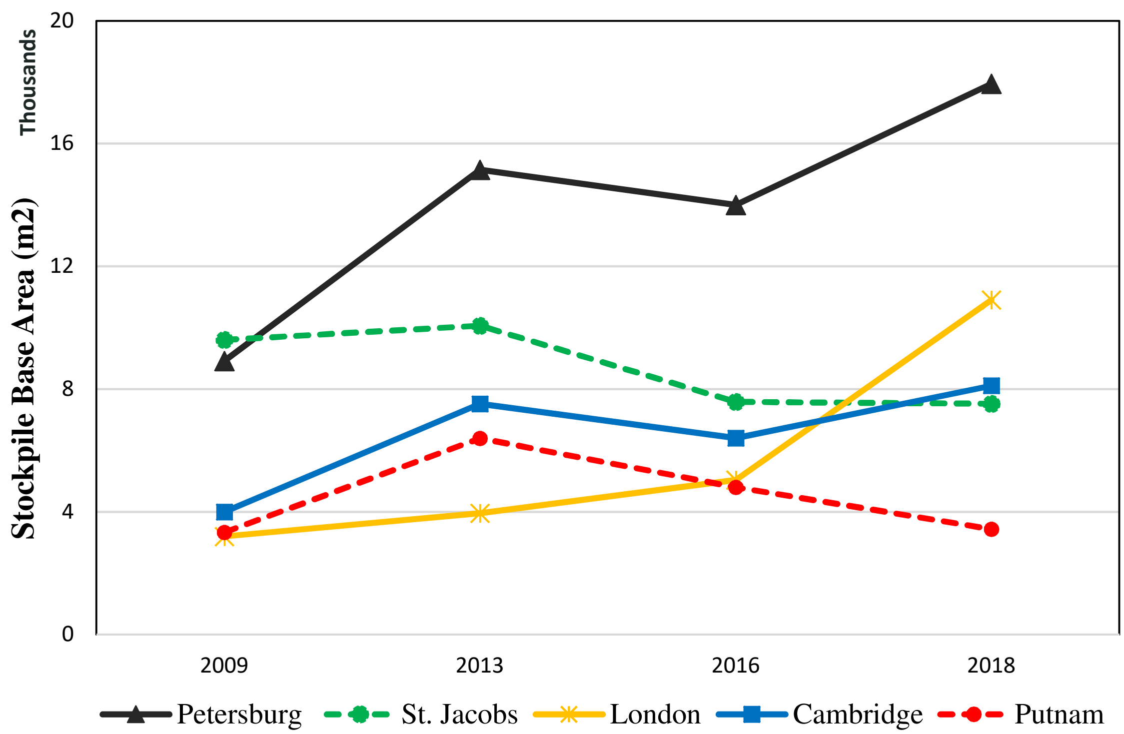

Figure 9 Historical trends in RAP quantities in municipalities in southwest Ontario

Next Steps

The authors' next steps include:

- Validating estimates of RAP from this study against stockpile quantities obtained from plant management in different locations.
- Examining a sample dataset from this study to identify relationships between crushed and uncrushed stockpile quantities using statistical analysis paired with a Monte Carlo simulation. This approach would provide estimates of the quantities of crushed RAP in Ontario. In satellite images, crushed RAP stockpiles are more challenging to identify than stockpiles of uncrushed RAP. In most locations observed in this study, crushed RAP stockpiles have similar visual characteristics to some aggregate stockpiles (Fig-10).

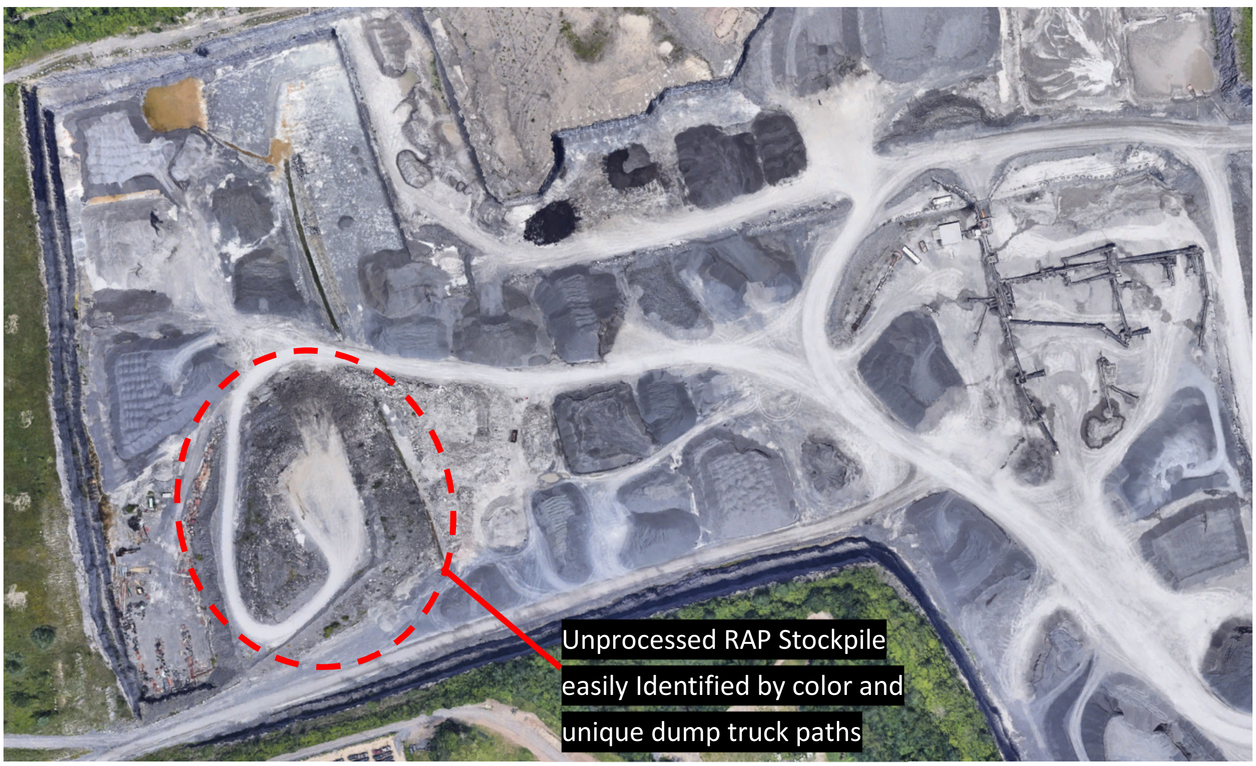

Figure 10 Satellite image of a quarry with RAP stockpile showing that visually identifying crushed RAP stockpile can be more challenging than of unprocessed RAP stockpiles.

- Identifying locations, other than HMA plants, in Ontario that may have RAP stockpiles, (e.g. municipal RAP storage locations, contractors' yards, and quarry locations). This step will be carried out through municipal surveys and questioners.
- Promoting the use of RAP in Ontario by developing and advertising a list of RAP best practices to help disseminate the knowledge and experience of large municipalities onto smaller, less experienced ones.

Summary and Conclusion

Towards the objective of quantifying available RAP in Ontario, a defined methodology was followed to locate, measure and estimate RAP quantities using Google Earth Pro software. This method proved to be a cost-effective approach to meeting the proposed objective. The total amount of available RAP was reported, and the breakdown of available RAP quantities over geographical zones was provided. Historical trends were captured on a span of 10 years for the southwest zone of Ontario.

The following conclusions were drawn from this study:

- In 2018, the total available RAP in Ontario was estimated at 4.3 Million Tonnes
- Two-thirds of the total RAP is located in the Central Zone, while only 4% is located in the northern zone
- A strong correlation was found between stockpile base area and stockpile quantity with an R^2 value of 0.92
- 94% increase in stored RAP was captured in the southwest zone from 2009 to 2018
- Remote locations with low population density are likely to have poor quality of satellite image data

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