Return to School Update Appendix B Revised

REVISED

Investigation of Indoor Air Quality

Three School Ventilation Study
Mother Cabrini, St. Jane Francis and St. Raphael

Prepared for:

Toronto Catholic District School Board
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EXECUTIVE SUMMARY

Pinchin Ltd. (Pinchin) was retained by the Toronto Catholic District School Board (TCDSB, the Client) to investigate ventilation rates in three schools and to understand how mechanical HVAC systems and window opening time / window style impacted ventilation. The investigation was undertaken at Mother Cabrini, St. Jane Francis and St. Raphael. This project was managed by Stephen Booth.

Window opening as it occurred during the study did not appear to have a significant positive impact on ventilation (carbon dioxide concentrations) in the schools. Carbon dioxide concentrations were relatively well controlled in the buildings equipped with mechanical HVAC systems. Carbon dioxide concentrations were persistently elevated through the afternoon period in the school with no mechanical ventilation even though windows were open at many points during the study period. In the non-mechanically ventilated school, the lack of ventilation was effectively offset by the installation of portable HEPA filter units.

The Board posed five specific questions which this study attempted to answer as follows. Additional detail is present in the body of the report.

1. **Did having windows open in the classrooms lead to improved ventilation?**

   No. While opening windows did not help significantly reduce CO2 concentrations during the study, it is possible that small improvements in ventilation could be obtained through a more systematic pattern of window operation.

2. **Was there indication that awning style or vertical sliding windows resulted in superior ventilation outcomes?**

   No. As no clear benefit was evident from either style no advantage was evident for one style over the other.

3. **Did the size of the window openings impact ventilation rates based on the number of open windows and CO_2 concentrations in the classes?**

   No. No clear benefit was evident by opening windows.

4. **Was the building effectively flushed via the HVAC system or natural ventilation in the vacant period between school days, over the weekend?**

   Yes. Mechanically ventilated schools were flushed nightly. The non mechanically ventilated school was flushed over the weekend period.

5. **Were there classroom occupant densities that lead to better controlled carbon dioxide concentrations?**

   In the non-mechanically ventilated school, occupant density was closely corelated with CO_2 concentrations although none of the occupant densities resulted in consistent CO_2 concentrations below the enhanced 800 ppm target set for this study. In mechanically ventilated schools, the association was not present and CO_2 concentrations were more likely related to the ventilation rates in the specific rooms.

Pinchin offers the following recommendations based on the study:

1. Continue to monitor CO_2 / ventilation rates at Mother Cabrini to confirm performance as colder weather arrives.
2. Review the HVAC system at St. Jane Francis and ensure:
   a. The system is properly balanced.
   b. The maximum efficiency filters (highest MERV rating) recommended by the manufacturer are installed. Ideally this would be MERV13.
   c. The humidification system is functioning properly.
   d. Consider deploying portable air filters in classrooms where ventilation performance is not maintaining CO_2 concentrations consistently below 800 ppm.
3. Operate HVAC systems and portable HEPA filters for a minimum of 2.5 hours before and after occupancy to help flush / filter airborne particulate between school days.
4. Implement the following strategies to maximize natural ventilation in schools not equipped with mechanical ventilation.
   a. Open all available windows to maximize window opening size. Where classrooms are equipped with windows that open both top and bottom this should include the upper window. Where cold temperatures and draft is an issue, and the classroom is so equipped, open the top section of the window only. Where the upper window is operable but difficult to operate consider having caretaking staff open the upper windows before class and close them after class.
5. Implement window operation changes in select classrooms at a suitable subject school. Monitor CO_2 and temperature over a 15 to 30-day period to determine if changes to window operation can improve ventilation outcomes.

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1.0 INTRODUCTION AND SCOPE

1.1 Statement of Understanding

Pinchin Ltd. (Pinchin) was retained by the Toronto Catholic District School Board (TCDSB, the Client) to conduct an investigation to evaluate ventilation rates in three schools and to understand how mechanical HVAC systems and window opening time / window style impacted ventilation. The investigation was undertaken at Mother Cabrini, St. Jane Francis and St. Raphael. This project was managed by Stephen Booth.

The project involved the installation of real time sensors for carbon dioxide, temperature, and relative humidity in representative classroom and staff space in each of three schools. The goal of the study was to provide data to help answer the following five questions:

1. Did having windows open in the classrooms lead to improved ventilation?
2. Was there indication that awning style or vertical sliding windows resulted in superior ventilation outcomes?
3. Did the size of the window openings impact ventilation rates based on the number of open windows and carbon dioxide (CO_2) concentrations in the classes?
4. Was the building effectively flushed via the HVAC system or natural ventilation in the vacant period between school days and over the weekend?
5. Were there classroom occupant densities that lead to better controlled CO_2 concentrations?

1.2 Scope of Work

Pinchin installed real-time CO_2, temperature, and relative humidity sensors in representative functional areas in three school buildings:

- Mother Cabrini (mechanically ventilated school with awning style windows)
- St. Jane Francis (mechanically ventilated school with a combination of double hung windows (original structure) and awning style windows (new addition))
- St. Raphael (no mechanical ventilation and vertical slider windows).

Pinchin installed door and window sensors on the main entry door and windows in each of the classrooms. The sensors provided a notification when each window or door was opened or closed. Pinchin manually calculated the total amount of time each window was open in the classrooms through the study period.

In addition to the preparation of this report, Pinchin assisted the TCDSB in the setup of real-time alerts that provided notification of low temperatures (<18°C) and CO_2 concentrations higher than 800 ppm and 1200 ppm.

Sensors were deployed in the following locations at each school based on feedback from TCDSB and site conditions:

Table I – Test Locations

Mother Cabrini	St. Jane Francis	St. Raphael
Classroom 203 – Kindergarten	Classroom 222 – Grade 6 – Original Building	Room 202 – Grade 7/8
Classroom 115 – Grade 2/3	Classroom 228 – Grade 4 – New Wing	Room 209 - Grade 2
Classroom 112 – Resource Room	Classroom 106 – Grade 7/8 – New Wing	Workroom 211
Classroom 113 – Grade SK/1	Classroom 221 – Grade 2/3 split – Original Building	Room 103 - Grade 1
Staffroom - Room 206	Classroom 302- Grade 5 – New Wing – No Windows	Room 216 – Grade 3
Workroom 214	Classroom 130 – JK – Original Building	Room 117 – Kindergarten
Principal's Office – Room 222	Admin Office Room 102	Admin Office Room 123
Outdoor	Outdoor	Outdoor

2.0 METHODOLOGY

Indoor air quality measurements were collected approximately every 15 minutes, 24 hours / day, seven days a week. Door and window activation data was transmitted at the time of each event.

This report is based on sensor data for the period of November 12, 2020 (00:01) to December 12, 2020 (23:59).

For the purposes of this report, Pinchin looked at three factors the provide answers to the questions posed by the TCDSB as part of this study:

1. Total time in each room in exceedance of 800 ppm CO_2.
2. Total time in each room in exceedance of 1200 ppm CO_2.
3. Total number of open window hours in each classroom. This was calculated by summing the number of hours each window in a classroom was open for through the study period.

For example, if 3 three windows in Classroom 101 were open for 2 hours each that would total 6 window hours.

To further inform the study, Pinchin gathered the following information through discussions with board staff and an online HVAC survey:

1. Details on HVAC operation and filtration in the two mechanically ventilated schools
2. Details on current and normal / non-COVID occupant loads in each of the schools.
3. Details on the occupancy in each of the rooms equipped with sensors.

2.1 Test Methods and Criteria

Pinchin installed the Elsys ERS CO_2 sensor in each of the subject rooms. The sensor has the following accuracy and resolution:

The sensor provides long term measurements:

- Carbon dioxide, 0-10,000 ppm, Accuracy ± 50ppm or 3% of reading.[1]
- Temperature, -40 to 120 °C, Resolution 0.1°C, Accuracy ± 0.2°C
- Relative Humidity, 1 – 100%, Resolution 0.1%, Accuracy @ 25°C ± 2%

The following table presents the parameters measured in this investigation, the instruments and sampling/analytical methods used, the applicable units of measurement, and the criteria selected by Pinchin for the evaluation of the results.

2.2 IAQ Standards

Table II – Parameters Tested, Recommended Limits and Instruments or Methods Used

Parameter	Unit of Measurement	Recommended Limit	Instrumentation or Test Method
Carbon Dioxide, CO_2	Parts per million in air (ppm)	< 800 ppm – Good[2] < 1,100 ppm (700 ppm + Outdoor) - Acceptable[3] >1,200 ppm - Investigate	Elsys ERS CO_2

[1] The carbon dioxide sensor has an internal automatic calibration routine. This routine calibrates the sensor to set 400 ppm to the lowest value that has been read in the last period of approximately 8 days. This means that in an 8-day period, the sensor must be exposed to fresh (well ventilated) air at least once for the calibration to work. The sensor can also be manually calibrated.

[2] Harvard T.H. Chan School for Public Health, Schools for Health Risk Reduction Strategies for Reopening Schools, Updated November 2020

3 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): Ventilation for Acceptable Indoor Air Quality [ANSI/ASHRAE Standard 62.1-2013]. Atlanta, GA: ASHRAE, 2013.

Table II – Parameters Tested, Recommended Limits and Instruments or Methods Used

Parameter	Unit of Measurement	Recommended Limit	Instrumentation or Test Method
Temperature, T	°C	21 to 25 °C, winter clothing[4] 24 to 27 °C, summer clothing	
Relative Humidity, RH	%RH	Winter 40%-50%[5] Summer 50%-60%[6]	

3.0 FINDINGS

3.1 School Overview

3.1.1 St. Jane Francis

St. Jane Francis consists of a two-storey original school structure with a three-storey addition. The original building is equipped with double hung metal windows in the classrooms. The double hung windows open both at the top and bottom although because of difficult access, opening the upper windows may be difficult. The double hung widows are equipped with a stopper to restrict the opening to 4". Most of the classrooms in the new addition are equipped with a combination of fixed windows and awning windows. In most classrooms, two awning windows are present on either end of the classroom. In some classrooms, there are no operable windows.

The building is equipped with HVAC systems consisting of a combination of main AHUs and perimeter fan coil units. The system is equipped with a building automation system and whole building humidification. The MERV rating of the filters is not known. The system is currently being operated with outdoor air dampers open to maximize ventilation. The HVAC system is also being operated one hour prior to school opening and one hour after closing to provide a building flush. It is not known when the system was last balanced.

During the pandemic, the school is operating at approximately 50% of it's normal daily occupant load (400 currently vs 750 normal).

4 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): *Thermal Environmental Conditions for Human Occupancy* [ANSI/ASHRAE Standard 55-2013]. Atlanta, GA: ASHRAE, 2013.
5 https://www.ashrae.org/technical-resources/reopening-of-schools-and-universities
6 https://www.ashrae.org/technical-resources/reopening-of-schools-and-universities

3.1.2 Mother Cabrini

Mother Cabrini is a two-storey school structure. The building is equipped with new awning style windows in the classrooms. There are two styles of awning window present. One set of windows open outward and the other opens inwards. Due to the window construction, sensors could only be installed on the inward opening windows. The top set of windows in each of the tested classrooms was not currently operable as the rolling shade blocked the window opening.

The building is equipped with a central AHU. The building is not equipped with a humidification system or a building automation system. The unit is being operated with outdoor air dampers in their fully opened position to maximize ventilation. Individual classrooms have also been equipped with stand-alone portable air cleaners. The HVAC unit is equipped with MERV13 filters.

During the pandemic, the school is operating at approximately 72% of it's normal daily occupant load (144 currently vs 198 normal).

3.1.3 St. Raphael

St. Raphael is a two-storey school structure. The building is equipped with vertical slider windows in the classrooms. Only the bottom portion of the window opens. The majority of widows are equipped with a stopper to restrict the opening to 4". One window in each classroom has been modified to allow a window opening of 12" in an effort to allow increased ventilation.

The building is not equipped with an HVAC system. Individual classrooms have also been equipped with stand alone portable air cleaners (Austin Air Systems Model HM400/410).

During the pandemic, the school is operating at approximately 75% of it's normal daily occupant load (425 currently vs 570 normal).

3.2 IAQ Data Summary

IAQ data is summarized for the period of 00:01 November 12, 2020 to 23:59 December 12, 2020.

Table III – Mother Cabrini CO_2 Summary

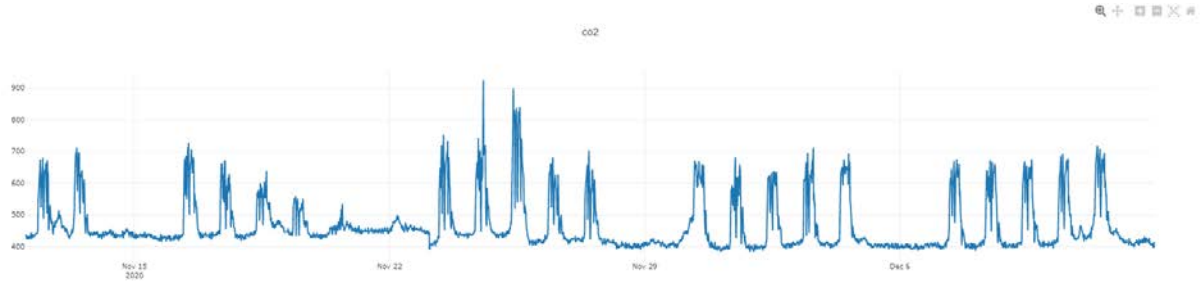
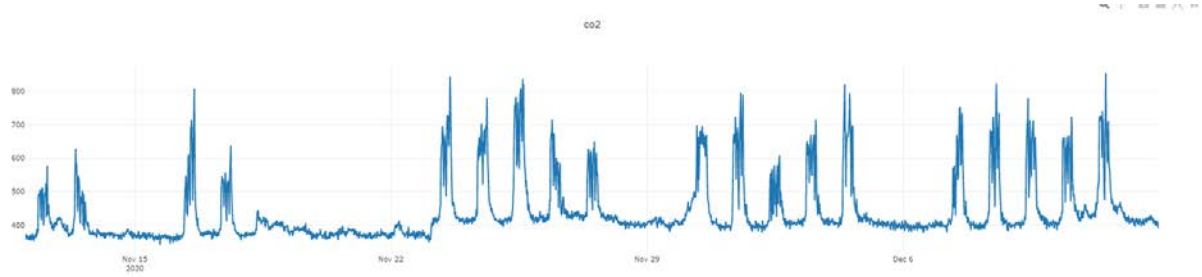
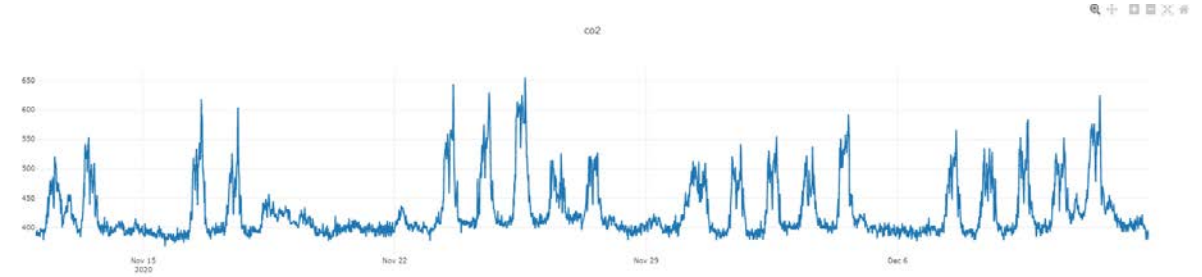
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Classroom 203 – Kindergarten	24+ECE+Teacher	8 min	0 min	194 hours
				
Classroom 115 – Grade 2/3	18+Teacher	10 min	0 min	138 hours
				
Classroom 112 – Resource Room	Infrequent Occupancy – 2-3 students + teacher when in use.	0 min	0 min	235 hours
				

Table III – Mother Cabrini CO_2 Summary

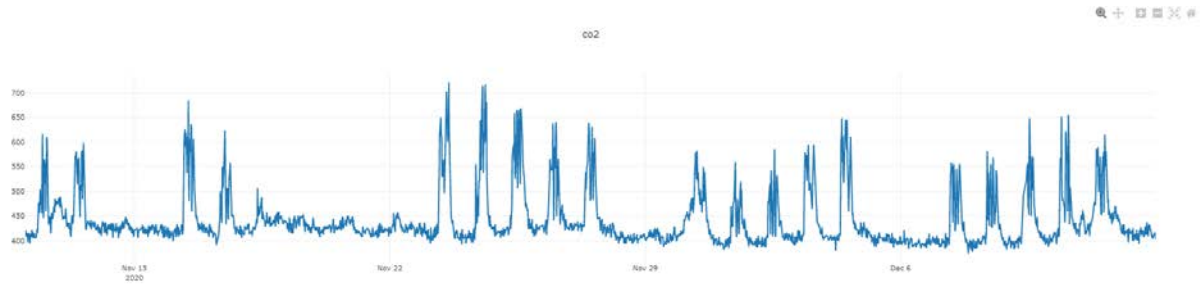
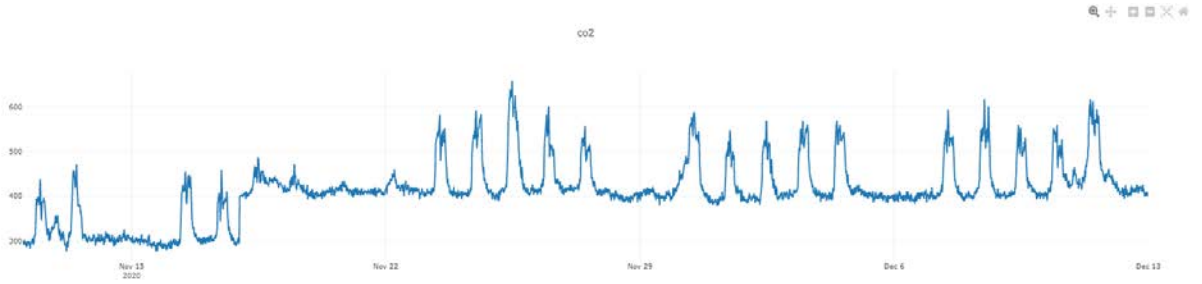
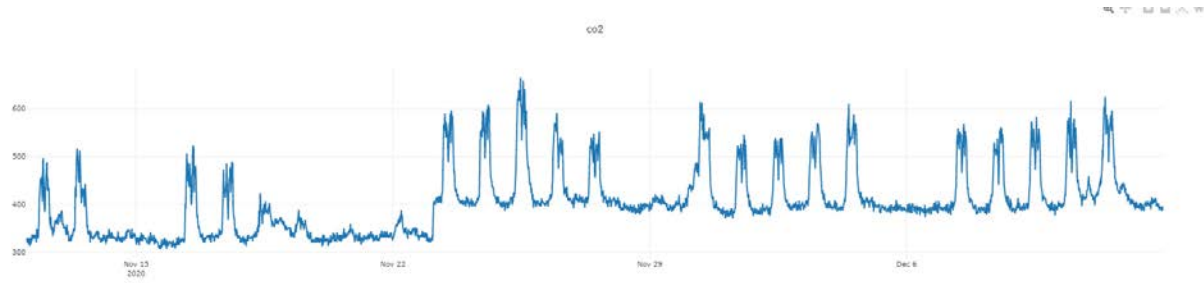
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Classroom 113 – Grade SK/1	17+T+CYW	0 min	0 min	690 hours
				
Staffroom Room - 206	3-4 Staff During Break	0 min	0 min	102 hours
				
Workroom 214	Up to 3+Teacher	0 min	0 min	-
				

Table III – Mother Cabrini CO_2 Summary

Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Principal's Office Room 222		0 min	0 min	-

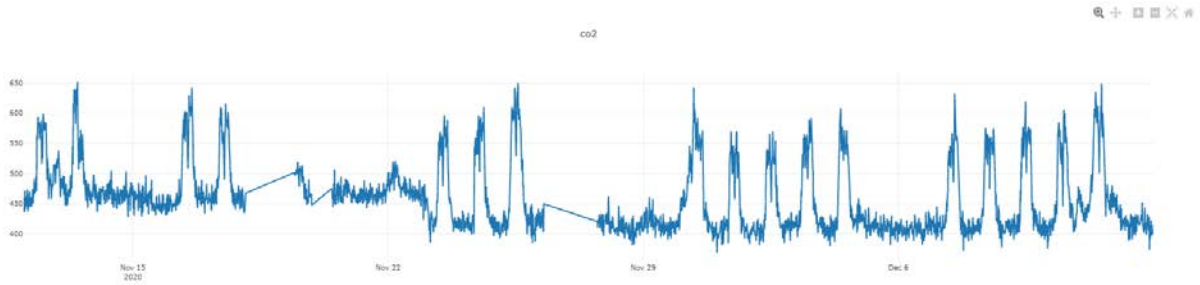


Table IV – St. Jane Francis CO_2 Summary

Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Classroom 228 – Grade 4 – New Wing	15+EA+Teacher	396 min	155 min	182 hours

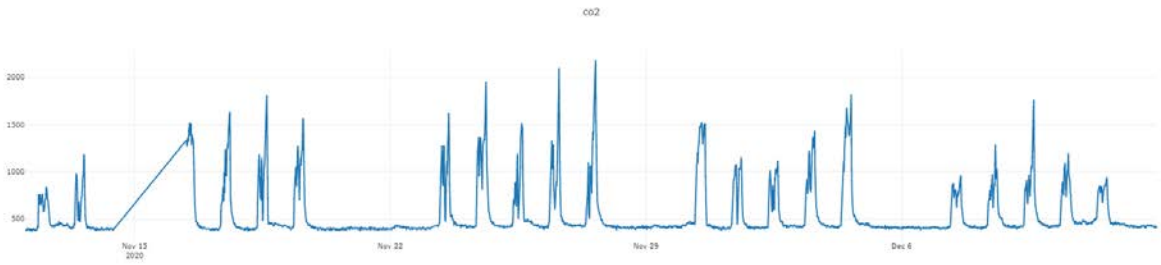


Table IV – St. Jane Francis CO_2 Summary

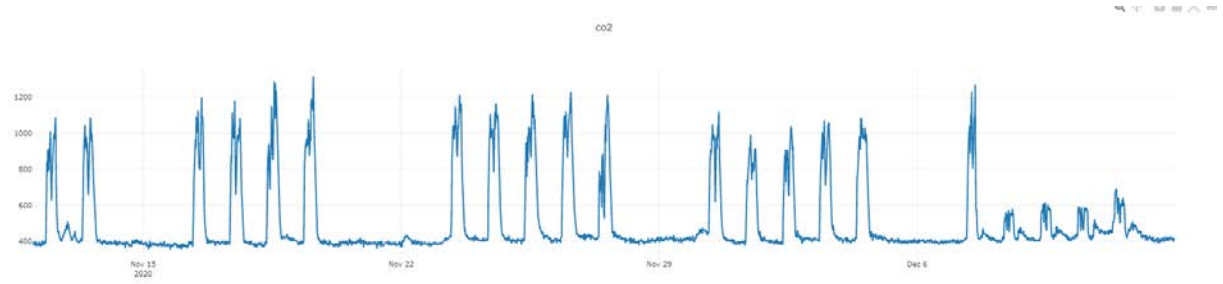
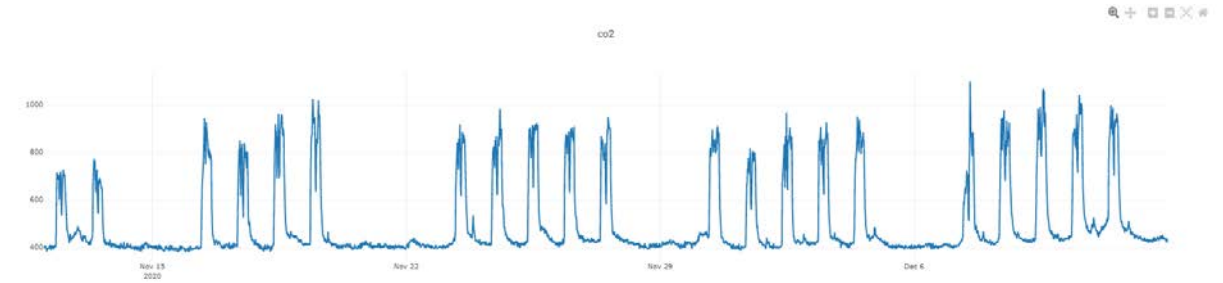
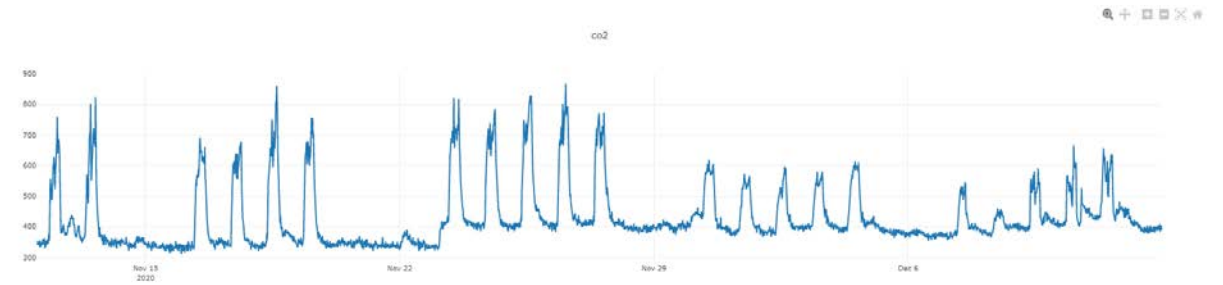
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Classroom 222 – Grade 6 – Original Building	20+Teacher	391 min	15 min	25 hours
				
Classroom 106 – Grade 7/8 – New Wing	20+Teacher	328 min	0 min	3 hours
				
Classroom 221 – Grade 2/3 split – Original Building	13 students + Teacher + 1	17 min	0 min	13 hours
				

Table IV – St. Jane Francis CO_2 Summary

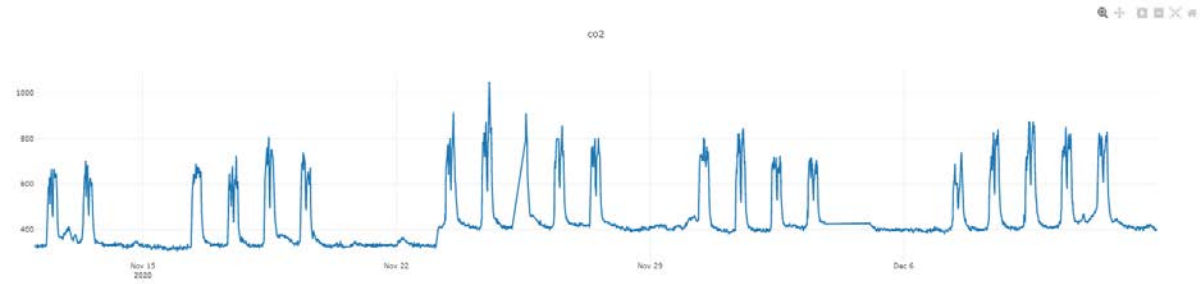
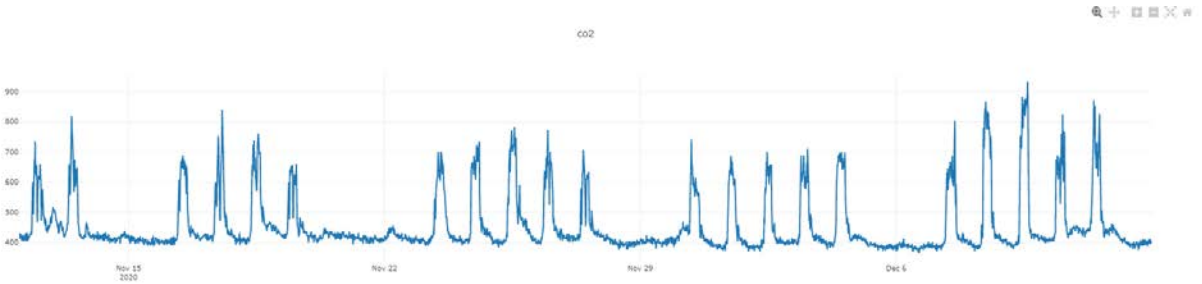
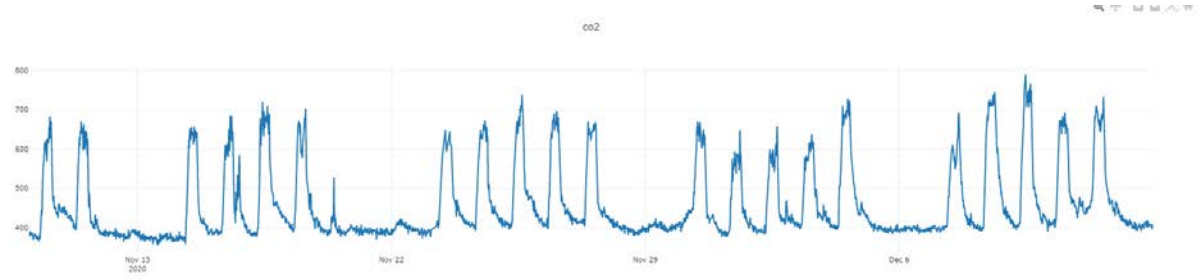
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Classroom 302- Grade 5 – New Wing – No Windows	20+EA+Teacher	54 min	0 min	0
				
Classroom 130 – JK – Original Building	15+DEC+EA+Teacher	29 min	0 min	198 hours
				
Admin Office Room 102		0 min	0 min	-
				

Table V – St. Raphael CO_2 Summary

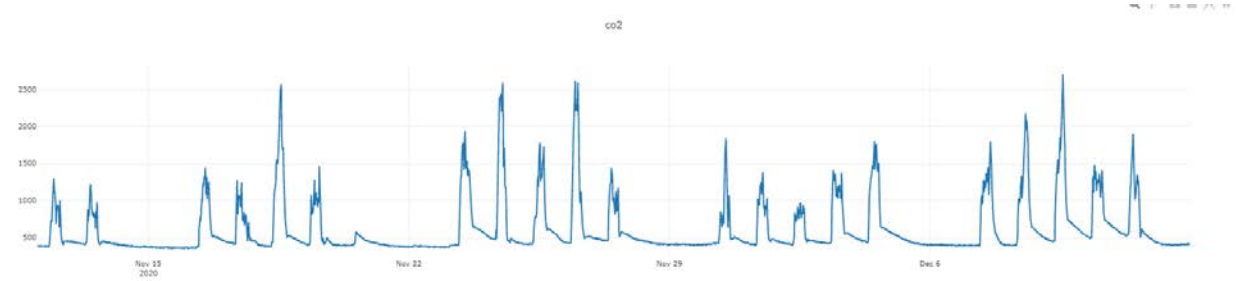
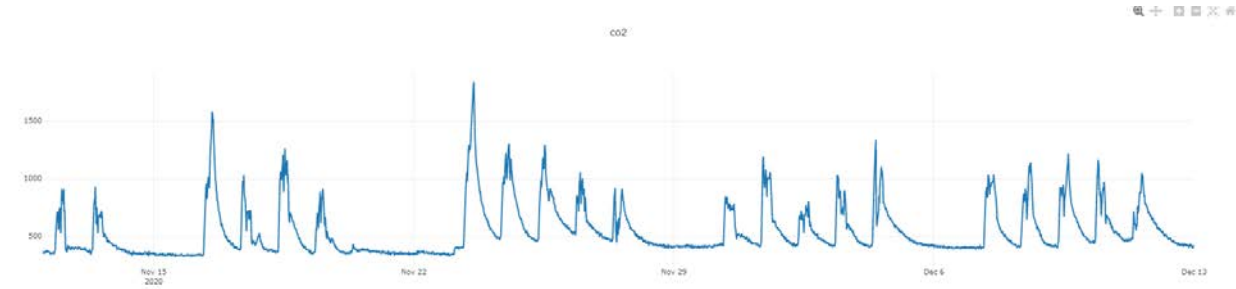
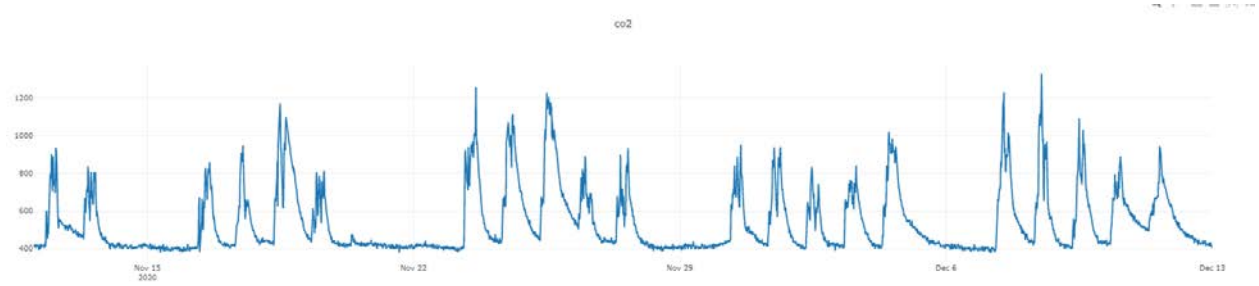
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Room 202 – Grade 7/8	19 + Teacher	535 min	270 min	950 hours[1]
				
Room 209 - Grade 2	15+Teacher	380 min	41 min	355 hours
				
Workroom 211	5 staff max.	295 min	6 min	87 hours
				

Table V – St. Raphael CO_2 Summary

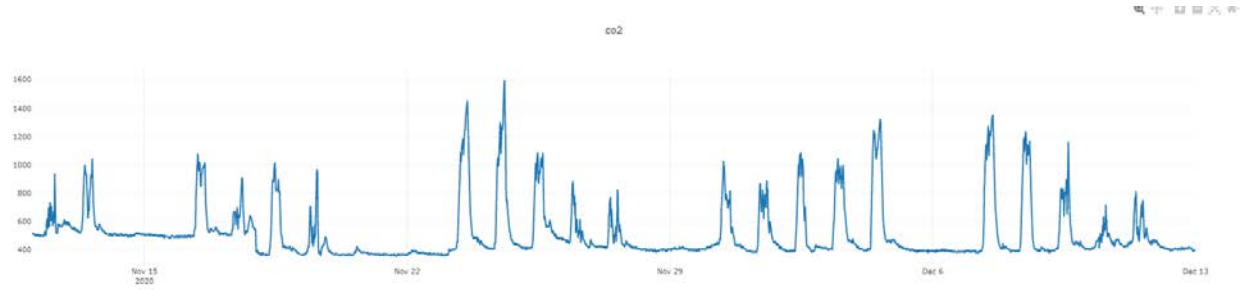
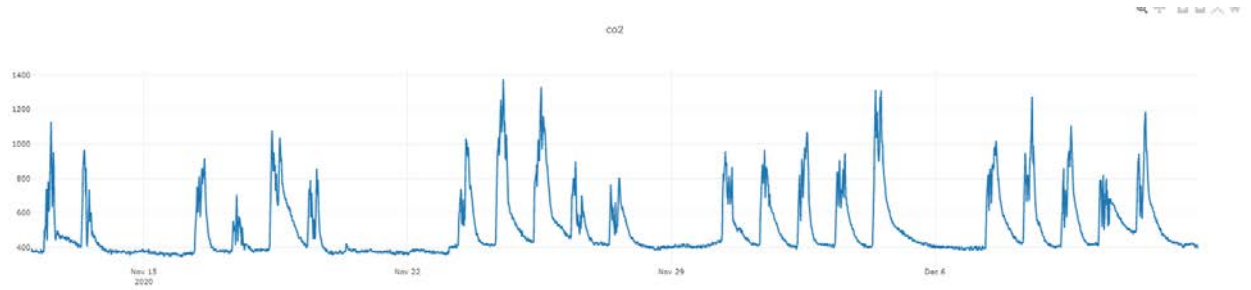
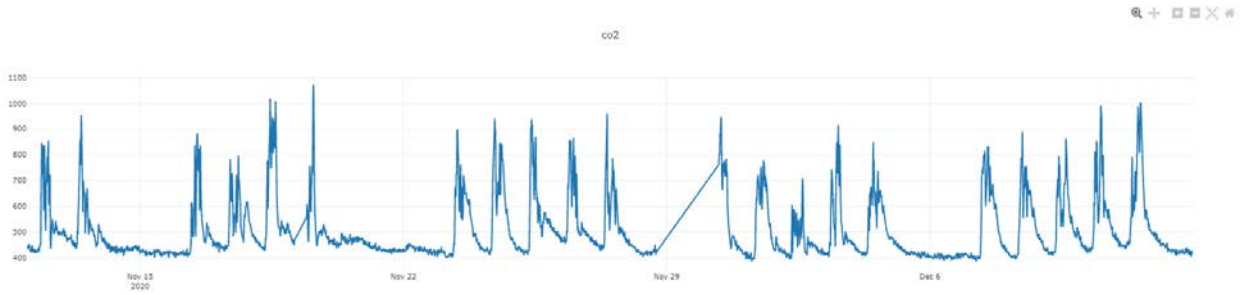
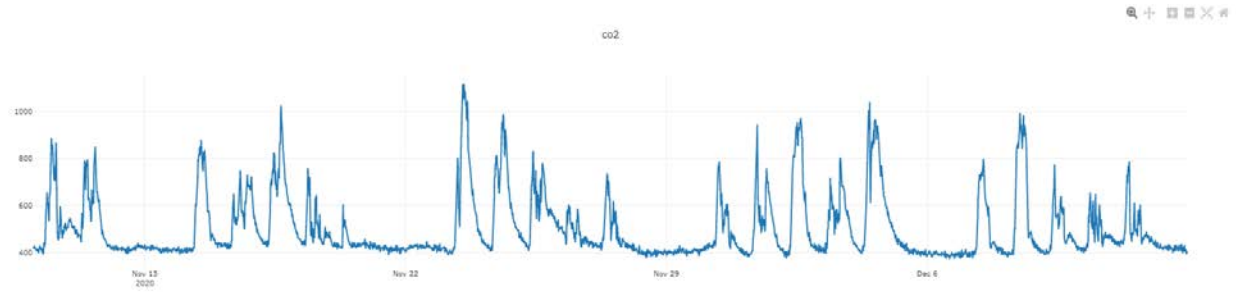
Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Room 103, Grade 1	13 + 1	297 min	47 min	326 hours
				
Room 216 – Grade 3	14+Teacher	260 min	15 min	432 hours
				
Room 117 – Kindergarten	15 + 5	107 min	0 min	626 hours
				

Table V – St. Raphael CO_2 Summary

Location / Grade	Occupancy	Total Time with CO_2 greater than 800 ppm	Total Time with CO_2 greater than 1200 ppm	Total Window Open Time
Admin Office Room 123		163 min	0 min	-

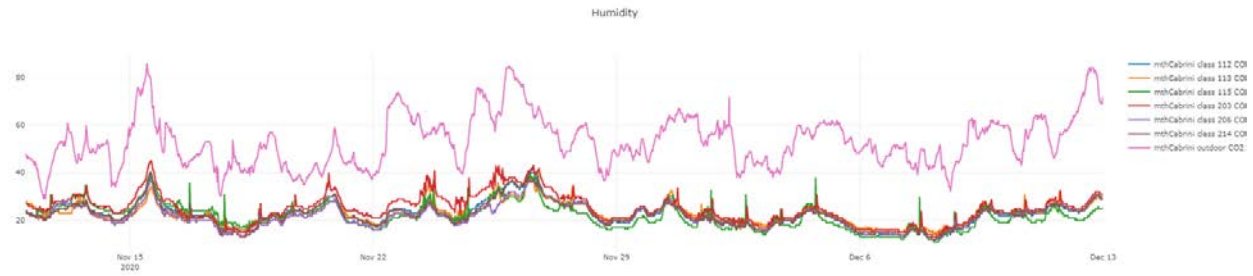


Note 1 – Window Sensors 3 & 4 in Classroom 202 came off their mounting following the installation. These sensors were reinstalled on November 25. The window time in Classroom 202 takes the average daily window open time from November 26 to December 12 and applies it to the full 31-day period. Window 2 was assumed closed from December 8 to 12 due to a sensor issue.

3.3 Relative Humidity Summary

Table VI – Relative Humidity Summary

Mother Cabrini



St. Jane Francis

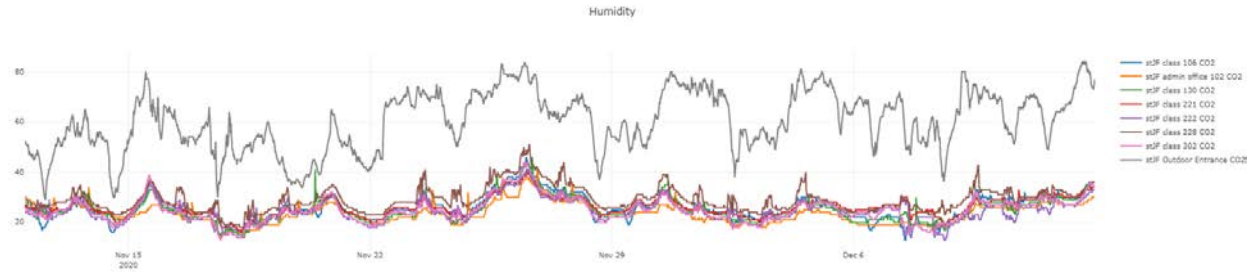
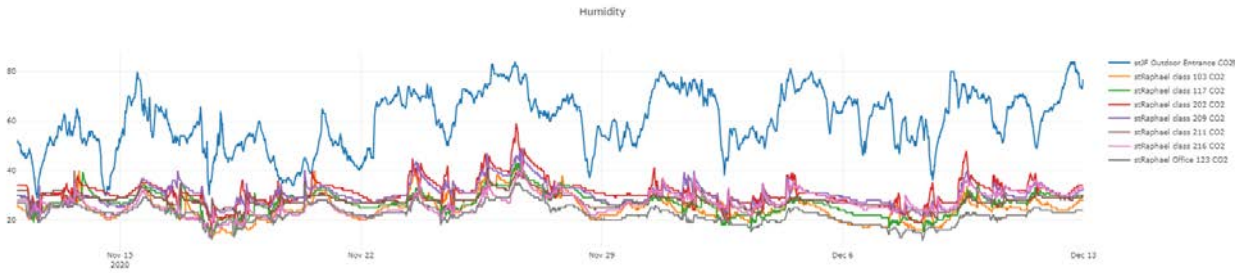


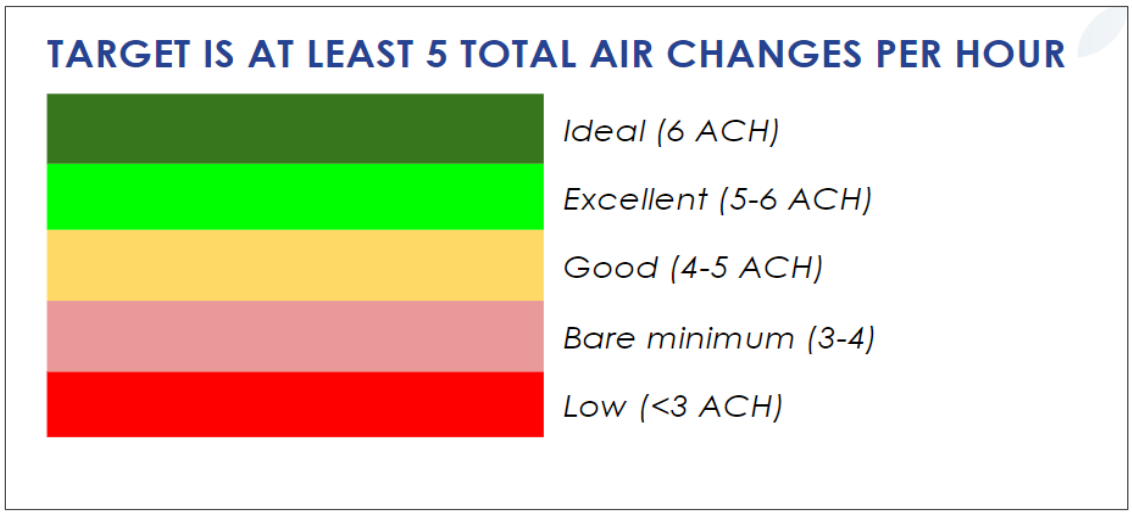
Table VI – Relative Humidity Summary

St. Raphael



4.0 DISCUSSION

Carbon dioxide is an ideal indicator of ventilation in occupied buildings. Indoor carbon dioxide concentrations rise with occupant load and respiration rates and are reduced based on the amount of outdoor air being introduced. In typical indoor air quality investigations, a steady state concentration of approximately between 1,000 ppm and 1,150 ppm is indicative of adequate ventilation for occupant comfort. In a typical classroom with 20 occupants this indicates approximately 2 air changes per hour. With ASHRAE's current recommendation to maximize ventilation and avoid recirculation to help minimize transmission of the SARS-CoV-2 virus, indoor carbon dioxide concentrations should ideally be considerably lower. The Harvard T.H. Chan School of Public Health has recommended classrooms maintain a bare minimum of 3-4 air changes per hour with 4-6 air changes per hour preferred. In a typical classroom an air change rate between 4 and 5 per hour results in a steady state CO_2 concentration of approximately 800 ppm.



https://schools.forhealth.org/covid-19-tools/

4.1 Proposal Specific Questions

1. **Did having windows open in the classrooms lead to improved ventilation?**

Windows did not play a significant role in improving ventilation rates. At St. Raphael where windows are the primary ventilation strategy, the amount of time with windows open did not result in improved ventilation. Room 222 consistently had the worst ventilation despite having windows open more frequently than any other room in the school. In both St. Raphael and St. Jane Francis, the classrooms with the highest CO_2 concentrations were also the classrooms with open windows for the longest time. It may be possible to provide some limited improvement in window ventilation by utilizing the windows in a more systematic way.

2. **Was there indication that awning style or vertical sliding windows resulted in superior ventilation outcomes?**

Awning windows were installed at Mother Cabrini and in the new addition at St. Jane Francis. Double hung windows were installed in the original wing at St. Jane Francis. Vertical sliders were installed at St. Raphael. The double hung windows and vertical sliders were fitted with a locking mechanism to prevent the window from opening more than 4". Awning windows opened either inward or outward. The opening at the awning window was approximately 4" at the open edge but the awning action exposes the full face of the screen for ventilation.

As indicated above, windows did not play a significant role in improving ventilation rates. With that in mind, there was no evidence that either style of window was superior to the other. At St. Jane Francis where both styles of windows were installed the occupant load and HVAC function outweigh any window related impact. Classroom 302 with 22 occupants and no windows performed better with respect to ventilation than Classroom 106 with 21 occupants and awning style windows, and Classroom 228 with 17 occupants and double hung windows, despite the windows in Classroom 228 being open for a total of 182 hours during the study period.

3. **Did the size of the window openings impact ventilation rates based on the number of open windows and CO_2 concentrations in the classes?**

Windows did not play a significant role in improving ventilation rates.

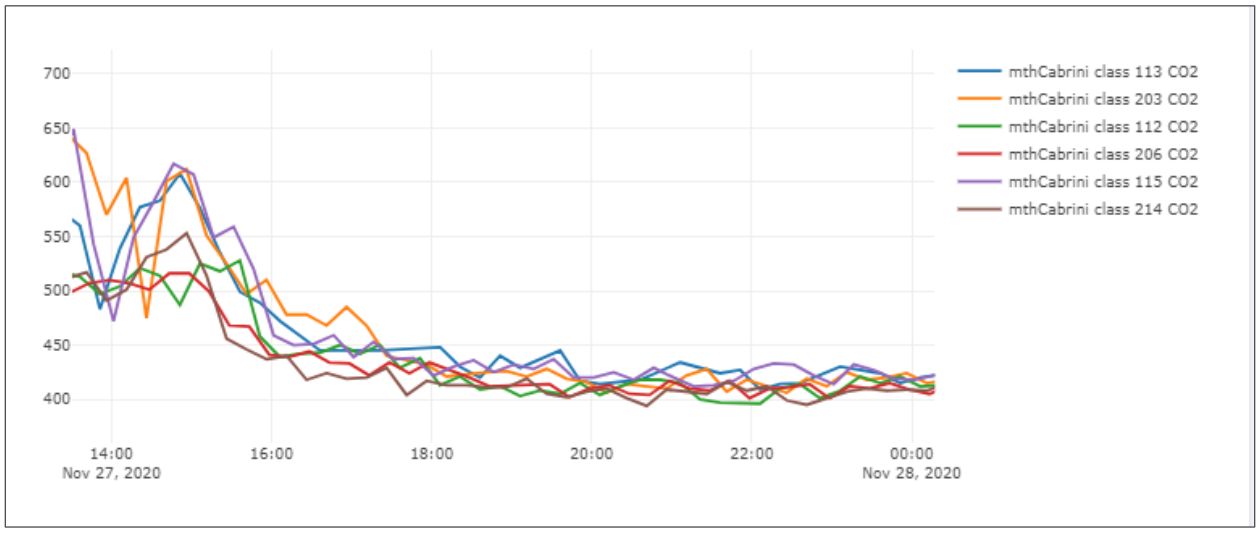
4. **Was the building effectively flushed via the HVAC system or natural ventilation in the vacant period between school days, over the weekend?**

In all cases the carbon dioxide concentrations returned to base line conditions through the weekend period suggesting adequate ventilation (mechanical or natural) to flush the building. For both Mother

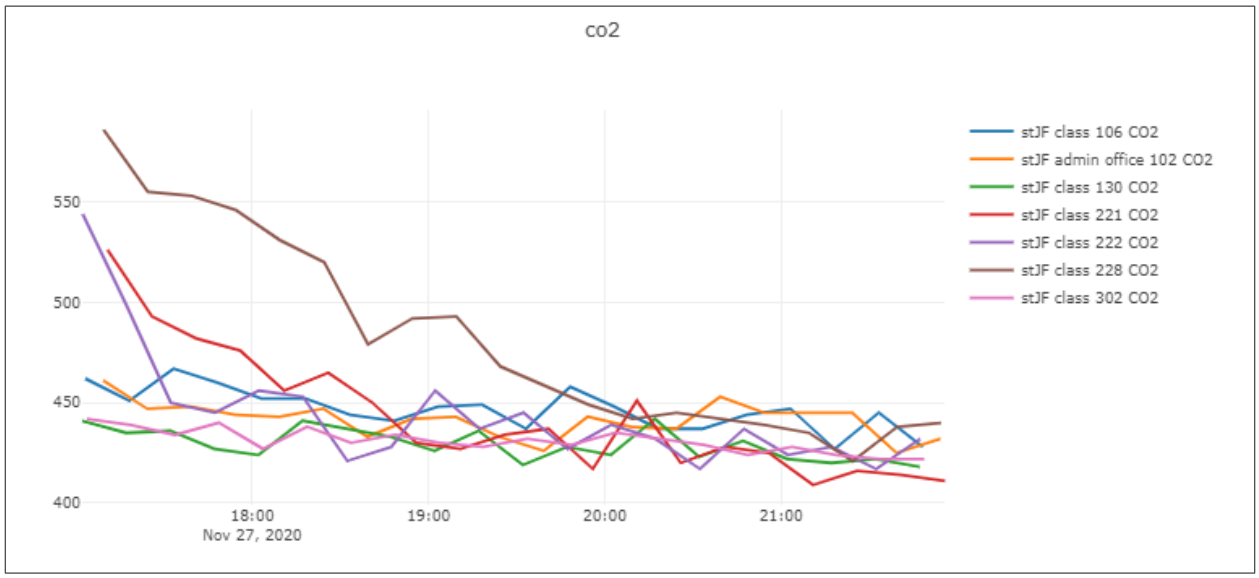
Cabrini and St. Jane Francis, CO_2 concentrations returned to baseline conditions each evening. CO_2 concentrations at St Raphael did not however fully flush in each of the classrooms each weeknight.

In order to evaluate the flushing, Pinchin examined the data from Friday November 27, 2020. Pinchin examined the data after school hours on the Friday to determine when all sensors had returned to baseline concentrations (all sensors <450ppm). Friday was picked as a worst case in that if flushing had not been completed earlier in the week, the overall Friday concentrations could be higher than other days.

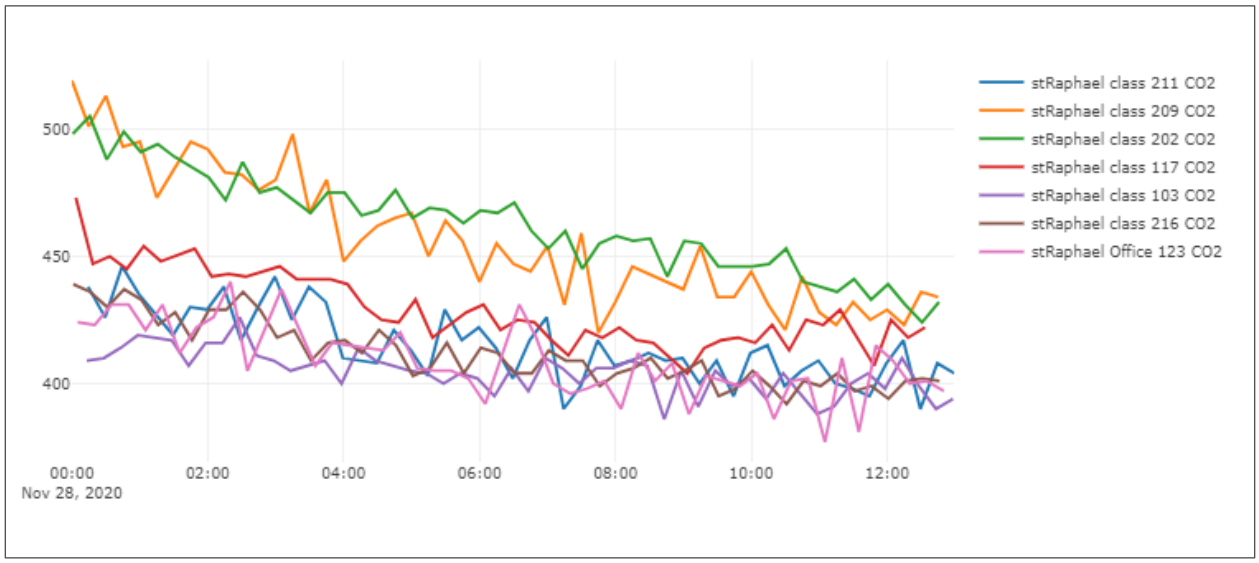
Mother Cabrini – CO_2 concentrations returned to baseline by approximately 18:00 Friday evening.



St. Jane Francis - CO_2 concentration returned to baseline by approximately 21:00 Friday evening



St. Raphael – CO_2 concentrations returned to baseline by approximately 11:00 on Saturday.



5. **Were there classroom occupant densities that lead to better controlled carbon dioxide concentrations?**

Occupant density plays a role in indoor CO_2 concentrations where ventilation does not compensate. At St. Raphael, occupant density and CO_2 concentrations have a high correlation with very similar rank orders of minutes over 800 ppm and occupant density. At St. Jane Francis there was not a strong correlation between occupant density and CO_2 concentrations. The HVAC system at St. Jane Francis plays a mitigating role in CO_2 concentrations.

At St. Raphael, even the lowest levels of occupancy (Classroom 103 with 14 occupants) regularly exceeded both the 800 ppm and 1200 ppm limits.

Table VII – St. Raphael Occupancy Summary

Location / Grade	Occupant Load	Approximate Room Size sf	Occupant Density Persons / 10sf	Minutes over 800 ppm	Minutes over 1200 ppm
Room 202 – Grade 7/8	21	815	0.26	535	270
Room 209 - Grade 2	16	760	0.21	380	41
Room 103 - Grade 1	14	760	0.18	297	47
Workroom 211	5	264	0.19	295	6
Room 216 – Grade 3	15	815	0.18	260	15
Room 117 – Kindergarten	20	760	0.26	107	0

Table VIII – St. Jane Francis Occupancy Summary

Location / Grade	Occupant Load	Approximate Room Size sf	Occupant Density Persons / 10sf	Minutes over 800 ppm	Minutes over 1200 ppm
Classroom 228 – Grade 4 – New Wing	17	825	0.21	396	155
Classroom 222 – Grade 6 – Original Building	21	816	0.26	391	15
Classroom 106 – Grade 7/8 – New Wing	21	825	0.25	328	0
Classroom 302- Grade 5 – New Wing – No Windows	22	825	0.27	54	0
Classroom 130 – JK – Original Building	18	912	0.20	29	0
Classroom 221 – Grade 2/3 split – Original Building	15	816	0.18	17	0

4.2 Window Ventilation General

The Chartered Institution of Building Services Engineers (CIBSE) recommend opening both the top and bottom windows simultaneously when possible and in cold weather opening the upper window to minimize draft / thermal comfort complaints. At Mother Cabrini the upper awning windows in the subject classrooms were prevented from opening due to window shade installation. The upper portion of the double hung windows at St Jane Francis were too high to be readily opened and are likely rarely used. The upper portion of the windows at St. Raphael are not openable operational.

During the study we rarely saw all the windows in a classroom open at the same time which would increase the overall window opening size. Further the 4” opening restriction on the vertical sliders and double hung windows, and the fact that the upper windows were very difficult to open further impacted the potential size of the window opening. The 4” window restrictors are a code requirement to prevent falls and cannot be changed without installation of safety cages on the building exterior. Where equipped operation of both the upper and lower windows should be considered when temperatures allow. In cold weather the upper window, where equipped, could be utilized to encourage ventilation and minimize temperature complaints. See attached report in Appendix 1 for additional information.

The CIBSE also suggest that window ventilation is most effective in rooms where the room width is less than twice the ceiling height. The CIBSE suggest that air circulation with fans may be required in these

rooms to avoid dead spots. The existing HEPA filtration units should help with air circulation within the classrooms where this ratio is not met.

Although window opening did not appear to significantly improve ventilation outcomes during this study it may be possible to provide some improvement as follows:

1. Make better use of the existing windows. Open all available windows to maximize window opening size. Where classrooms are equipped with windows that open both top and bottom this should include the upper window. Where cold temperatures and draft is an issue, and the classroom is so equipped, open the top section of the window only. Where top opening windows are available but difficult to operate consider having caretaking staff open the upper windows before class and close them after class.
2. Continue to use HEPA filtered portable air filters in conjunction with the window ventilation to provide mixing in the rooms and to address the potential impact of the introduction of increased volumes of unfiltered outdoor air in the classrooms.

The amount of improvement possible with these changes is not clear. The changes above should be implemented in suitable subject school. The subject school should be a non-mechanically ventilated school equipped with windows that open both top and bottom. These rooms can be equipped with CO_2 sensors for a two-week to four-week period to determine if acceptable ventilation levels are achieved.

4.3 General

4.3.1 Mother Cabrini

Overall, the HVAC system at Mother Cabrini is providing excellent ventilation. CO_2 exceedances above 1200 ppm did not occur at the school and exceedances over 800 ppm were very rare. This is likely related primarily to HVAC operation which is currently allowing for maximum ventilation with outdoor air dampers open 100%. It will be important to review performance as colder weather arrives which may prevent that level of ventilation in order to maintain thermal comfort.

4.3.2 St. Jane Francis

Overall, the HVAC system at St. Jane Francis is providing acceptable ventilation. While exceedances above 800 ppm occurred, exceedances over 1200 ppm were rare only occurring in two of the subject rooms. The variation in ventilation at St. Jane Francis may suggest that the system is not properly balanced and therefore providing differing levels of ventilation to different rooms. It might be prudent to review the current operation of the system and undertake a balancing to ensure the design level air volumes are being delivered to all Classrooms.

Given the variation in the system and the exceedances observed in the data, installation of portable HEPA filtration units in the classrooms would be a reasonable precautionary measure.

4.3.3 St. Raphael

No mechanical ventilation is in place at St. Raphael and as a result, this school performed poorly with respect to CO_2 concentrations. At the occupancy levels during the study period, none of the classrooms were able to consistently maintain CO_2 concentrations below the 800 ppm threshold.

Austin Air Systems Model HM400/410 portable air filters were installed in each of the subject classrooms. The units operate on low (75 CFM), medium (200 CFM) and high (400 CFM) settings. Assuming a room volume of (850 sf and 9’ ceilings) 7650 cubic feet, these units can provide 0.6 air changes per hour (ACH), 1.6 ACH, and 3.1 ACH on each of the respective settings. The peak CO_2 concentrations suggest approximately 1 ACH by natural ventilation. The combined natural ventilation and filtration provide in total approximately the equivalent on 4.1 ACH.

Operating high speed, one unit can result in 99.9% of particulate removal in approximately 132 minutes. The units should be left to run on high at least this long before and after class.

4.4 Relative Humidity

ASHRAE has recommended maintaining indoor relative humidity in classrooms between 40-50% during winter months as a COVID-19 control. Relative humidity across the three schools was maintained between roughly 15% and 50% and was primarily influenced by outdoor conditions. St. Jane Francis is equipped with a humidification system. As colder weather approaches, maintaining indoor relative humidity above 30% will become more difficult. The humidification system at St. Jane Francis should be reviewed and adjusted to ensure adequate humidification as colder weather approaches. Ensure any adjustments consider the potential for condensation and microbial growth on cold surfaces.

4.5 Filtration

Staff at Mother Cabrini report that the HVAC system is currently equipped with MERV13 filters. This meets ASHRAE’s recommendation with respect to filtration of recirculated air. Staff at St. Jane Francis were not aware of the MERV rating of the current filter there. The HVAC equipment should be reviewed at St. Jane Francis and the maximum efficiency filters (highest MERV rating) recommended by the manufacturer should be installed.

As discussed above, classrooms at St. Raphael are equipped with portable HEPA filtration units.

5.0 RECOMMENDATIONS

Pinchin offers the following recommendations:

1. Continue to monitor CO_2 / ventilation rates at Mother Cabrini to confirm performance as colder weather arrives.
2. Review the HVAC system at St. Jane Francis and ensure:
    a. The system is properly balanced.
    b. The maximum efficiency filters (highest MERV rating) recommended by the manufacturer are installed. Ideally this would be MERV13.
    c. The humidification system is functioning properly.
    d. Consider deploying portable air filters in classrooms where ventilation performance is not maintaining CO_2 concentrations consistently below 800 ppm.
3. Operate HVAC systems and portable HEPA filters for a minimum of 2.5 hours before and after occupancy to help flush / filter airborne particulate between school days.
4. Implement the following strategies to maximize natural ventilation in schools not equipped with mechanical ventilation.
    a. Open all available windows to maximize window opening size. Where classrooms are equipped with windows that open both top and bottom this should include the upper window. Where cold temperatures and draft is an issue, and the classroom is so equipped, open the top section of the window only. Where the upper window is operable but difficult to operate consider having caretaking staff open the upper windows before class and close them after class.
5. Implement window operation changes in select classrooms at a suitable subject school. Monitor CO_2 and temperature over a 15-30 day period to determine if changes to window operation can improve ventilation outcomes.

6.0 TERMS AND LIMITATIONS

This work was performed subject to the Terms and Limitations presented or referenced in the proposal for this project.

Information provided by Pinchin is intended for Client use only. Pinchin will not provide results or information to any party unless disclosure by Pinchin is required by law. Any use by a third party of reports or documents authored by Pinchin or any reliance by a third party on or decisions made by a third party based on the findings described in said documents, is the sole responsibility of such third parties.

Pinchin accepts no responsibility for damages suffered by any third party as a result of decisions made or actions conducted. No other warranties are implied or expressed.

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Template: Master Report for Investigation of Mould Growth and IAQ, IEQ, August 22, 2019

APPENDIX I

Window Assessment Report

February 12, 2021 PRIVATE & CONFIDENTIAL

St. Raphael Catholic School
3 Gade Drive
North York, ON M3M 2K2

Re: Window Assessment
3 Gade Drive, North York, Ontario
Pinchin File: 287111.000

At the request of Toronto Catholic District School Board (TCDSB) (Client), Pinchin Ltd. (Pinchin), conducted a review of the windows at St. Raphael Catholic School located at 3 Gade Drive, North York, Ontario, (Site). A general condition assessment of the windows was conducted for the purpose of making recommendations for improving the amount natural ventilation in response to the COVID-19 pandemic.

This investigation was requested in response to potential issues regarding the amount of natural ventilation provided by the existing window of the Site building. A visual review of the Site building was carried out on January 26, 2021.

1.0 BUILDING DESCRIPTION

The Site consists of a two-storey institutional building with brick masonry cladding, a flat roof, concrete masonry unit (CMU) backup walls and metal-framed windows and doors. The windows consist of aluminum frames with a combination of fixed and operable (i.e., vertical slider) Insulated Glass (IG) units. The windows also feature spandrel panels at the top sections of the windows that feature a cork board finish on the interior and a metal salmon-colored finish on the exterior.

2.0 OBJECTIVE

The purpose of the condition assessment was to assess and provide recommendations relating to the potential for increasing the amount of natural ventilation that could be achieved through windows, existing or new, while meeting application standards and minimizing the risk for pinching and fall hazards.

A visual assessment of the interior side of the windows was carried throughout both floors of the Site building. The assessment was conducted in order to document current opening capabilities, restrictors used, ease of operation, and general condition of the windows, all of which were used to determine the best option (i.e. refurbishment or replacement).

Furthermore, a visual assessment of the exterior side of the windows was carried out from the ground level to assess overall condition. The visual survey was conducted in order to document condition of

sealants, staining, corrosion and other evidence of deterioration on the windows as well as the condition of interface joints between components.

3.0 OBSERVATIONS

3.1 General Window Observations

The windows of the Site building consist of a combination of fixed and operable (i.e., vertical slider) aluminum framed IG units with spandrel panels as the top sections of the windows. The majority of the windows were found to have been manufactured in 2004 (i.e. approximately 17 years old), with a few units having been manufactured in 2014 (i.e. approximately 7 years old). The windows were noted to feature stone sills on the interior and precast concrete sills on the exterior (refer to Photographs 1 to 4).

3.2 Interior Review

1. Pinchin noted that the typical opening for the vertical slider windows were found to open to a height of approximately 4 inches (“) on the interior side of the frame. While it was noted that at least one window assembly per classroom were noted to have been modified with the restrictors moved upwards to allow for a window opening of approximately 13” on the interior side (Refer to Photographs 5 and 6).
2. All of the operable units tested were generally found to be relatively easy to open, however, they were generally very hard to close.
3. Washroom windows were observed to not have any restrictors at the time of the Site review; it is presumably due to their height above floor level and access.

3.3 Exterior Review

1. The windows on the ground floor on the east elevation of the building were noted to have protective cages / screens covering the window assemblies. The protective cages / screens were noted to generally be in good condition with the exception of minor corrosion (Refer to Photograph 7).
2. The exterior face of the frames and spandrel panels were noted to be generally in good condition with no significant signs of discoloration or deterioration that could be observed during the Site review.

4.0 PHOTOGRAPHIC DOCUMENTATION

The following photographs were taken during our cursory review of the Site building.

Photograph No. 1
Interior view of typical classroom window assembly.

Photograph No. 2
Exterior view of typical classroom window assembly.

Photograph No. 3
Interior view of typical office window assembly.

Photograph No. 4
Interior view of typical staircase window assembly.

Photograph No. 5

View of regular opening restrictor.

Photograph No. 6

View of modified opening restrictor.

Photograph No. 7

Exterior view of typical window protection on the ground floor window assembly with minor corrosion.

5.0 DISCUSSION

Overall, the windows of the Site Building were noted to generally be in fair to good condition with the exception of the aforementioned deficiencies. Aluminum-framed window assemblies of the type employed throughout the Site Building typically have a Projected Useful Life (PUL) of 30 to 35 years provided that routine maintenance, including cleaning of the drained window tracks and replacement of handles, etc., is performed on an as-required basis. The majority of the window assemblies appeared to be from circa 2004 (i.e. approximately 17 years old) and are anticipated to have approximately 13 or more years of useful life remaining. However, the PUL of exterior grade sealant is approximately 12 to 15 years, based on Pinchin's observations, it appears that the perimeter sealants and exterior sealants at the window frames have reached their PUL and are recommended for replacement in the short term.

Pinchin reviewed the potential for increasing the opening sizes of the operable windows (i.e. the vertical sliders) for the purpose of ventilation and found that the options are limited. The Ontario Building Code (OBC) 2012 restricts the window openings to 4" (100mm) if the window opening is located at a height less than 42" (1070mm) high from floor level and if there is more than 24" (600mm) of difference in the level between the window (i.e. window sill height) and the exterior ground level (i.e. at grade) (Refer to OBC 3.3.1.17 (1)(c) and 3.3.1.17 (2)). This entails that all second floor windows and first floor windows with climbable access (i.e. millwork or radiators) have a greater than 24" (600mm) distance to grade and would need to have their openings limited to 4" (100mm). Overall, Pinchin found that most of the windows at the Site Building meet the requirement for the restriction of the openings to 4" (100mm).

As well, considering the *"Investigation of Indoor Air Quality*" report prepared by Pinchin for TCDSB concluded that increasing the window opening did not result in better ventilation, Pinchin recommends the continued limit of the window openings to 4" (100mm) at all the windows of the Site Building. If there is still a desire to open the window beyond the recommended 4" (100mm), despite it not increasing the air movement, Pinchin noted that a protective cage or screen would need to be installed at the windows to create the required guard to protect from fall hazards. However, Pinchin does not recommend this course of action as the cost related to installing protective cages is greater than any benefit from doing so. In addition, structural design of the protective cages is required to ensure code compliance and adequate anchorage to the existing window frames and walls.

Moreover, as the windows reach their PUL, Pinchin recommends that the windows be replaced with an awning, casement, or hopper style opening in order to better address any safety concerns related to fall hazards and risk of pinching. Pinchin also recommends incorporating more operable sections located higher up within the new window assemblies to further reduce the fall hazards and risk of pinching. Finally, another benefit of replacing the slider windows with awning/casement/hopper style windows would be energy efficiency. Awning/casement/ hopper style windows are generally considered to be more energy efficient than sliders due to the compression of the window seals necessary to properly close the windows, which reduces the air leakage, and therefore increases energy efficiency.

6.0 OPTIONS

The following recommendations are intended to provide direction regarding repairs/replacement that, in Pinchin's opinion, are required to rectify the reported ventilation and safety concerns, as well as the water infiltration and other problems identified at the Site building during our review. As this report is of a cursory nature, further investigation may be necessary to fully identify all repair requirements. Pinchin would be pleased to assist St. Raphael Catholic School in the remediation of the identified problems found at 3 Gade Drive, North York, Ontario. Specification development may be required to provide a

Contractor with a fully developed Scope of Work including specified materials and repair / installation methods.

6.1 Exterior Window Protective Cage Installation

1. Conduct a Structural Review of the current window assemblies to determine the requirements for the protective cages and their installment.
2. Remove all existing exterior window protective caging, without damaging adjacent finishes or causing damage to the window assembly.
3. Supply and install protective cages on the exterior of the window assemblies to act as fall protection or as a guard. Colour of window assemblies protective cage to be chosen by Owner.

6.2 Window Replacement (Awning/Casement/Hopper Style)

1. Supply and install one (1) mock-up assembly for each of the windows. Colour of window assemblies to be chosen by Owner.
2. Remove and dispose of existing windows (glass, frames and sill flashings), including all associated sealants.
3. Clean and prime all surfaces to receive membrane as per the membrane manufacturer's written specifications.
4. Install aluminum upstand angle on interior side of rough opening.
5. Install new sub-sill flashing membrane onto sill rough opening.
6. Install new windows in existing openings with frames plumb, true, level, with frames square, free from warp, twist and superimposed loads.
7. Cap exterior sill with new prefinished metal flashing.
8. Completely fill void around frame perimeters with spray foam.
9. Apply sealant using equipment in accordance with manufacturer’s written instructions.
10. Remove sealant smears and droppings on completion of sealant installation in affected areas. Clean out sill track and drainage paths.

Should you wish to proceed with the recommended actions, do not hesitate to contact our office to discuss the appropriate steps for full remediation of the building related problems discussed in this report.

7.0 REPAIR COST ESTIMATES

The following tables represent Pinchin's estimated construction costs for the repair work options recommended in Section 6.0 for the Site building located at 3 Gade Drive, North York, Ontario.

SECTION	DESCRIPTION OF WORK	ESTIMATED COST (excluding taxes)
6.1	**Structural Review**	$10,000
	Exterior Window Protective Cages	$140,000
Additional Items		
Mobilization & Overhead		$10,000
Contingency Allowance (10%)		$16,000
Subtotal		$176,000
Tender Variance (+/- 10%)		$17,600
Total Estimated Construction Costs		$158,400 to $193,600

The noted repair costs above exclude the following:

1. Harmonized Sales Tax (HST).
2. Consulting fees.

SECTION	DESCRIPTION OF WORK	ESTIMATED COST (excluding taxes)
6.2	**Window Replacement (Including Sealant Replacement)**	$475,000
Additional Items		
Mobilization & Overhead		$35,000
Contingency Allowance (10%)		$50,500
Subtotal		$560,500
Tender Variance (+/- 10%)		$56,050
Total Estimated Construction Costs		$504,450 to $616,550

The noted repair costs above exclude the following:

1. Harmonized Sales Tax (HST).
2. Engineering and Consulting fees

The above estimated costs are Class D estimates only. Quotes should be obtained from qualified contractors based on technical specifications and drawings prepared by Pinchin Ltd., to obtain accurate project pricing.

8.0 TERMS AND LIMITATIONS

This work was performed subject to the contractual and technical Terms and Limitations presented or referenced in the proposal for this project.

Information provided by Pinchin is intended for Client use only. Pinchin will not provide results or information to any party unless disclosure by Pinchin is required by law. Any use by a third party of reports or documents authored by Pinchin or any reliance by a third party on or decisions made by a third party based on the findings described in said documents, is the sole responsibility of such third parties. Pinchin accepts no responsibility for damages suffered by any third party as a result of decisions made or actions conducted. No other warranties are implied or expressed.

The assessment is based, in part, on information provided by others. Unless specifically noted, Pinchin has assumed that this information was correct and has relied on it in developing the conclusions. Environmental audits, or the identification of designated substances, hazardous materials and mould are excluded from this report.

The intent of Pinchin's comments on water infiltration inspection is for the sole purpose of identifying areas where Pinchin has observed a noteworthy condition.

Unexpected conditions may be encountered at the Site that has not been explored within the scope of this report. Should such an event occur, Pinchin should be notified in order to determine if modifications to the conclusions are necessary.

9.0 CLOSURE

Pinchin trusts that the aforementioned report addresses your requirements. Should you require clarification or information regarding this report, please contact the undersigned.

Sincerely,

Pinchin Ltd.

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Template: Building Envelope Condition Assessment, Short Report, BSS, March 11, 2020