Group O

April 25th, 2026
Queen's Facilities
355 King Street West, Kingston, ON K7L 2X3
Alumni Way Atrium Project

Dear Mr. Nathan Splinter & Mr. David Gerrish,

As discussed throughout the course of this project, we are pleased to submit our final report entitled *Alumni Way Atrium Final Report* for our CIVL 460 Capstone Project.

This report presents the completed design proposal for the Alumni Way atrium, including the development and evaluation of multiple design concepts, selection of the preferred concept, and supporting structural analysis. It further outlines the rationale behind key decisions related to structural systems, material selection, and glazing, supported by weighted evaluation matrices. In addition, the report addresses constructability, cost considerations, maintenance requirements, sustainability, and social impacts to demonstrate the overall feasibility of the proposed design.

We believe that this report fulfills the project objectives by delivering a comprehensive, code-informed, and practically viable atrium design that aligns with the needs and priorities of Queen's Facilities.

We appreciate the opportunity to work on this project and thank you for your guidance and feedback throughout the term. Should you have any questions or wish to discuss any aspect of the report further, we would be happy to discuss at your convenience.

Best,

Liam McDonell
F Colombe

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CIVL 460

Civil Engineering Design & Practice IV F25

Alumni Way Atrium Final Report

Group O

April 25th, 2026

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Following professional engineering practice, we bear the burden of proof for original work. Therefore, we have read the Policy on Academic Integrity posted on the Faculty of Engineering and Applied Science website (http://engineering.queensu.ca/policy/Honesty.html) and confirm that this work is in accordance with the Policy.

Our signatures below attest that this submission is our original work:

Signature: Date: ______ Apr. 25/26____
Signature Date: ______ Apr. 25/26____
Signature: Liam MacDonell Date: ______ Apr. 25/26____
Signature: F Colombe Date: ______ Apr. 25/26____

Disclaimer

This report has been prepared by undergraduate engineering students as part of an academic exercise in a structural design case. The authors are not licensed Professional Engineers and do not provide professional engineering services.

The design concepts, calculations, and analysis contained in this report are intended solely for academic and conceptual evaluation purposes. This document presents as a proof-of-concept study and does not constitute a final design suitable for construction, tendering, or regulatory approval.

The structural systems, member sizes, load assumptions, and detailing included in this report should be reviewed, verified, and sealed by a licensed Professional Engineer prior to implementation. Site-specific investigations, detailed code compliance checks, constructability reviews, and coordination with other disciplines have not been fully undertaken.

The authors assume no liability for the use or misuse of the information contained in this report beyond its academic context.

Executive Summary

This report presents a conceptual structural design for an atrium system utilizing a primarily steel load-resisting framework with integrated timber elements and insulated glass units (IGUs). The objective is to evaluate the system's structural feasibility, constructability, and alignment with the assumed project constraints.

Two design concepts were developed and assessed using defined performance criteria. While both were viable at a conceptual level, Design Concept 2 demonstrated a clearer load path, improved structural efficiency, and a more coherent force-resisting strategy, and was therefore selected for further development.

The proposed system uses steel as the primary structural material, with timber incorporated into column elements to improve material efficiency and support sustainability objectives. IGUs are included to address envelope and thermal performance. This combination supports efficient force transfer and constructability while allowing each material to be used where it is most effective.

Preliminary analysis, carried out in accordance with governing building provisions, indicates that the system satisfies strength requirements and exhibits acceptable serviceability behaviour under the governing load cases. These results support the structural feasibility of the design at a conceptual level.

In addition to structural considerations, the design was qualitatively evaluated in terms of cost, constructability, durability, and sustainability. The selected configuration demonstrates a balanced approach across these factors and is a reasonable candidate for further development.

However, key aspects such as detailed connection design, lateral system validation, and verification of the existing structure remain outside the scope of this study and require further investigation. As such, the results presented should be interpreted as preliminary.

Overall, Design Concept 2 provides a clear and efficient structural strategy that meets the project objectives within the scope of a conceptual study and establishes a foundation for continued refinement and detailed design.

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1.0 Introduction

Group O has been contracted to assess and design an atrium to enclose Alumni Way, a narrow pedestrian corridor connecting the John Deutsch University Centre (JDUC) and Mitchell Hall. This corridor is used by students, staff, and visitors and experiences persistent pigeon nesting, leading to ongoing maintenance and sanitation issues. To address this, Queen's Facilities proposed constructing an atrium that connects the roof lines of Mitchell Hall and the JDUC, effectively enclosing the area and preventing birds from accessing the corridor. The proposed atrium will span approximately 10 metres between the two buildings.

The atrium must be designed to resist snow, wind, live, and dead loads in accordance with the National Building Code of Canada 2020 (NBCC) Climate Data Table [1], and the 2024 Ontario Building Code (OBC) Part 4 [2]. In addition to structural performance requirements, the design is subject to several architectural and institutional constraints. The historical character of the JDUC must be preserved, while the atrium must integrate with the more modern architectural expression of Mitchell Hall. Furthermore, load limitations of the existing structures must be carefully considered to ensure compatibility with the proposed system.

The final design will adhere to the Queen's University Heritage Policy [3] and Building Design Standards [4] to ensure compliance with all institutional requirements. A successful solution will improve user comfort, reduce maintenance demands, and resolve ongoing sanitation issues. This report outlines the progress of the team's design for Queen's Facilities.

2.0 Background Information

2.1 Site Description

Mitchell Hall and the JDUC are located along Union Street on Queen's University main campus in Kingston, Ontario. The Alumni Way corridor is located behind the JDUC shown in Figure 1. The corridor is approximately 10 metres wide and 35 metres long, with access doors at either end leading into Mitchell Hall and the JDUC.

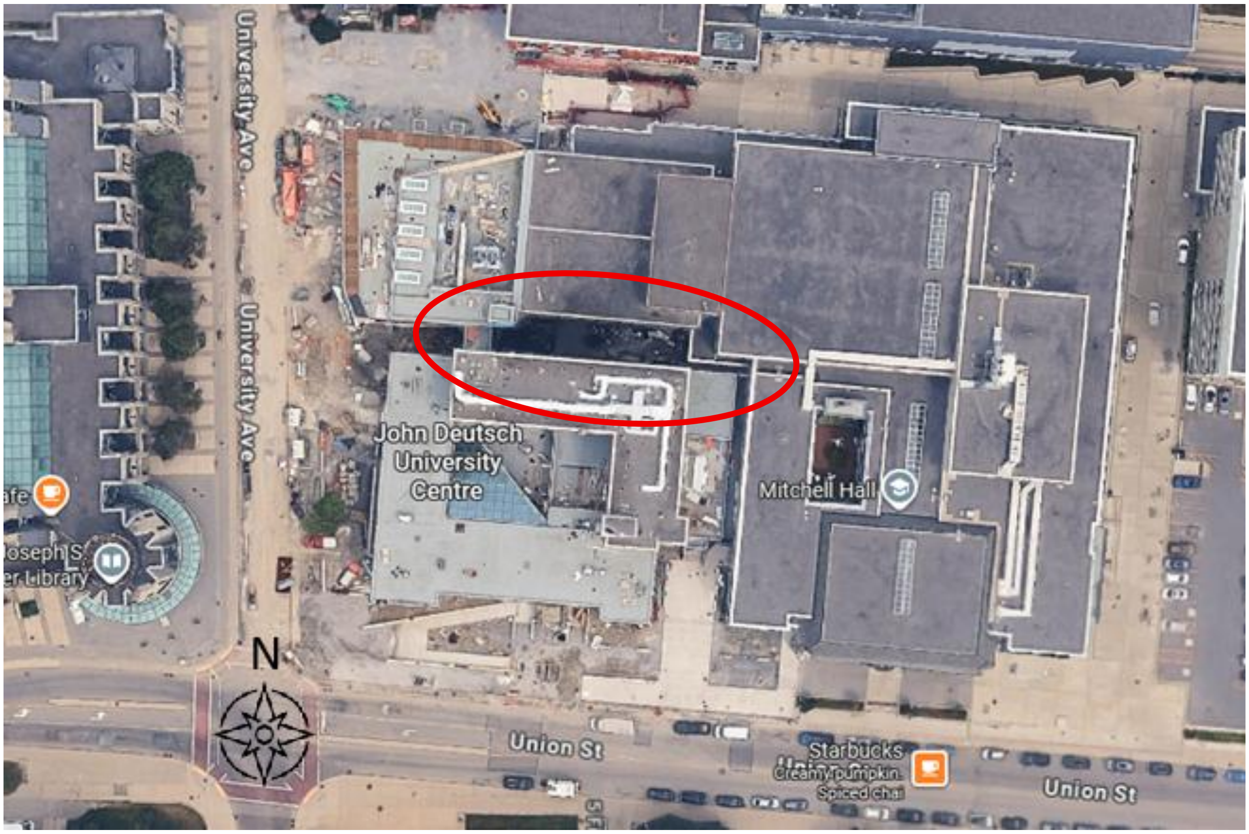


Figure 1: Location of the Alumni Way Corridor, Base Map: Google Maps, 2025

A site visit was conducted to document existing conditions that may influence the atrium design. Along the north wall of the corridor, a continuous planter approximately 30 metres long and 1 metre wide contains existing vegetation. The presence of this planter introduces two key design considerations. First, the atrium must allow sufficient sunlight exposure to sustain plant health and growth. Second, because the enclosure will eliminate natural precipitation, an artificial irrigation system or revised maintenance protocol will be required to ensure adequate watering.

Above the planter, two large exhaust vents, each approximately 1 m^2 in area, were observed. These vents may interfere with the proposed atrium and could require duct redirection. At the easternmost end of the corridor, an air conditioning condenser unit must remain unobstructed and exposed for ventilation. As a result, the atrium will terminate in line with the access door at the eastern end of the corridor.

The site is further constrained by the surrounding buildings, which limit direct construction access to the corridor. However, sufficient staging and vehicle access space is available along the wide pedestrian walkway adjacent to the JDUC on University Avenue. The installation of the atrium will also alter the existing drainage conditions. Currently, rainwater entering the corridor drains through surface runoff. Once enclosed, precipitation will be intercepted by the roof structure and must be redirected into the existing stormwater infrastructure through a newly designed drainage system.

Finally, there is an approximate 9 metre height difference between the two rooflines of the JDUC, reaching approximately 23 metres at its tallest point. Because the atrium will be constructed at roof level, it will be subjected to significant wind exposure. Wind effects, in accordance with OBC Part 4, will therefore govern both structural design and construction considerations. These existing features are shown in Figure 2.

Figure 2: Alumni Way Corridor with Existing Features, Source: David Gerrish

2.2 Environmental and Climatic Considerations

The proposed atrium presents an opportunity to integrate green and sustainable building practices that enhance the space and user comfort, reduce operational energy demand, and support long-term environmental performance. The design will prioritize passive and low-energy systems such as efficient daylight lighting, thermal regulation, and material selection. To maximize daylight efficiency, the atrium will incorporate paneling designed to refract natural light throughout the space. This approach will improve visibility for users and support the health of existing vegetation within the corridor. Thermal regulation will be addressed through glazing, to maintain consistent temperature over seasonal conditions and reduce reliance on adjacent building's HVAC systems.

Glazing refers to the system of transparent panels and its supporting framework. Material selection will emphasize durability while attempting to limit embodied carbon to reduce the projects overall carbon footprint. These strategies align with the Canadian Green Building Council's *Leadership in Energy and Environmental Design* (LEED) [5] framework. The LEED framework promotes energy efficiency, indoor environment quality, and sustainable material use. The design will also take guidance from the WELL Building Standard [6], which promotes occupant health and comfort. By utilizing these strategies in the atrium design, the project also supports Queen's University's broader sustainability goals.

2.3 Heritage and Architectural Constraints

The proposed atrium must respect the architectural character of the John Deutsch University Centre (JDUC), which is subject to Queen's University Heritage Policy [3]. As a heritage building, the JDUC contains several character-defining elements that must be preserved. These include its masonry façade, fenestration pattern, roofline geometry, and overall visual prominence along Union Street. Any structural intervention must avoid permanent alteration to these defining features and minimize visible attachment points where possible.

In addition to preservation requirements, the visual impact of the atrium must be carefully considered. The enclosure will be visible from adjacent pedestrian routes and upper building levels and therefore must not detract from the architectural identity of either the JDUC or Mitchell Hall. The atrium should read as a complementary addition rather than a dominant structure. Transparency, material selection, and framing proportions will influence how visually integrated the structure appears within the existing campus context.

Accordingly, the integration approach will prioritize a lightweight structural expression and minimal visual obstruction. Connections to the existing buildings will be designed to reduce invasive modifications while maintaining reliable load transfer. The atrium must form a cohesive transition between the heritage masonry of the JDUC and the more contemporary design of Mitchell Hall, ensuring that both architectural styles remain legible and respected.

3.0 Problem Statement

3.1 Project Scope and Objectives

Group O has been tasked with evaluating the feasibility and developing the structural design of an atrium to enclose Alumni Way by connecting the rooflines of the JDUC and Mitchell Hall. The primary objective of this project is to improve the pedestrian experience along the corridor by eliminating the ongoing sanitation and maintenance issues caused by nesting pigeons.

The proposed atrium must integrate the heritage character of the JDUC with the modern architectural expression of Mitchell Hall, while maintaining adequate lighting and ventilation to ensure user comfort and the health of existing vegetation. In addition to architectural compatibility, the design must account for load limitations of the existing structures and minimize disruption to current building operations.

From a structural standpoint, the atrium will be designed in accordance with the 2020 NBCC and the 2024 OBC, with all applicable dead, live, snow, and wind loads evaluated to ensure compliance with Ultimate and Serviceability Limit States requirements. Structural systems will be selected and sized to provide adequate strength, stiffness, and durability while remaining constructible within the constraints of the site.

A successful design will provide a code-compliant and feasible enclosure that enhances functionality, reduces long-term maintenance demands, and aligns with the operational goals of Queen’s Facilities.

3.2 Constraints

The design of the proposed atrium is governed by a combination of structural, environmental, operational, and regulatory constraints. These requirements collectively define the feasible design space and directly influence system selection, geometry, and detailing.

3.2.1 Structural and Environmental Requirements

The atrium must satisfy both Ultimate Limit State (ULS) and Serviceability Limit State (SLS) requirements in accordance with the 2020 National Building Code of Canada (NBCC) and the 2024 Ontario Building Code (OBC). Due to its location at roof level and full exposure to the elements, environmental loading is expected to govern several aspects of the design.

For Kingston, the governing specified snow load is 2.27 kPa, determined in accordance with NBCC 2020 provisions using regional climatic data. This load will control the design of primary structural members. Rain loads must also be considered to account for potential ponding effects, and wind loading will be critical given the elevation of the structure above grade. These environmental actions will be combined with dead and live loads using prescribed load combinations to determine factored design demands.

As the atrium is intended as a long-term installation, thermal expansion and contraction resulting from seasonal temperature variations must be accommodated. Differential movement between the new structure and the existing buildings may require expansion joints or flexible connections. Reliable load transfer, waterproofing integrity, and durability over the structure’s service life are essential performance requirements.

3.2.2 Mechanical and Operational Constraints

Existing HVAC systems along the corridor present additional design limitations. Two exhaust vents are located above the planter along the north wall, and an air conditioning condenser unit is positioned at the eastern end of the corridor. The atrium must maintain adequate airflow, prevent the accumulation of exhaust gases within the enclosed space, and preserve access to all equipment for maintenance.

The enclosure may require localized duct rerouting or supplemental ventilation to ensure proper air circulation. Adequate clearance must also be maintained around the condenser unit to allow proper heat dissipation. These constraints directly influence the geometry and termination of the atrium at the eastern end of the corridor.

3.2.3 Vegetation and Natural Light

The existing vegetation along the north wall is a key environmental consideration. Queen's Facilities has indicated that the corridor may be revitalized as a student hub, with increased aesthetic value and the inclusion of native, low-maintenance plant species. The atrium must therefore maintain sufficient daylight penetration to support plant health while preserving clear circulation space.

Because the enclosure will eliminate natural precipitation, irrigation and drainage systems must be incorporated to sustain vegetation and prevent localized ponding. The selection and configuration of glazing systems will influence both daylight availability and structural performance. Glazing panels will be sized and specified to resist environmental loading while maintaining long-term clarity and durability under UV exposure and fluctuating temperatures. These requirements reinforce the need for coordination between structural framing, roof transparency, and drainage strategy.

3.2.4 Elevation and Geometric Constraints

There is an approximate 9 m elevation difference between the JDUC and Mitchell Hall along the corridor. This vertical offset will influence the slope and overall geometry of the atrium roof system, particularly when determining the extent of coverage.

Roof slope is a critical design parameter, as it affects snow accumulation patterns, drainage performance, and wind pressure distribution. A steeper slope may reduce snow buildup but increase wind exposure, while a shallower configuration may increase the risk of ponding or drift formation. The selected geometry will therefore directly influence governing load cases and long-term serviceability performance.

3.2.5 Timeframe

The most common constraint in these projects is timeframe. Construction is limited to the summer months when student traffic is low and less classes are being held. This short window means strict scheduling with contingency planning required for delays.

3.2.6 Regulatory Framework

The design of the atrium must comply with the 2024 Ontario Building Code, which adopts the National Building Code of Canada 2020 with Ontario-specific amendments. Structural design will follow the requirements of Division B, Part 4, while mechanical and ventilation considerations will be addressed in accordance with Division B, Part 6.

As the JDUC is a designated heritage building, the project must also comply with the Ontario Heritage Act [7] and align with Queen's University Heritage Policy [3]. All structural and architectural interventions must respect character-defining elements and minimize permanent alterations to the existing buildings.

3.3 Stakeholders

To effectively prioritize stakeholder needs, the team decided to evaluate them based on two criteria: impact (to measure how much the project will affect them) and influence (their ability to shape the project's outcome). This approach ensures that even high-influence groups (such as regulatory bodies or funders) are considered appropriately despite not being affected by day-to-day operations. The stakeholder score can be assigned based on the formula below:

$$Stakeholder\ Weight = Impact \times Influence$$

Where scores are assigned as:

Impact:
5 – Daily users / those responsible for safety and operations
4 – Regular but not daily users
3 – People affected by construction or disruption
2 – Indirectly affected community members
1 – Peripheral interest only

Influence:
5 – Regulatory authority, funders, project owners
4 – Senior decision-makers / unions
3 – Organized groups (associations, NGOs)
2 – Occasional input, low decision power
1 – Minimal ability to influence outcome

The impact and influence of stakeholders can vary throughout the construction process. In later deliverables, the stakeholder scores will be re-evaluated based on the changing landscapes. For now, the team has developed the following stakeholder weight scores in Table 1:

Table 1: Stakeholder Weighted Scores

Stakeholder	Description	Impact (1-5)	Influence (1-5)	Score
Queen's University Administration	Approves design feasibility, budget, and alignment with heritage guidelines; final decision and approvals	5	5	25

Queen’s Facilities	Maintains and improves campus facilities at Queen’s	5	4	20
Group O	Responsible for the design of atrium	4	4	16
City of Kingston	Has regulation and bylaws on buildings, zoning, and urban aesthetics	3	5	15
University Heritage Committees	Ensures the design adheres to the heritage policy for both buildings	4	3	12
Queen’s Alma Mater Society (AMS)	Operates many services out of the JDUC, will affect service during construction	4	3	12
Building Manager	Need to coordinate structural tie-ins, accessibility, and interior impacts during construction. JDUC and Mitchell Hall are managed by Don Conners (connersd@queensu.ca)	4	3	12
Construction Contractors/Architects	Will implement the designs and deal with structural loads and constructability	4	3	12
Students	Daily users of the Alumni Way	5	2	10
Residents of JDUC	Grad students living on the upper floors of the JDUC	5	2	10
Sustainable Queen’s	Responsible sustainability initiatives at Queen’s	3	3	9
Campus Security	Responsible for ensuring safety during construction and adherence to accessibility codes	3	3	9
Faculty/Staff	Regular users of the corridor	4	2	8
Maintenance Staff	Directly responsible for cleaning and maintenance of the Alumni Way currently, will be affected by reduction in pigeon related messes.	4	2	8
Event Coordinators	The JDUC and Mitchell Hall are often used for events, so logistics will be affected during construction	3	2	6
Landscaping Consultants	Will give advice on lighting and plant life in the Alumni Way	3	2	6
Environmental Impact (Wildlife Displacement)	Pigeons and other wildlife have formerly used the Alumni Way and will be displaced after construction	4	1	4
Visitors	Visitors’ impression of the University can be affected by outward appearances	3	1	3

General Public	Has opinion on building aesthetics and heritage	2	1	2
Alumni Community	May have some symbolic interest, especially if their funding is involved	1	2	2
Pest Control Services	Responsible for pigeon control concerns	2	1	2

Currently, stakeholders with scores of 15 or higher are consulted on a bi-weekly basis through progress meetings, while those below are being considered only on an as-needed basis. This structure ensures that the most engaged stakeholders will be given their proper consideration and remain integrated in the project. Please see Section 11.3 for more details regarding meetings.

4.0 Design Development and Evaluation

4.1 Design Concept 1: Atrium Over Corridor and Rooftop

The first design alternative proposes a large atrium structure that spans Alumni Way and extends over a portion of the Mitchell Hall rooftop adjacent to the corridor (Figure 3). During the site visit, this rooftop area near the mechanical penthouse was identified as a potential opportunity for a student-oriented space, such as a greenhouse. The proposed coverage area is shown in Figure 4 and primarily reflects the main sloped roof surface; additional enclosure elements would require further detailing.

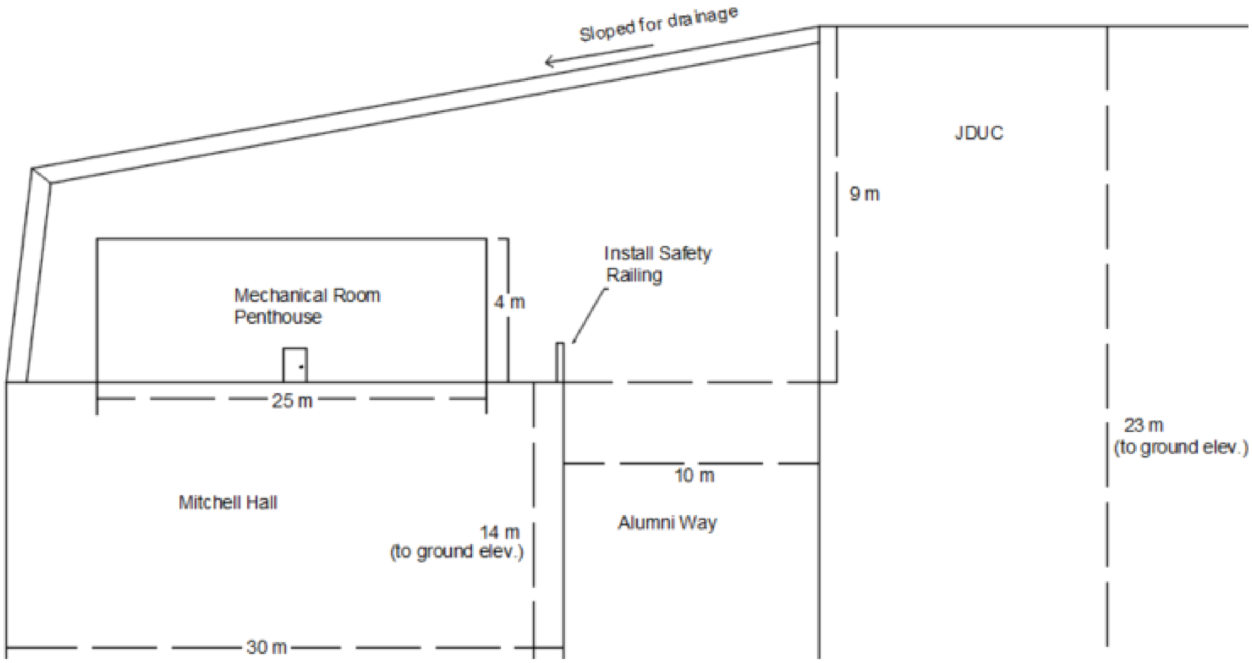


Figure 3: Preliminary Design 1 - Atrium and Rooftop

Figure 4: Atrium Roof Coverage

To better understand the spatial impact and integration with existing rooflines, a 3D model was developed (Figure 5). This visualization supports evaluation of geometry, slope, and connection feasibility between the two buildings.

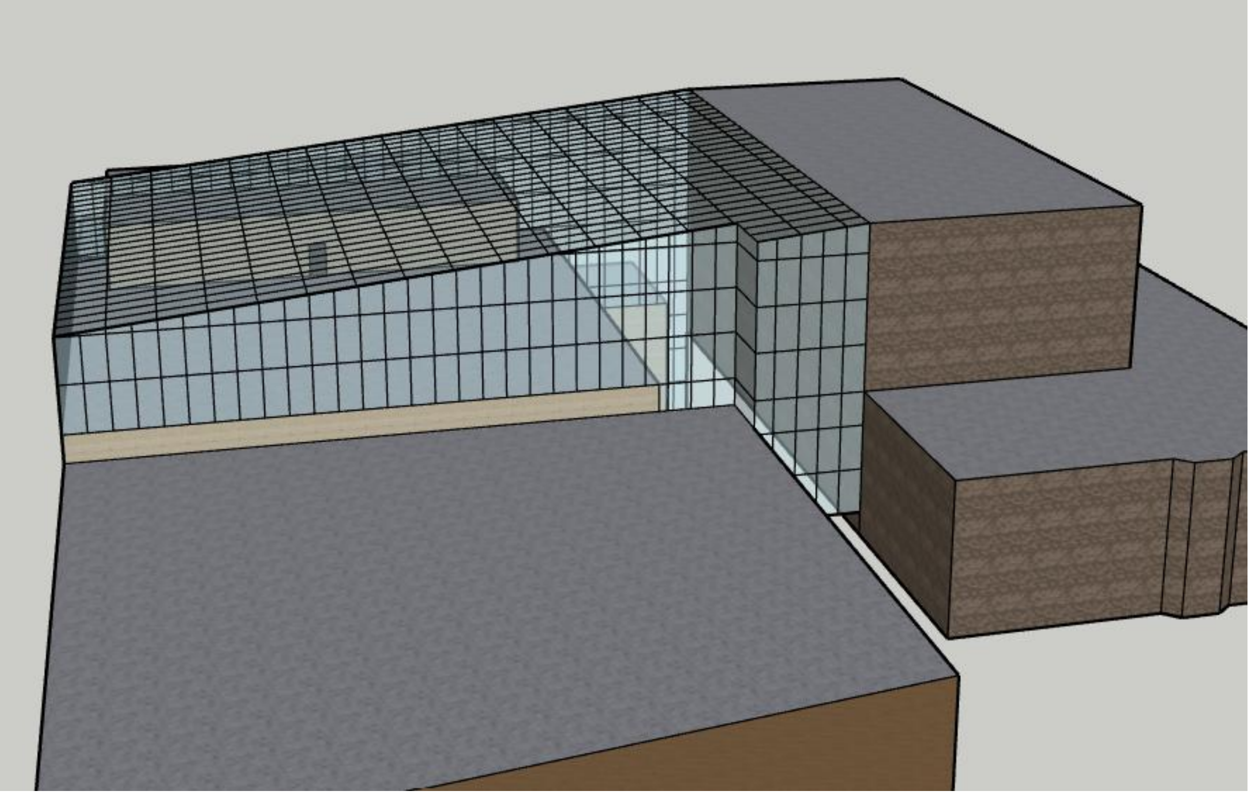


Figure 5: Design Concept 1 - Atrium Roof for Alumni Way and Roof

4.1.1 Design Loads

The atrium is classified as a normal importance structure under the 2024 OBC, and this classification is applied consistently across all environmental loading calculations. The roof is considered **non-accessible**, meaning snow loading is expected to govern over live loading in most cases. All loads are presented in kPa for consistency.

4.1.1.1 Snow Load

Snow loading is determined in accordance with OBC 2024 Section 4.1.6, given in Equation 1:

$$S = I_s[S_s(C_b C_w C_s C_a) + S_r] \tag{1}$$

For Kingston:

- Ground snow load, $S_s = 2.1$ kPa
- Associated rain load, $S_r = 0.4$ kPa
- Importance factor, $I_s = 1.0$
- Basic roof factor, $C_b = 0.8$

- Wind exposure factor, $C_w = 1.0$
- Slope factor, $C_s = 1.0$ (6° slope, slippery glass surface)
- Accumulation factor, $C_a = 1.0$ (no significant geometric discontinuities or adjacent higher roofs promoting drift accumulation)

The accumulation factor $C_a = 1.0$ is considered appropriate because the proposed geometry does not create confined snow pockets or step conditions that would significantly increase drift formation.

$$S = 1.0[2.1(0.8 \cdot 1.0 \cdot 1.0 \cdot 1.0) + 0.4]$$
$$S = 2.08 \text{ kPa}$$

The specified snow load for Design Concept 1 is 2.08 kPa. Given the non-accessible nature of the roof, snow loading is expected to govern over live loading.

4.1.1.2 Wind Load

Wind loading is determined in accordance with OBC 2024 Section 4.1.7, given in Equation 2:

$$p = I_w q C_e C_g C_p \tag{2}$$

For Kingston:

- Reference velocity pressure, $q = 0.47$kPa
- Importance factor, $I_w = 1.0$ (normal importance)
- Exposure factor, $C_e = 0.83$ (rough urban terrain)
- Gust factor, $C_g = 2.0$ (main structural system)
- External pressure coefficient, $C_p = 1.0$ (preliminary assumption)

The external pressure coefficient $C_p = 1.0$ is adopted as a conservative preliminary value for overall roof surfaces. This assumption will require refinement in detailed design to account for edge zones and wind directionality effects.

$$p = 1.0 \cdot 0.47 \cdot 0.83 \cdot 2.0 \cdot 1.0$$
$$p = 0.78 \text{ kPa}$$

The specified wind pressure for the atrium is 0.78 kPa.

4.1.1.3 Live Load

As the atrium roof is considered non-accessible, live loading is taken in accordance with NBCC Table 4.1.5.3:

- Uniformly distributed live load = 1.0 kPa

- Concentrated live load = 1.3 kN

Member design will consider both cases, with the governing effect used for sizing. However, given the environmental exposure and non-accessibility, snow loading is expected to control primary structural member design.

4.1.1.4 Dead Load

Dead load consists primarily of glazing panels and the supporting structural system.

For preliminary design, the dead load for the roof glazing system is idealized as a uniform pressure of 0.294 kPa. This value is used as a design assumption to support early member sizing and is not intended to represent the final insulated glazing unit (IGU) build-up.

This assumption is considered appropriate at this stage because:

- It provides a reasonable order-of-magnitude estimate for lightweight glazing systems during conceptual design.
- It includes a small conservative allowance that implicitly accounts for framing self-weight.
- The exact IGU configuration and its true unit weight has not yet been finalized.

Once the final IGU build-up is selected, the dead load will be recalculated using the actual glass thickness and spacing, and member sizing will be checked and updated accordingly.

4.1.1.5 Load Combinations

Ultimate limit state (ULS) load combinations are taken from NBCC Table 4.1.3.2.-A.

For vertical loading on the roof (z-axis), the governing combination is:

$$1.25D + 1.5S + 1.0L$$

Resulting in a factored design pressure of:

$$4.49 \text{ kPa}$$

This combination governs roof member design.

For lateral loading on the frames (x- and y-axes), wind governs. The controlling case is:

$$1.4W$$

Resulting in a factored lateral design pressure of:

$$1.09 \text{ kPa}$$

Thus, roof members are governed by snow-dominated combinations, while lateral frames are governed by wind loading.

4.1.2 Other Performance Considerations

Beyond strength requirements, several serviceability and operational factors influence this design. The extended sloped geometry introduces deflection and glazing movement concerns under snow and wind loading. Excessive deflection could result in glass cracking, sealant failure, or water infiltration. Drainage design is critical to prevent ponding at the low end of the slope.

Constructability presents additional challenges. The irregular geometry and multi-level connections between buildings will require complex detailing and likely crane-assisted installation. Temporary pedestrian closures and rooftop access coordination will be necessary during construction. If the rooftop space above Mitchell Hall is developed for student use, additional structural reinforcement of the existing roof may be required.

Maintenance demands are expected to be high due to the extensive glazed surface area. Regular cleaning, inspection of sealants, and potential snow removal in extreme conditions must be anticipated.

From a cost perspective, this concept is expected to be the highest-cost option due to:

- Increased structural steel and glazing area
- Complex connection detailing
- Potential roof reinforcement
- Construction logistics

Sustainability considerations are mixed. While increased glazing may elevate solar heat gain and heat loss, it may also provide passive daylighting benefits and enable potential greenhouse use. The final environmental performance will depend on glazing specifications, shading strategy, and integration with HVAC systems.

4.2 Design Concept 2: Atrium Covering Hallway

Design Concept 2 was developed as a lower-intervention alternative to Concept 1. Unlike the first option, this atrium does not extend over the Mitchell Hall rooftop. Instead, it spans only Alumni Way, reducing structural demands, construction complexity, and impact on the existing roof system. This concept prioritizes constructability, cost efficiency, and minimized modification to heritage fabric while still achieving the primary goals of enclosure, weather protection, and improved usability of the corridor.

The proposed system consists of a greenhouse-style gable roof formed by transparent glass panels supported on steel framing. The enclosure seals Alumni Way, deters nuisance wildlife, and enhances the pedestrian environment. Landscape upgrades associated with this concept are detailed in Section 4.5. A 3D model of the proposed geometry is shown in Figure 6.

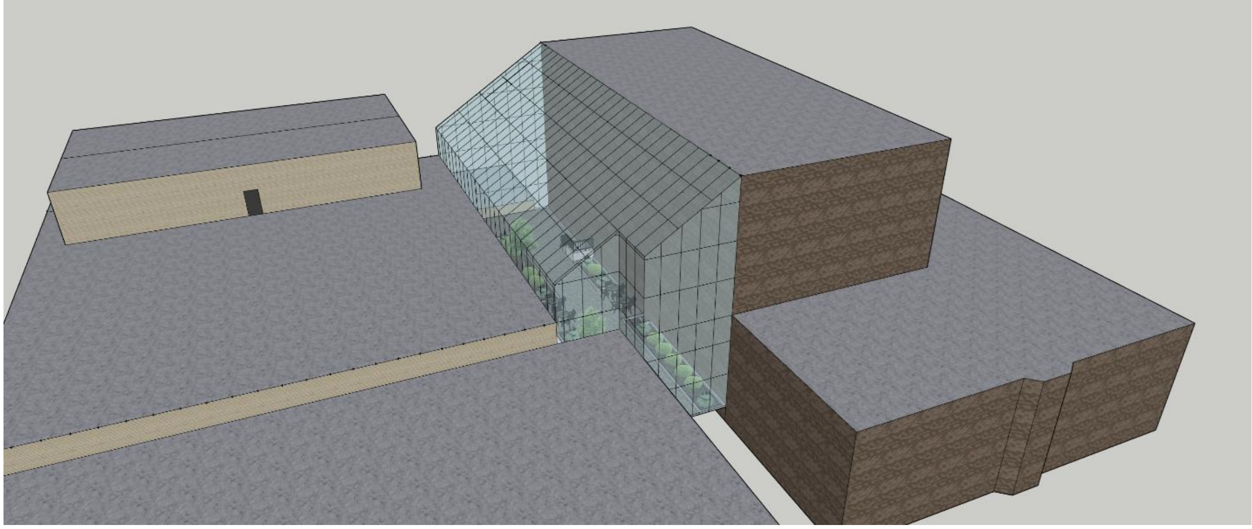


Figure 6: Design Concept 2 - Greenhouse Style Atrium Roof for Alumni Way

4.2.1 Design Loads

The atrium is classified as a normal importance structure under the NBCC 2020 and 2024 OBC. The roof is considered **non-accessible**, meaning environmental loading is expected to govern over live loading. All loads are presented in kPa for consistency.

4.2.1.1 Snow Load

Snow loading is determined in accordance with NBCC 2020 Article 4.1.6.2, given by Equation 1 again:

$$S = I_s[S_s(C_b C_w C_s C_a) + S_r] \tag{1}$$

For Kingston:

- Ground snow load, $S_s = 2.1$ kPa
- Associated rain load, $S_r = 0.4$ kPa
- Importance factor, $I_s = 1.0$
- Basic roof factor, $C_b = 0.8$
- Wind exposure factor, $C_w = 1.0$
- Slope factor, $C_s = 0.89$ (gable roof, $30° < \alpha < 70°$)
- Accumulation factor, $C_a = 1.25$

The accumulation factor $C_a = 1.25$ reflects the gable roof configuration and the potential for localized drift formation along the valley or adjacent building interfaces, as permitted under NBCC provisions for sloped roofs.

Substituting:

$$S = 1.0[2.1(0.8 \cdot 1.0 \cdot 0.89 \cdot 1.25) + 0.4]$$
$$S = 2.27 \text{ kPa}$$

The specified snow load for Design Concept 2 is 2.27 kPa.

4.2.1.2 Wind Load

Wind loading is determined in accordance with NBCC 2020 Section 4.1.7, given by Equation 2 again:

$$p = I_w q C_e C_t C_g C_p \tag{2}$$

For Kingston:

- Reference velocity pressure, $q = 0.47\text{kPa}$
- Importance factor, $I_w = 1.0$
- Exposure factor, $C_e = 0.7$
- Topographic factor, $C_t = 1.0$
- Gust factor, $C_g = 2.0$
- External pressure coefficient, $C_p = 1.0$

The external pressure coefficient $C_p = 1.0$ is adopted as a conservative preliminary value for global wind loading on the roof surface. Detailed zone effects, suction conditions, and edge coefficients will be evaluated during detailed design.

$$p = 1.32 \text{ kPa}$$

The specified wind pressure for Design Concept 2 is 1.32 kPa.

4.2.1.3 Live Load

In accordance with NBCC Table 4.1.5.3, the roof live load for a non-accessible roof is:

- Uniform load = 1.0 kPa
- Concentrated load = 1.3 kN

These loads account for maintenance access and cannot be reduced using live load reduction factors because the roof classification does not meet reduction criteria. However, given the environmental exposure and non-accessible designation, snow loading governs the vertical design of primary members.

4.2.1.4 Dead Load

Dead load consists primarily of glazing panels and the supporting structural system.

For preliminary design, the dead load for the roof glazing system is idealized as a uniform pressure of 0.294 kPa. This value is used as a design assumption to support early member sizing and is not intended to represent the final insulated glazing unit (IGU) build-up.

This assumption is considered appropriate at this stage because:

- It provides a reasonable order-of-magnitude estimate for lightweight glazing systems during conceptual design.
- It includes a small conservative allowance that implicitly accounts for framing self-weight.
- The exact IGU configuration and its true unit weight has not yet been finalized.

Once the final IGU build-up is selected, the dead load will be recalculated using the actual glass thickness and spacing, and member sizing will be checked and updated accordingly.

4.2.1.5 Load Combinations

Ultimate limit state (ULS) load combinations are taken from NBCC Table 4.1.3.2.-A.

For vertical loading on the roof (z-axis), the governing combination is:

$$1.25D + 1.5S + 1.0L$$

Resulting in a factored design pressure of:

$$4.77 \text{ kPa}$$

This combination governs roof member design.

For lateral loading on the frames (x- and y-axes), wind governs. The controlling case is:

$$1.4W$$

Resulting in a factored lateral design pressure of:

$$1.85 \text{ kPa}$$

Thus, roof members are governed by snow-dominated combinations, while lateral frames are governed by wind loading.

4.2.2 Other Performance Considerations

From a serviceability perspective, this concept benefits from its simpler geometry. The gable roof slope promotes snow shedding and improves drainage compared to Concept 1, reducing long-term accumulation risk. However, snow drift at roof intersections and deflection of glazing panels under load must still be verified to prevent seal failure or water infiltration.

Constructability is significantly improved relative to Concept 1. The reduced footprint eliminates the need for rooftop reinforcement of Mitchell Hall and simplifies connection detailing. Standardized framing layouts allow for more efficient fabrication and installation, reducing crane requirements and construction duration. Temporary closures of Alumni Way would still be necessary but would be shorter and less disruptive.

Maintenance demands remain present due to the glazed surface. Routine cleaning, inspection of sealants, and monitoring of thermal movement in the glass panels will be required. However, the steeper slope reduces the likelihood of manual snow removal.

From a cost perspective, this concept is expected to be substantially lower than Concept 1 due to:

- Reduced structural steel quantity
- Smaller glazing area
- Elimination of rooftop reinforcement
- Simplified construction sequencing

Operational energy demand may also be lower, as the enclosed volume is reduced. While solar heat gain remains a consideration, the smaller footprint limits overall heating and cooling loads. Embodied carbon is expected to decrease due to reduced steel demand, though glazing production remains energy intensive.

Overall, Design Concept 2 achieves the primary functional objectives of enclosure and revitalization while reducing structural complexity, cost, and intervention on adjacent heritage structures.

4.3 Optional Features

Two optional features are proposed to enhance the atrium’s performance by addressing structural load management, maintenance reduction, and daylight optimization. These are left optional to allow flexibility depending on budget, project priorities, and desired performance. Cost analyses for these features will be provided in the final report to support informed decision-making.

4.3.1 Heated Atrium Panels

Heated glazing panels can mitigate snow and ice accumulation, which otherwise introduces additional loading demands on adjacent structures, particularly Mitchell Hall, pending verification. By melting snow in a controlled manner, loads can be safely managed without requiring structural reinforcement or manual snow removal. An additional performance benefit is improved solar transmittance through the panels, supporting passive heating and natural light for both occupants and any plant life within Alumni Way.

4.3.2 Rainwater Recycling and Irrigation

Rainwater collection and irrigation systems are optional to reduce maintenance and potable water use. Since the atrium roof intercepts natural precipitation, plants beneath the roof would otherwise require conventional watering. By incorporating eaves troughing and piping to collect roof runoff, water can be directed to planting beds below. The system would need to be winterized—e.g., through seasonal drainage or shutoff—to prevent freeze damage, providing a sustainable alternative without being strictly required.

4.4 Material Selection

This section evaluates the structural configuration and material options considered for the proposed atrium system. Alternative structural arrangements and primary framing materials are assessed based on performance requirements, constructability constraints, cost implications, and sustainability considerations. The objective of this section is to identify viable design candidates rather than immediately select a final solution.

A formal decision regarding the preferred structural system and material will be made in Section 4.6 using weighted evaluation matrices (WEMs). This structured evaluation framework ensures that the final selection is based on quantifiable criteria aligned with project priorities, including structural performance, serviceability, cost effectiveness, aesthetics, and sustainability.

4.4.1 Structural Members

Following selection of the preferred structural system configuration, the next stage of evaluation focused on identifying an appropriate material for the primary load-resisting members. Material selection significantly influences structural efficiency, constructability, architectural integration, durability, and overall cost.

For this project, two viable materials were identified for the atrium framing system: structural steel and engineered timber. Each material was evaluated in relation to the project's performance requirements and site constraints.

4.4.1.1 Structural Steel

Structural steel was considered due to its high strength-to-weight ratio and well-established application in long-span roof and atrium systems. Its material efficiency allows for relatively slender member profiles, which supports the architectural objective of maintaining visual openness within the atrium space.

Steel offers predictable mechanical properties and standardized section availability, enabling accurate structural modelling and reliable performance under ultimate and serviceability limit states. Its ductility provides favourable behaviour under extreme loading conditions, and its stiffness can be optimized through member selection without significantly increasing cross-sectional dimensions.

From a constructability perspective, steel members can be prefabricated off-site and erected efficiently, which is advantageous given rooftop access constraints. Bolted connection detailing allows for controlled installation and potential future disassembly if required [10]. However, steel requires corrosion protection through coatings or galvanization, and material costs can fluctuate based on market conditions.

Given the need for efficient load transfer to existing structural tie-in points and minimal additional dead load, steel presents a structurally efficient and adaptable solution for the atrium frame.

4.4.1.2 Timber

Engineered timber, such as glulam or mass timber elements, was also evaluated as a potential alternative material. Timber offers architectural warmth and may enhance the visual character of the atrium space.

From a sustainability perspective, timber can provide lower embodied carbon relative to conventional structural steel, depending on sourcing and manufacturing processes. Engineered timber members can span moderate distances while maintaining adequate strength and stiffness when appropriately sized.

However, timber introduces additional considerations related to moisture protection, long-term dimensional stability, and connection detailing. In a rooftop environment, exposure to humidity variations and potential water ingress requires careful detailing to prevent deterioration. Member sizes may also increase relative to steel to satisfy stiffness and deflection limits, which could affect visual proportions and connection complexity [11].

While timber presents environmental and architectural advantages, its suitability must be assessed against serviceability requirements, long-term durability in an exposed environment, and integration with the existing structure.

4.4.2 Transparent Panel Glazing

The glazing selection balances structural performance, serviceability, thermal properties, daylighting, cost, and sustainability. Two options were considered: double low-emissivity (Low-E) insulated glass units (IGUs) and multiwall polycarbonate panels.

4.4.2.1 IGUs

High compressive strength, linearly elastic behavior, and predictable deflections facilitate serviceability. Low-E coatings allow passive solar heat gain while minimizing glare. IGUs are more expensive and have higher embodied carbon but offer long-term durability and aesthetic quality [19].

4.4.2.2 Multiwall Polycarbonate Panels

Lower dead load and good impact resistance, with sunlight diffusion reducing glare. Lower stiffness requires shorter support spacing or closer purlins to meet deflection limits. Cost and embodied carbon are lower, but long-term weathering and haze are concerns.

In summary IGUs provide superior thermal performance, durability, and aesthetics at higher cost, while polycarbonate panels are a cost-effective, lighter-weight alternative with reduced long-term performance. Section 4.6 provides an evaluation matrix comparing the two options.

4.5 Landscape Design

The updated landscape design introduces two patio areas located on the north and south sides of the Alumni Way. Each patio will include two small table-and-chair sets to provide informal seating. The existing central pathway will remain, maintaining circulation and visually separating the two patio spaces.

Existing concrete and interlocking brick will be removed and replaced with new interlocking brick to ensure a cohesive and refreshed aesthetic. Techo Bloc Eva Paver in Shale Grey is recommended for this space as it is a balance of affordable, functional, and aesthetically pleasing. Planting beds will be installed on both the east and west sides of the patios to frame the seating areas and soften the landscape.

Proposed planting includes Wild Ginger (Asarum canadense), Foam Flower (Tiarella cordifolia), Jack-in-the-Pulpit (Arisaema triphyllum), Wild Columbine (Aquilegia canadensis), and several Serviceberry (Amelanchier canadensis), Climbing Hydrangea (Decumaria barbara), and Virginia Creeper (*Parthenocissus quinquefolia*). Wild ginger and foam flower would provide great low level green cover for a solid base to fill in between larger, higher plants. Jack in the pulpit and wild columbine would provide a pop of color to bring vibrance to the space. The serviceberry is a beautiful low-level tree that would add depth (by bringing height) as well as a beautiful aesthetic with it's white blooms. The climbing hydrangea and Virginia creeper could coexist on the bare north wall and create a beautiful display, softening the space. All plants recommended are native to Ontario [8].

The primary objective of the landscape update is to make the space more inviting and functional. Seating within the JDUC is currently limited; therefore, the addition of outdoor seating is intended to encourage the use of Alumni Way and create a more welcoming and active environment. Figure 7 displays a 3D render of this design concept. Plants included in the render are not visually accurate to plants recommended due to limitations of the software.

Figure 7: Landscape design concept, incorporating more plant space with usable patio areas.

4.6 Key Evaluations

4.6.1 Evaluation of Design Concepts

The two design concepts were evaluated using a Weighted Evaluation Matrix (WEM). Both concepts are assumed capable of resisting the required factored design loads. Therefore, the structural performance metric assesses long-term behaviour—including creep susceptibility, fatigue resistance, stiffness, and deflection control—rather than ultimate strength capacity.

Six performance metrics were selected and weighted according to project priorities. The narrative order below matches the order presented in Table 11.

4.6.1.1 Structural Performance

This metric, weighted at 25%, evaluates long-term reliability, including susceptibility to creep, fatigue, and excessive deflection. Because the atrium supports glazing and is expected to perform over a long service life with minimal intervention, predictable long-term behaviour is critical. Structural performance was assigned the highest weight.

4.6.1.2 Serviceability

Weighted at 20%, serviceability reflects occupant comfort and safety, including vibration performance and deflection control to prevent glazing damage. Serviceability failures would result in immediate operational concerns; therefore, this criterion was also heavily weighted.

4.6.1.3 Constructability

Constructability was given a weighting of 20%. It evaluates erection complexity, sequencing, temporary works requirements, and schedule risk. Given the project's constraints and the cost implications of delays, constructability was assigned a high weighting equal to serviceability.

4.6.1.4 Cost Effectiveness

At a weighting of 15%, cost effectiveness reflects capital efficiency within the available budget and the financial flexibility required by Queen's Facilities. This metric evaluates relative material quantity, fabrication complexity, and anticipated construction costs. It is treated independently from sustainability considerations.

4.6.1.5 Maintenance

Maintenance was assigned a weighting of 10%. It addresses long-term inspection requirements, access complexity, and lifecycle operating costs. While important, it is weighted lower than structural and construction-related risks.

4.6.1.6 Sustainability

Sustainability was assigned a weighting of 10%. This metric reflects embodied carbon, material efficiency, and alignment with Queen's sustainability goals. Although sustainability is a priority, it was weighted slightly lower than cost because the project must first satisfy structural reliability and budget constraints.

A summary of the criteria and their weightings can be found below in Table :

Table 2: Evaluation Criteria and Weighting for Design Concepts

Metric	Weighting (%)	Description
Structural Properties	25	Reflects the importance of long-term performance and reliability. The geometry of the design will determine its susceptibility to creep and fatigue
Serviceability	20	Addresses the degree of safety, occupant comfort, and the design's ability to control deflections & vibrations.
Constructability	20	The feasibility of the design, the logistics, and the planning required to execute. Schedule risks also have a big implication on costs.
Cost Effectiveness	15	Assesses capital cost efficiency within the project budget constraints
Maintenance	10	Addresses long-term operating costs and inspection requirements

Sustainability	10	Addresses Queen’s sustainability goals, modern design priorities, and commitment to long-term sustainability.

4.6.2 Weighted Evaluation Matrix – Design Concepts

Scores were assigned on a 1–5 scale, where:

1 = Poor
2 = Below Average
3 = Adequate
4 = Good
5 = Excellent

The WEM to evaluate the two designs can be found below in Table 33:

Table 3: WEM of Design Concepts

Metric	**Weight (%)**	**Design 1**		**Design 2**		**Rationale**
		Score	Weighted Score	Score	Weighted Score	
Structural Properties	25	3	75	4	100	Design 1’s geometry introduces greater sensitivity to long-term deflection and secondary stress effects. Design 2 utilizes a simpler sloped configuration with more direct load paths, resulting in improved global stiffness and more predictable long-term behaviour.
Serviceability	20	3	60	4	80	Design 1 presents increased risk of localized deflection and vibration due to geometric irregularity. Design 2’s simpler framing layout provides improved stiffness and more reliable deflection control, reducing glazing risk.
Constructability	20	2	40	4	80	Design 1 requires irregular member geometry, more

						complex connections, additional lifts, and greater reliance on temporary works and sequencing control. This increases schedule and coordination risk. Design 2 uses repetitive framing, simpler connections, fewer unique lifts, and reduced temporary works, significantly lowering construction risk. The magnitude of this difference justifies the two-point score gap.
Cost Effectiveness	15	2	30	4	60	Design 1 requires greater material quantities and more complex detailing, increasing fabrication and erection costs. Design 2's simplified framing reduces steel tonnage, connection complexity, and labour time, resulting in improved capital efficiency.
Maintenance	10	2	20	3	30	Design 1 includes more complex interfaces and penetrations, increasing inspection and water-management requirements. Design 2 reduces detailing complexity and potential water ingress points, resulting in lower anticipated maintenance burden.
Sustainability	10	3	30	3	30	Neither concept clearly dominates in sustainability. Design 1 offers improved daylight performance but requires greater material quantities and higher embodied carbon. Design 2 reduces steel tonnage but incorporates polycarbonate

						glazing with shorter service life and petroleum-based content. The trade-offs result in comparable overall sustainability performance.
Total	100		255		380	

Based on the WEM, Design 2 is recommended (380pts vs. 255pts). It performs significantly better in constructability, serviceability, and cost effectiveness, while maintaining strong structural reliability. The simplified geometry reduces technical risk, construction complexity, and long-term operational uncertainty. Design 1 underperforms primarily due to constructability and cost concerns, which introduce elevated contractor risk, greater detailing requirements, and increased QA/QC demands.

Queen's Facilities had chosen to follow this recommendation, and Design 2 was selected for further design development.

4.6.3 Evaluation of Structural Material

To determine the most suitable structural material for the atrium frame, a weighted evaluation matrix (WEM) was developed to compare structural steel and glulam timber. The criteria reflect the project constraints outlined in this report, including long-span structural requirements, constructability within a constrained rooftop environment, long-term serviceability, overall cost-effectiveness, maintenance demands, and sustainability objectives.

4.6.3.1 Structural Performance

This metric, weighted at 25%, evaluates span efficiency, stiffness, wind performance, and the ability to meet strict deflection limits required for glazing interfaces. The atrium spans between existing buildings and is exposed to wind loads, making structural stiffness and strength critical. Because long-span performance governs both safety and glazing compatibility, structural properties were assigned the highest weighting.

4.6.3.2 Serviceability

Weighted at 20%, serviceability assesses long-term creep behaviour, deflection control, and movement compatibility with glazing seals and connections. Even when ultimate strength requirements are satisfied, excessive long-term deflection or creep can compromise glazing systems. Given the sensitivity of the atrium envelope to movement, serviceability was heavily weighted.

4.6.3.3 Constructability

Constructability was assigned a weighting of 20%. This metric evaluates erection feasibility in a constrained rooftop environment, weather sensitivity during construction, sequencing complexity, member handling, and tolerance control. Because the project involves exposed rooftop construction and tight glazing tolerances, constructability represents a significant project risk factor.

4.6.3.4 Cost Effectiveness

At a weighting of 15%, cost effectiveness reflects capital efficiency within the available project budget. This includes relative material cost, fabrication complexity, erection efficiency, and construction-related cost implications. Cost is evaluated independently of sustainability performance.

4.6.3.5 Maintenance

Maintenance was assigned a weighting of 10%. This metric evaluates long-term inspection requirements, protective systems such as coatings or sealants, susceptibility to environmental degradation, and expected lifecycle maintenance intensity. While important for long-term operations, maintenance was weighted lower than structural and construction considerations.

4.6.3.6 Sustainability

Sustainability was assigned a weighting of 10%. This metric evaluates embodied carbon, renewable material considerations, and alignment with Queen's University's sustainability goals. Although sustainability is an important project objective, it must be balanced with structural reliability, constructability, and budget constraints.

A summary of criteria and weightings is provided in Table 4.

Table 4: Evaluation Criteria and Weighting for Structural Material

Metric	**Weighting (%)**	**Description**
Structural Properties	25	Long span between buildings, wind exposure, and limited deflection limits for glazing.
Serviceability	20	Long-term creep and deflection control. Movement compatibility with glazing seals.
Constructability	20	Weather exposure, construction sequencing, tolerance sensitivity.
Cost Effectiveness	15	Relative cost difference with construction efficiency.

Maintenance	10	Inspection, coatings, and protection need.
Sustainability	10	Embodied carbon considerations; alignment with Queen's sustainability goals.

4.6.4 Weighted Evaluation Matrix – Structural Material

The evaluation criteria, descriptions, and assigned weightings are provided in Table 5. The scoring scale used in the WEM is like that used in 4.6.2: based on a 1–5 scale, where 1 = Poor and 5 = Excellent.

Table 5: WEM of Structural Material

Metric	**Weight (%)**	**Steel**		**Timber**		**Rationale**
		Score	Weighted Score	Score	Weighted Score	
Structural Properties	25	5	125	2	50	Steel’s higher modulus of elasticity and strength allow longer spans with smaller sections and reduced deflections. Timber requires significantly larger member sizes to achieve equivalent stiffness, reducing efficiency for long glazed spans.
Serviceability	20	5	100	2	40	Steel’s higher modulus of elasticity and strength allow longer spans with smaller sections and reduced deflections. Timber requires significantly larger member sizes to achieve equivalent stiffness, reducing efficiency for long glazed spans.

Constructability	20	5	100	3	60	Steel erection is less sensitive to weather and accommodates tighter tolerances required for glazing systems. Timber requires moisture protection during construction and involves larger members, increasing handling and sequencing complexity.
Cost Effectiveness	15	4	60	2	30	Steel members are typically 55–65% less expensive than equivalent glulam members. Timber's larger sections and added protection requirements increase overall construction cost.
Maintenance	10	4	40	2	20	Steel requires periodic coating inspection and touch-ups. Timber requires ongoing monitoring for moisture ingress, seal integrity, and potential biological degradation.
Sustainability	10	3	30	5	50	Timber stores carbon and aligns strongly with Queen's University sustainability goals when responsibly sourced. Steel carries higher embodied carbon, though this may be reduced with low-carbon steel products.

Total	100		455		250	

Steel achieved higher scores in structural performance, serviceability, constructability, maintenance, and cost effectiveness — the criteria most directly influencing feasibility and long-term reliability for this atrium application.

Timber performed strongly in sustainability; however, its larger required member sizes, greater susceptibility to long-term creep, and higher sensitivity during construction reduced its overall suitability for the long-span glazed structure.

Based on the weighted evaluation, structural steel is recommended as the primary framing material for the atrium. Timber will still be considered for design but will not be used as often as steel and not be used for critical members

Queen's Facilities had chosen to follow the recommendation provided, placing steel as the primary framing material and timber to be used to support the system.

4.6.5 Evaluation of Glazing Material

To determine the most appropriate glazing system for the atrium, a weighted evaluation matrix (WEM) was developed to compare Insulated Glass Units (IGUs) and multiwall polycarbonate panels.

Constructability and maintenance were omitted from this evaluation because both systems require similar framing integration, comparable installation sequencing, and routine inspection protocols. Neither option introduces unique construction risks or maintenance demands significant enough to govern material selection.

Given the atrium's architectural prominence, aesthetic quality was included as an evaluation metric, as the glazing will be the most visually dominant element of the structure.

4.6.5.1 Structural Performance

This metric, weighted at 25%, evaluates panel stiffness, span capability between framing members, wind resistance, and deflection performance. Because the atrium glazing spans between structural supports and is subject to wind and snow loading, adequate stiffness is required to limit deflection and prevent seal failure. Structural performance was heavily weighted due to its influence on both safety and envelope integrity

4.6.5.2 Cost Effectiveness

Cost effectiveness was weighted at 25%. This metric evaluates material cost, fabrication requirements, installation efficiency, and lifecycle replacement considerations. Given budget constraints and the large surface area of glazing, cost has a substantial impact on overall project feasibility.

4.6.5.3 Aesthetic

Aesthetic was assigned a weighting of 25%. As the atrium is a highly visible architectural feature, the glazing material significantly influences transparency, light quality, and integration with the surrounding buildings. This is a qualitative metric; however, it is critical to the project's architectural intent and user experience.

4.6.5.4 Serviceability

Weighted at 15%, serviceability assesses long-term deflection behaviour, elastic predictability, and compatibility with framing systems and seals. Movement characteristics affect long-term glazing performance and potential air or water infiltration. While important, serviceability was weighted lower than structural performance and cost.

4.6.5.5 Sustainability

Sustainability was assigned a weighting of 10%. This metric evaluates embodied carbon, production energy intensity, and alignment with Queen's University's sustainability goals. While important, sustainability was weighted lower than structural, aesthetic, and cost considerations.

A summary of criteria and weightings is provided in Table 6.

Table 6: Evaluation Criteria and Weighting for Glazing Material

Metric	Weighting (%)	Description
Structural Performance	25	Long span between buildings, wind exposure, and limited deflection limits for glazing.
Cost Effectiveness	25	Relative cost difference with construction efficiency.
Aesthetic	25	Overall aesthetic, how well it blends with existing architecture.
Serviceability	15	Long-term creep and deflection control. Movement compatibility with glazing seals.
Sustainability	10	Embodied carbon considerations; alignment with Queen's sustainability goals.

4.6.6 Weighted Evaluation Matrix – Glazing Material

The evaluation criteria, descriptions, and assigned weightings are provided in Table 7. The scoring scale used in the WEM is like that used in 4.6.4: based on a 1–5 scale, where 1 = Poor and 5 = Excellent.

Table 7: WEM of Glazing Material

Metric	**Weight (%)**	**IGU**		**Multiwall Polycarbonate**		**Rationale**
		Score	Weighted Score	Score	Weighted Score	
Structural Performance	25	4	100	3	75	IGUs provide higher stiffness and greater resistance to deflection under wind and snow loads. Polycarbonate has a lower modulus of elasticity, requiring closer support spacing to meet deflection limits..
Cost Effectiveness	25	2	50	4	100	IGUs involve higher material and fabrication costs, including sealed units and aluminum framing. Polycarbonate panels are less expensive per square metre and reduce framing demands, improving capital efficiency.
Aesthetic	25	5	125	3	75	IGUs provide high clarity, refined appearance, and long-term resistance to discoloration, aligning with the surrounding architecture. Polycarbonate offers light diffusion but is more prone to surface haze and aging.

Serviceability	15	4	60	3	45	IGUs exhibit predictable linear-elastic behaviour with stable long-term stiffness. Polycarbonate is more susceptible to creep and long-term deformation under sustained loading.
Sustainability	10	3	30	4	40	Polycarbonate production is generally less carbon-intensive than IGU manufacturing, which requires high-temperature glass processing and aluminum components.
Total	100		365		335	

The weighted evaluation matrix yields a total score of 365 for IGUs and 335 for multiwall polycarbonate panels. IGUs perform strongly in structural performance, serviceability, and aesthetic quality. Polycarbonate panels achieve higher scores in cost effectiveness and sustainability. Although polycarbonate offers cost and carbon advantages, the atrium's architectural prominence and performance requirements favor IGUs due to their superior stiffness, long-term clarity, and refined integration with the existing buildings.

Based on the weighted evaluation, IGUs were recommended as the glazing material for the atrium.

Queen's Facilities had chosen to follow this recommendation and proceed with IGUs.

5.0 Detailed Design of Selected Concept

5.1 Structural Layout and Load Paths

The atrium structural layout follows the design direction provided by Queen's Facilities decisions and the loading parameters established during the preliminary concept phase. The framing plan was developed to minimize span lengths while ensuring clear and efficient load paths into the existing JDUC and Mitchell Hall structures. The structural layout can be seen in the plan view and elevation view found in Appendix C in Figure 19 Figure 20. The JDUC roofline along Alumni Way extends approximately 35 m. Diagonal primary beams span the distance across Alumni Way at 5 m spacing, forming the main support for the loads and glazing system. Smaller framing members are introduced between the primary beams to support the glazing. On the Mitchell Hall side, a 35 m long girder provides continuous support for the diagonal beams. Timber columns, spaced at 5 m along the Mitchell Hall roofline, support this girder and transfer loads into the existing building. Each diagonal beam carries loads from the tributary width halfway to the adjacent beams, resulting in a 5 m tributary width for interior beams and 2.5 m for the exterior beams, as illustrated in Figure 8. These loads are transferred to both the JDUC and Mitchell Hall.

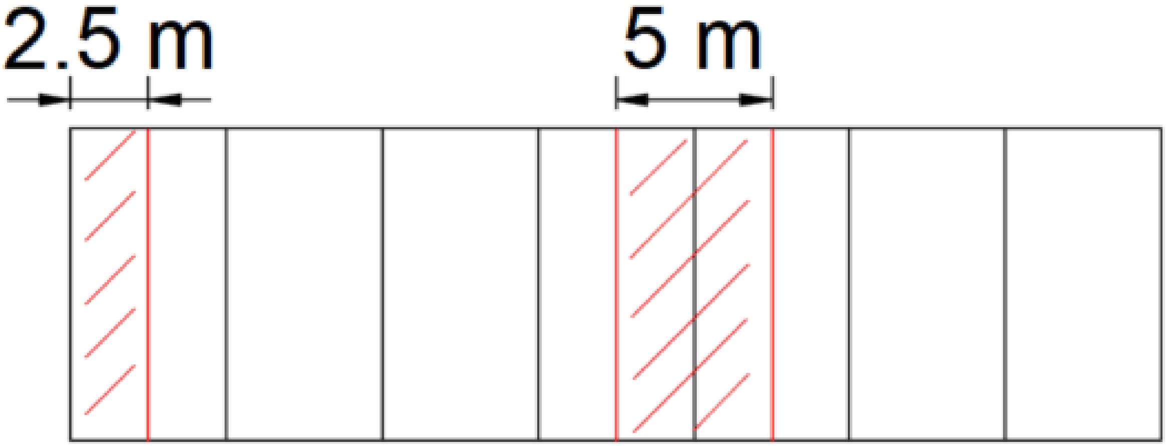


Figure 8: Tributary widths visualized for diagonal primary beams

The girder similarly receives loading from half the span between the two buildings, approximately 4.65 m. This load is then transferred into the timber columns and subsequently into the Mitchell Hall structure.

All beam-to-column and beam-to-girder connections are designed as pin-pin connections to allow rotation and avoid unintended moment transfer, ensuring that axial and shear forces are the primary load effects carried into the existing buildings.

5.1.1 Wind Loads and Exclusion of Connection Designs

The resulting lateral load on the frame were calculated previously in accordance with relevant building codes to assess the environmental conditions of the structure. The loads were used to assess the overall structure, but the gravity loads governed the design of the primary members. As a result, the member selection presented in this report revolved mainly around dead and live loads. Lateral loading effects would be expected to have a bigger impact in the design of connections and bracing elements. However, detailed connection designs were considered outside the scope of the project and would require further development in later stages prior to implementation.

5.1.2 Assumed Lateral System

The atrium is assumed to rely on the existing lateral force-resisting systems within both the JDUC and Mitchell Hall structures. Wind loads were calculated to establish environmental demands; however, detailed lateral design is outside the current scope of this project.

The following assumptions define the lateral load path:

- The in-plane action of the glazing support system transfers lateral loads into the primary diagonal beams.

- These loads are assumed to be delivered into the existing JDUC and Mitchell Hall lateral systems through the secondary girder and columns, and the beam-to-building interfaces.
- No new bracing, moment frames, or shear walls are designed as part of this submission.
- All new connections are treated as pin-pin, meaning they do not provide lateral stiffness and do not form part of a new lateral system.

As a result, the lateral load path and the adequacy of the existing buildings to resist the additional wind forces remain unverified and would require detailed analysis and connection design in later project stages.

5.2 Structural Analysis and Modelling

SAP2000 Student Version 7.40 was used for the structural modelling of the structure. Due to limitations in the software, the structure was split into two components to model separately. The first component was the frame, modelled from a top-down perspective. The second was the transfer from the frame to the JDUC through columns.

The frame that will be the roof essentially (we will refer to it as the roof frame) is attached to the student residence and the columns that rest onto the JDUC. The loading described in Section 5.1 inputted along with section and material properties. The frame was drawn to scale and the model was run. The bending moment on the members were the same as what was found in hand calculations. The results can be found below in Figure 9 below:

The material property inputs to create this model for SAP2000 can be found in Figure 10 below:

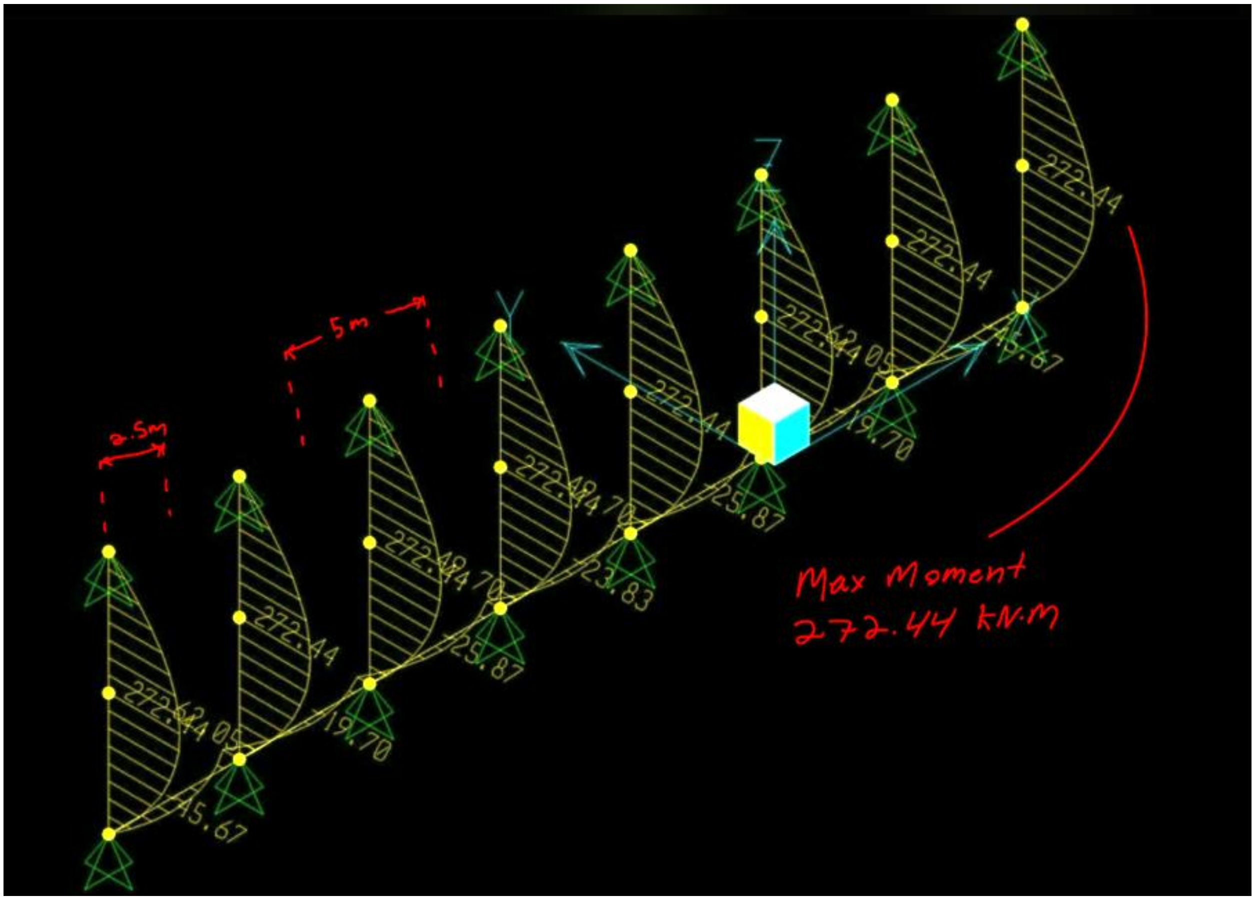
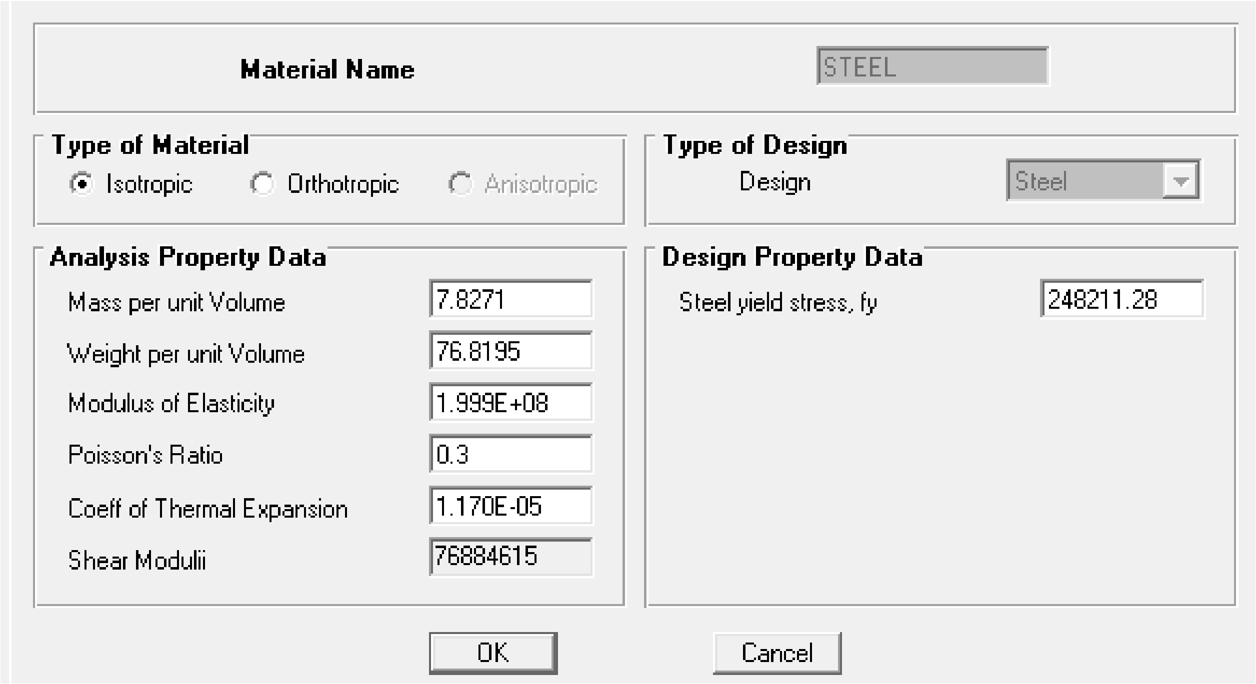


Figure 9: Bending moment diagrams from SAP2000 modelling



Material Name	STEEL

Type of Material

● Isotropic ○ Orthotropic ○ Anisotropic

Type of Design

Design	Steel

Analysis Property Data

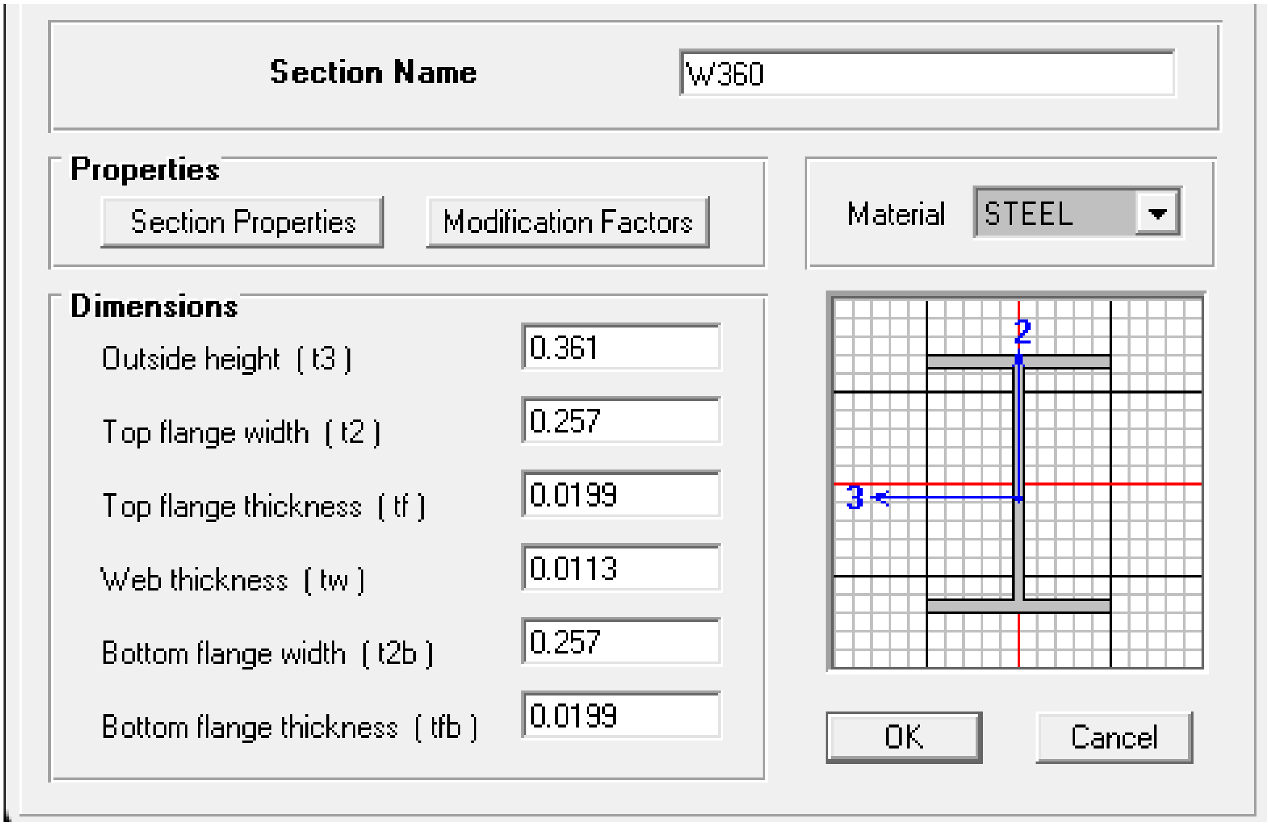
Mass per unit Volume	7.8271
Weight per unit Volume	76.8195
Modulus of Elasticity	1.999E+08
Poisson's Ratio	0.3
Coeff of Thermal Expansion	1.170E-05
Shear Modulii	76884615

Design Property Data

Steel yield stress, fy	248211.28

Figure 10: Roof steel material properties

Section properties can be found in Figure 11 below:



Section Name	W360
Material	STEEL

Properties

Dimensions

Outside height (t3)	0.361
Top flange width (t2)	0.257
Top flange thickness (tf)	0.0199
Web thickness (tw)	0.0113
Bottom flange width (t2b)	0.257
Bottom flange thickness (tfb)	0.0199

Figure 11: Roof steel section properties

An applied load of 25.2 kN/m was used, as found in member design for primary members below. This was applied to all members.

Next, the column frame that transfers the load from the roof frame to the JDUC was modelled. The axial forces found by SAP2000 can be found below in Figure 12. The highest axial force found was 149.56 kN, which is lower than the axial resistance of 179 kN. This confirms the design is adequate even though modelling axial forces were higher than hand calculations.

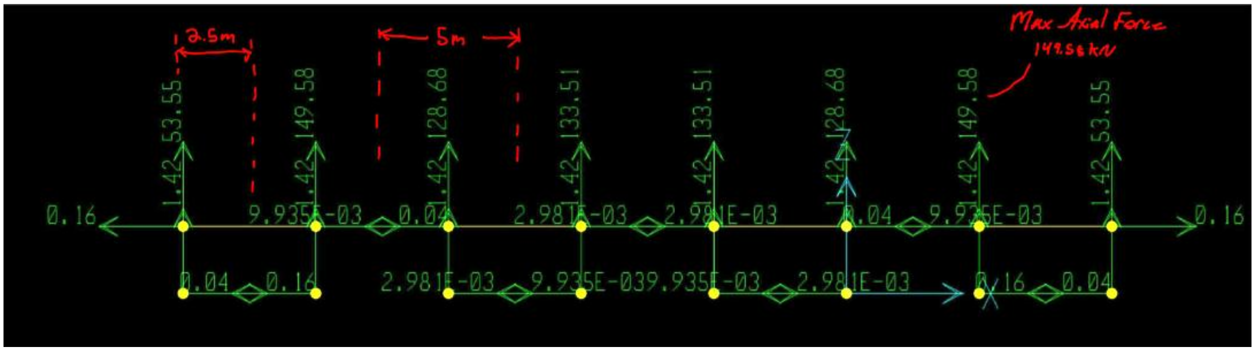
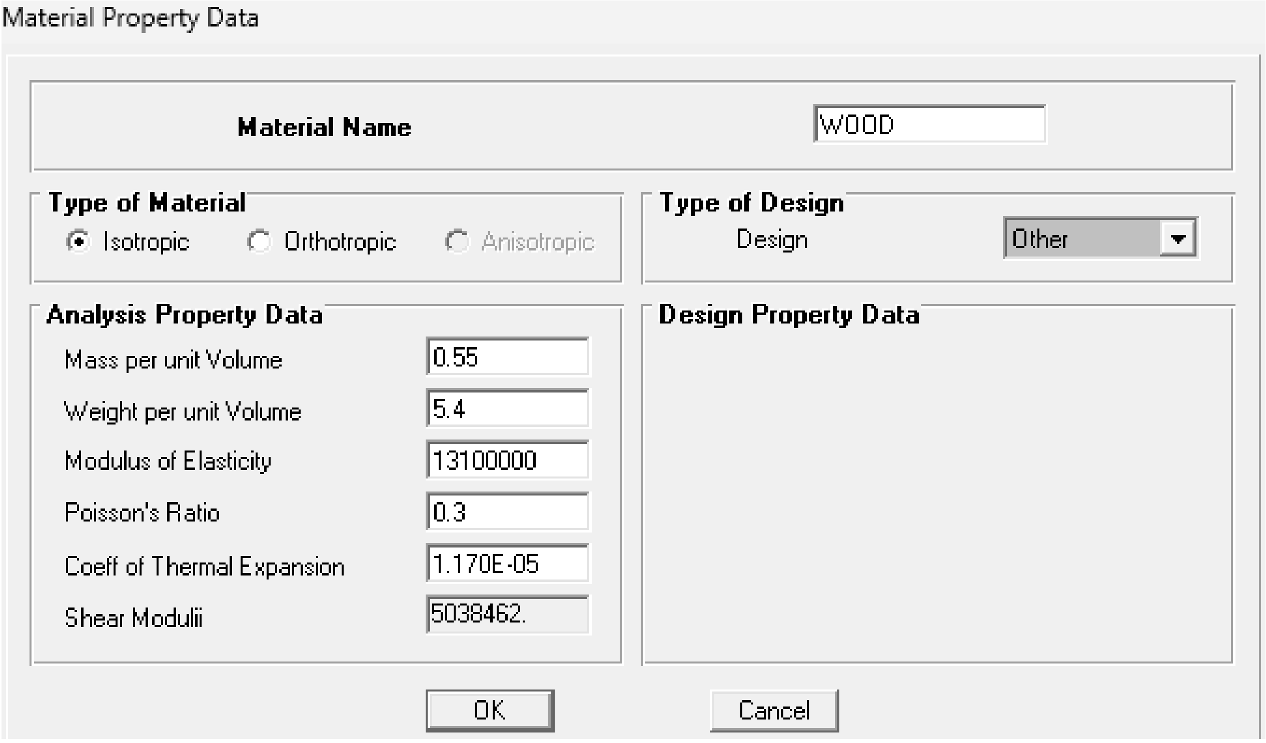


Figure 12: Analysis results of transfer column frame

The material property inputs to create this model for SAP2000 can be found in Figure 13 below:


Material Property Data

Material Name: WOOD

Type of Material

● Isotropic ○ Orthotropic ○ Anisotropic

Type of Design

Design: Other

Analysis Property Data

Mass per unit Volume: 0.55

Weight per unit Volume: 5.4

Modulus of Elasticity: 13100000

Poisson's Ratio: 0.3

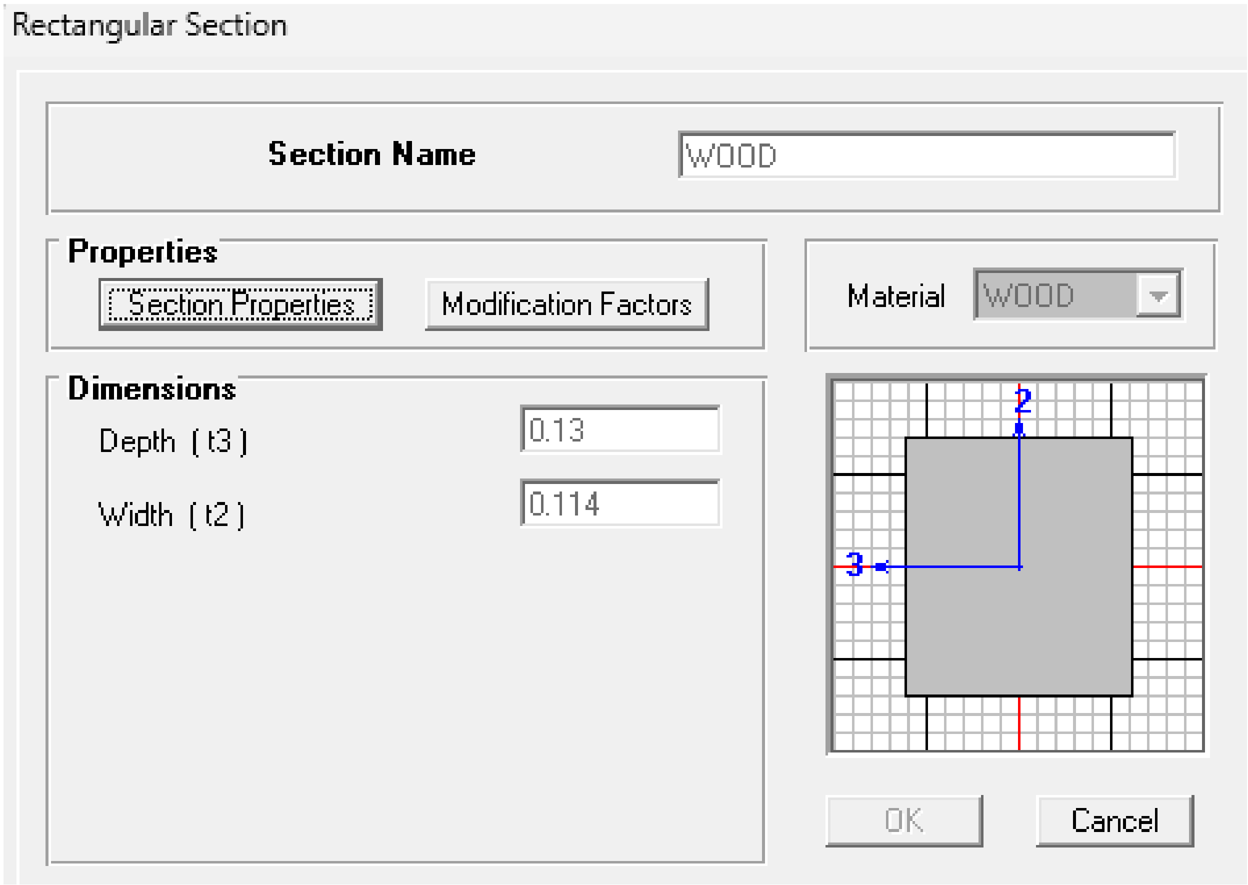
Coeff of Thermal Expansion: 1.170E-05

Shear Modulii: 5038462.

Design Property Data

Figure 13: Column steel material properties

Section properties can be found in Figure 14 below:



Section Name: WOOD

Properties

Material: WOOD

Dimensions

Depth (t3): 0.13

Width (t2): 0.114

Figure 14: Column steel section properties

5.3 Member Design

5.3.1 Primary Members

The governing pressure of 4.77 kPa is applied across the entire atrium. Based on the load paths outlined in Section 5.3, the primary beams have a tributary width of 5 m, resulting in a uniformly distributed load (UDL) of:

$$w = 4.77\ kPa * 5\ m = 23.9\frac{kN}{m}$$

This value represents the applied loading only and does not include the beam self-weight. Using this load, and the equation provided in the beam diagrams in the CSA S16:19 steel handbook for a UDL on a simply supported beam:

$$M_f = \frac{wl^2}{8} \tag{3}$$

The maximum factored moment was calculated to be 258 kN-m. This value was used as the basis for selecting an appropriate beam section. Beam selection tables in the CSA steel handbook were used to select a section with a moment resistance greater than this factored moment.

Once a preliminary section was selected, its self-weight (provided in the tables) was added to the uniformly distributed load, increasing the total UDL to 25.2 kN/m. This updated load was used for subsequent moment and deflection checks. This process was repeated until a section was found with adequate moment resistance under the increased loading.

After selecting a section based on moment capacity, the beam was checked against deflection limits for supporting glass panels. According to NBCC 9.4.3.1, the maximum allowable deflection is:

$$\Delta_{max} = \frac{l}{240} = \frac{9300}{240} = 39\ mm \tag{4}$$

The maximum deflection for the selected beam was then calculated using the CSA S16:19 deflection equation outlined in the beam diagrams for a simply supported beam loaded with a UDL:

$$\Delta_{max} = \frac{5wl^4}{384EI} \tag{5}$$

The resulting deflection was 45.6 mm, which exceeds the allowable limit and is therefore unacceptable for preventing cracking in the glass panels. As a result, the design of the primary members was ultimately governed by deflection limits rather than moment capacity.

5.3.2 Deflection Checks

To select a beam section with sufficient stiffness to satisfy the NBCC 9.4.3.1 deflection limit, the allowable deflection of 39 mm was substituted into the maximum deflection, equation 5:

$$\Delta_{max} = \frac{5wl^4}{384EI} \tag{5}$$

Rearranging for the required second moment of inertia and substituting the governing load, span length, allowable deflection, and modulus of elasticity:

$$I_{req} = \frac{5wl^4}{384E\Delta_{max}} = \frac{5(25.2)(9300)^4}{384(200000)(39)} = 312 \times 10^6\ mm^4 \tag{6}$$

This value represents the minimum acceptable second moment of inertia required to satisfy the deflection limit. Using this I value, along with the previously calculated factored moment, the CSA steel handbook beam selection tables were used to select a beam that satisfied both the moment resistance and deflection requirements. A W360x110 I-beam was selected. This beam provides a moment resistance of 372 kN-m, and the deflection associated with this section is 37.1 mm, which is within the allowable limit of 39 mm.

5.3.3 Secondary Members

5.3.3.1 Girder

With the primary beams finalized based on deflection limitations, the girder was designed using a similar approach. Using the governing pressure applied to the atrium and the tributary width of 4.65 m, the uniformly distributed load applied was calculated to be 23.5 kN/m. Since the columns supporting the girder are spaced at 5 m, the resulting factored moment demand is significantly lower than that of the primary beams.

For ease of construction, material standardization, and simplified ordering, the girder was selected to also be a W360x110 section. These sections provide a moment resistance of 500 kN-m and a corresponding deflection of 2.9 mm, both of which are well within acceptable limits.

5.3.3.2 Columns

To determine the axial force the columns must resist, the reactions of the primary beams were calculated to be approximately 100 kN. Using the Wood Design Manual (Section 7.5.8), the compressive resistance of a 130x114 mm Douglas Fir-Larch glulam column was evaluated using:

$$P_r = \emptyset F_c A K_{Z_{cg}} K_c \tag{7}$$

Where:

- Material reduction factor, $\emptyset = 0.8$
- Adjusted compressive strength, $F_c = 25.2$ MPa
- Cross-sectional area, $A = 14820$ mm^2
- Size factor, $K_{Z_{cg}} = 1.0$
- Slenderness factor, $K_c = 0.60$

Substituting:

$$P_r = (0.8)(25.2)(14820)(1.0)(0.60)$$

$$P_r = 179\ kN$$

Since the required axial resistance is approximately 100 kN and the available resistance is 179 kN, the selected section is adequate. Based on this compressive resistance, a 130x114 mm 24f-EX Douglas Fir-Larch glulam section was selected for the columns supporting the girder.

Detailed calculations of all members are provided in Appendix A.

5.3.4 Long-Term Performance Considerations

Long-term performance of the primary and secondary steel members was evaluated with respect to creep, fatigue, and environmental exposure. Although the governing design criteria for the beams and girder were short-term deflection limits, it is important to confirm that the selected sections will maintain acceptable performance over the service life of the structure.

Creep in structural steel is negligible at normal service temperatures. Significant creep deformation only occurs when steel temperatures exceed approximately 400-500 °C, well above any conditions expected in an enclosed atrium environment. Even with projected increases in summer temperatures due to climate change, ambient conditions remain far below the threshold at which creep becomes a concern. The selected W360x110 sections therefore do not require additional design considerations for creep. However, to ensure the sections remain acceptable and do not experience unexpected deformations, routine inspections during the building's service life are recommended. Maintenance and testing of the structural elements can be used to confirm that no unexpected long-term deformations are occurring, particularly in areas exposed to solar or elevated temperatures.

Fatigue in steel members is governed by the magnitude and frequency of cyclic loading. In this structure, the primary source of cyclic load would be wind-induced pressure fluctuations and minor thermal movements. These cycles are low in both amplitude and frequency and fall well below the expected threshold associated with fatigue damage in structural steel. As a result, fatigue is not expected to govern the design of the beams or girders.

Although neither creep nor fatigue are expected to be critical for this structure, a conservative maintenance strategy is recommended to ensure long-term performance. Periodic inspections should focus on verifying that deflections remain within acceptable limits, checking for corrosion or coating deterioration on exposed steel, confirming that connections remain tight and free of fatigue-related cracking, and monitoring areas subject to elevated temperatures or solar exposure. These measures provide a contingency plan that ensures the structural system continues to perform as intended throughout its service life.

6.0 Constructability Considerations

The atrium is located between two existing occupied buildings, introducing spatial, logistical, and safety constraints. Construction must be sequenced to ensure temporary stability during erection and to minimize disruption to building occupants. It is well established that structures during construction may experience load paths and stability conditions that differ from final design assumptions, requiring review during the construction phase to prevent unintended instability [20].

The feasibility of the final design is therefore contingent not only on structural adequacy but also on practical erection sequencing and safe construction planning.

6.1 Construction Sequencing

Construction would begin with installation of primary framing members to establish the principal load path between the buildings. Temporary bracing may be required until full structural continuity is achieved and lateral stability is provided. Secondary members would be installed following alignment verification of primary elements. Sequencing must account for anticipated self-weight deflections prior to glazing installation to ensure compatibility with glazing tolerances and prevent localized stress concentrations. Construction sequencing must also consider wind exposure during partially completed stages. Temporary conditions may govern stability during erection, particularly for elevated rooftop structures [20].

6.1.1 Access Constraints

Site access is limited by rooftop mechanical equipment, constrained staging space, and proximity to existing building edges. As a result, a phased material delivery system may be required to reduce on-site storage demands. Crane placement must consider available swing radius, roof load capacity, and clearance from adjacent structures. Lift planning should account for member geometry and anticipated weights. Localized roof penetrations may be required to establish structural tie-ins. Sequencing must minimize the duration of envelope exposure and ensure timely reinstatement to prevent moisture ingress. Efficient logistics planning reduces construction duration and limits construction-stage environmental impacts associated with equipment use and material transportation [21].

6.1.2 Work Over an Active Pedestrian Corridor

The atrium spans an active pedestrian corridor, introducing elevated safety requirements during construction. Overhead protection systems, such as temporary decking or debris netting, must be implemented to mitigate falling object hazards. Controlled exclusion zones should be established during major lifting operations. Coordination with facility operations is necessary to schedule high-risk activities during periods of reduced occupancy. Public safety considerations are critical in construction projects involving occupied facilities, and careful sequencing reduces both operational disruption and safety risk [20].

7.0 Cost Considerations

7.1 Cost Drivers

The structural steel members costs are based on the selected W360x110 beam section. The total beam length required to construct the atrium structure is calculated as 144.4 m. A supplier quote from Kawartha Metals (see Appendix C) states a cost of $4,592 per 45 feet. To proceed with preliminary cost estimates, a linear relationship between member length and cost is assumed, and the unit price is converted to a cost of $334.79 per meter. The estimated cost of the steel members is:

$$144.4m * 334.79\frac{\$}{m} \cong \$49{,}000.00$$

This estimate represents the material cost of the primary steel members only and does not include the additional expenses typically associated such as connection plates, bolts, welding, or transportation.

The glulam timber columns are costed based on the selected 130 x 114 mm DFL 20F-EX section. A total of eight columns, each with a length of 2.5 m, are included in the design. The total timber volume is calculated using the cross-sectional area and total member lengths, resulting in a total volume of 0.286 m^3. A pricing inquiry provided by Western Archrib yielded an estimate of approximately \$7000 per m^3. As such, the material cost for the glulam timber columns is determined to be:

$$0.286\ m^3 * 7000\frac{\$}{m^3} \cong \$2{,}000.00$$

Due to the preliminary nature of this estimate and lack of a detailed construction scheduling, the total duration of construction is not explicitly determined, Instead, labour and equipment costs are expressed on an hourly basis to provide a scalable estimate. A typical installation crew of approximately 8-12 workers at peak activity is assumed. Labour costs are taken as \$25 per hour per worker, resulting in an estimated cost ranging from \$200 to \$300 per hour, depending on the number of workers present. In addition to labour, crane services are required for lifting and placing the structural members. Based on supplier information from Mr. Lift Crane Services, the crane operation rate is \$189 per hour. Combining labour and equipment, the total hourly construction cost is estimated to be \$389 to \$489 per hour. A summary of the total material, labour, and equipment costs is available in Table 13.

The glazing system is costed based on an assumed unit price of \$30 per square foot for low-emissivity insulated glazing units (IGUs). This value is selected as a representative mid-range cost, consistent with published market data suggesting standard IGUs ranging from \$10-30 per square foot, and systems with premium features such as low-E and gas-filled units extending into the \$30-55 range per square foot. The total glazing surface area required for the atrium is calculated as 470.43 m^2. Using the equivalent rate of \$323/m^2, the total estimated cost of the glazing system is determined as:

$$470.43\ m^2 * 323\frac{\$}{m^2} \cong \$152{,}000.00$$

7.2 Carbon Costs

The embodied carbon of the structural materials is calculated using the published embodied carbon rates for various structural materials, by The Institution of Structural Engineers (see Appendix C). This approach determines the embodied carbon by multiplying the material mass by the appropriate corresponding emission factor ($kgCO_2e/kg$). For structural steel, a production stage carbon factor of 1.55 $kgCO_2e/kg$ and transportation factor of 0.032 $kgCO_2e/kg$ is applied, assuming the material is transported approximately 300 km. Using the nominal mass for a W360x110 beam of 110.2 kg/m to yield a total steel mass of 15,913 kg, the embodied carbon is:

$$\left(1.55\frac{\mathrm{kgCO2e}}{\mathrm{kg}}\right) * (15913\ \mathrm{kg}) + \left(0.032\frac{\mathrm{kgCO2e}}{\mathrm{kg}}\right) * (15913\ \mathrm{kg}) = 25{,}174.4\ \mathrm{kgCO2e}$$

For the glulam timber columns, a production stage factor of 0.437 $kgCO_2e/kg$ is applied, alongside the 0.032 $kgCO_2e/kg$ transportation factor. With a total timber mass of 166 kg, the embodied carbon contributed by the glulam members is:

$$\left(0.437\frac{\mathrm{kgCO2e}}{\mathrm{kg}}\right)*(166\ \mathrm{kg})+\left(0.031\frac{\mathrm{kgCO2e}}{\mathrm{kg}}\right)*(166\ \mathrm{kg})=77.9\ \mathrm{kgCO2e}$$

To evaluate the cost implications of these emissions, the embodied carbon values are converted to a carbon cost using the federal carbon pricing framework established by the Government of Canada. A representative carbon price of $110 per tonne of CO_2e is adopted, which accounts for the annually increasing carbon rate of $15 per tonne from 2023 to 2030. The resulting carbon costs are $2,714 for the structural steel and $8 for the glulam timber. These results demonstrate that the steel contributes the vast majority of embodied carbon and associated carbon cost, while the environmentally efficient timber columns contribute a comparatively negligible amount. A summary of the embodied carbon and resulting carbon costs is available in Table 13.

8.0 Maintenance Considerations

Long-term performance of the atrium depends on inspection accessibility, corrosion protection strategies, and glazing durability. Proactive maintenance reduces lifecycle cost and extends service life.

8.1 Maintenance Access

Safe access must be provided to facilitate inspection, cleaning, and repair. Roof access routes should remain unobstructed and fall protection anchorage should be incorporated. Exposed steel elements require periodic inspection for corrosion and coating degradation, particularly in rooftop environments subject to moisture and temperature fluctuations. Glazing systems require routine cleaning to maintain transparency and daylight performance. Accessible detailing supports safe and efficient asset management.

8.2 Lifecycle Considerations

Protective coating systems for structural steel typically require inspection and potential reapplication within 15–25 years depending on environmental exposure conditions. Glazing sealants commonly require replacement within 20–30 years [22]. The proposed configuration should allow for localized panel replacement without dismantling primary structural members. Lifecycle planning prioritizes durability, modularity, and maintainability to ensure long-term structural reliability.

9.0 Sustainability Considerations

Sustainability performance is influenced by material efficiency, operational energy implications, durability, and long-term material recovery potential.

9.1 Material Efficiency and Embodied Carbon

Material production dominates embodied emissions in structural systems [23]. Reducing material demand through structural optimization is therefore a primary carbon mitigation strategy. Rational geometry and repetitive detailing reduce fabrication waste and improve material utilization efficiency. Material efficiency was considered alongside structural performance requirements to avoid overdesign while maintaining safety margins.

9.2 Daylighting and Operational Performance

The atrium increases natural daylight penetration between buildings, potentially reducing reliance on artificial lighting during daytime operation. Daylighting strategies are recognized as contributing to reduced operational energy consumption [24]. However, increased glazing introduces solar heat gain considerations. Appropriate glazing specification is necessary to balance daylight benefits with thermal performance to avoid excessive cooling demand. Operational sustainability depends on achieving equilibrium between transparency and energy efficiency.

9.3 Long-Term Durability

Durability is fundamental to sustainable performance. Premature deterioration increases both financial and environmental costs due to repair or replacement. Corrosion protection strategies and effective drainage detailing reduce degradation risk. Steel is highly recyclable at end-of-life, supporting circular material flows and reduced demand for virgin resource extraction [25]. Designing for durability ensures that embodied carbon invested during construction delivers long-term functional value.

10.0 Social Impacts

Aside from the structural and economic considerations of the proposed design, there are also several social implications for the users of the JDUC. As a central student hub on the campus, the building supports a wide range of daily activities including dining, studying, social gatherings, and residential use by graduate students. Construction activities associated with the atrium installation may temporarily disrupt these functions through noise, restricted circulation, and partial closures of interior spaces.

Despite the initial nuisance, the completed atrium has the potential to improve the overall usability of the space by providing weather protection, increased natural daylight, and a communal area between the two buildings. These improvements may enhance the experience of students and visitors who frequently visit the JDUC for study or social purposes. As a results, the social impacts of the project can be seen as a balance between short-term construction disruptions and longer-term improvements to the campus environment.

10.1 Regular Users

The two groups expected to be impacted by the project the most are the graduate students residing in the JDUC and food services such as the Queen's Pub amongst other restaurants. During the construction phase, activities such as material delivery, equipment staging, and structural installation may generate noise and temporary access restrictions in surrounding areas. For graduate student residents, this may result in periods of increased disturbance, particularly during daytime construction operations.

Similarly, restaurants and food service providers located in the JUDC rely on consistent pedestrian traffic and operational continuity. Construction occurring above or adjacent to these spaces could temporarily affect customer access or the general atmosphere of the dining areas. To mitigate these impacts, careful construction sequencing and scheduling would be crucial during implementation. Strategies such as conducting the most disruptive work during off-peak hours, maintaining clear pedestrian routs, and coordinating closely with facility management could help minimize disruption to both residents and businesses.

Despite these temporary impacts, the completed atrium could provide greater long-term benefits to regular users by creating a more sheltered and visually appealing space within the JDUC. Increased daylighting and improved spatial quality may encourage greater use of the area for social interaction and informal study, potentially benefitting both student residents and nearby food services.

10.2 Stakeholder Engagement

Successful implementation of the atrium would require continuous engagement with the various stakeholders who use the JDUC. Throughout the design refinement and construction process, it would be important for the engineering and project team to actively seek feedback from affected groups, including students, staff, graduate student residents, and the businesses operating within the building. Maintaining open communication helps ensure that concerns related to construction impacts, accessibility, and building operations are identified early and addressed properly.

One approach to supporting this engagement would be the use of regular stakeholder meetings or "town hall" sessions, where project updates can be shared and users of the space can raise questions or concerns. These meetings would provide transparency regarding construction timelines, anticipated disruptions, and mitigation strategies. In addition, they would allow the project team to gather feedback that could inform scheduling decisions, access planning, or operational adjustments during construction.

By maintaining a consistent dialogue with stakeholders, the project team can better understand how the space is used and respond to the needs of the campus community. This collaborative approach helps build trust, improves transparency during the construction process, and supports the goal of delivering a final design that enhances the experience of those who regularly use the JDUC.

11.0 Project Management

11.1 Major Tasks

The project was organized into sequential and interdependent phases to ensure delivery of a feasible, code-compliant, and constructible atrium design.

The first phase focused on problem definition and constraint identification, including confirmation of site limitations, existing rooftop mechanical equipment, planter locations, and structural tie-in points. This stage was led by Keinar Widjaja and Liam MacDonell, who coordinated client and TA communications to validate scope assumptions and project objectives.

This was followed by a review of applicable building codes, heritage requirements, and sustainability guidelines to establish the technical framework governing the design. This stage was led by Frankie Colombe.

The next phase involved development and evaluation of preliminary design concepts. Dean Martin and Frankie Colombe led the conceptual design development. These concepts were evaluated using the weighted evaluation matrices presented in Section 4.6, directly informing selection of the preferred structural system and glazing material. This ensured structural performance, serviceability, constructability, cost, and sustainability considerations were incorporated early in the decision-making process. The development of the WEMs were led by Keinar Widjaja and Dean Martin.

Following concept selection, the project transitioned into detailed structural design. This phase includes structural member layout, section sizing, and connection detailing to the existing structures. Structural modelling is being performed using SAP2000, supported by SketchUp for geometric coordination. This task was led by Frankie Colombe and Liam MacDonell.

Detailed member design is being completed collaboratively by Liam MacDonell, Dean Martin, and Frankie Colombe, with internal cross-checking conducted by another team member prior to finalization to ensure compliance with CSA S16 requirements. This internal peer review process provides quality control and accountability before advancing to subsequent stages.

Cost analysis was conducted in parallel with detailed design to support iterative decision-making. As member sizes are finalized, material quantities and associated costs are updated. The cost analysis includes:

- Steel tonnage and connection hardware
- Glazing quantities
- Protective coatings and miscellaneous materials
- Labour, equipment, and sequencing considerations

Running cost analysis concurrently ensured that design decisions remain aligned with budget constraints and avoids late-stage redesign.

The final phase involved preparation of construction recommendations, long-term maintenance considerations, and assembly of final deliverables. These include structural calculations, modelling outputs, design validation summaries, and documentation of compliance with applicable standards

A summary of the major tasks and their breakdown can be found below in Figure 15:

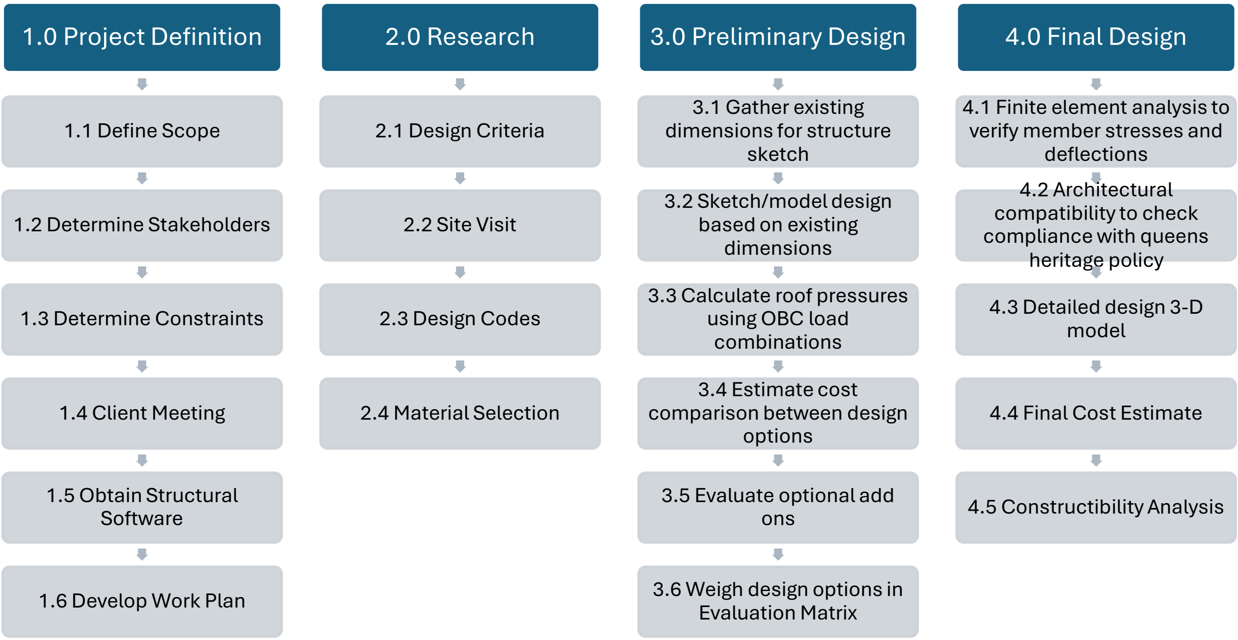


Figure 15: Work Breakdown Structure of Major Tasks

11.2 Implementation Outlook

At completion of this final report, the atrium structure has been validated for strength and serviceability under CSA S16 requirements. Member sizing, global frame behaviour, and deflection performance have been verified through SAP2000 modelling, and material quantities have been established to support feasibility assessment. If advanced toward implementation, several technical refinements would be required beyond the scope of this project.

11.2.1 Existing Structure Verification

The current design assumes adequate capacity at identified tie-in locations based on available documentation. Prior to construction, field verification of existing member sizes, connection conditions, and roof deck composition would be required to confirm load transfer assumptions. Any discrepancies may necessitate localized reinforcement or connection redesign.

11.2.2 Connection Design Development

The proposed structural system in this report did not detail connection design as it was considered outside the scope of the project. Prior to implementation, the connections between steel members, timber columns, and existing building structures would require detailed engineering design in accordance with applicable standards. This would include the design of welded or bolted steel connections, steel-to-timber interfaces, and anchorage points capable of transferring both gravity and lateral loads through the structure.

11.2.3 Movement Compatibility and Interface Detailing

Compatibility between the new atrium structure and the existing building envelope warrants further refinement. Differential deflection, thermal expansion, and long-term movement effects may influence glazing performance and seal durability. Expansion joints, slip connections, and glazing tolerances should be finalized during detailed engineering.

11.2.4 Drainage Integration

While the concept incorporates controlled roof drainage paths, implementation should include confirmation of tie-ins to existing drainage infrastructure. Redundancy against ponding and water ingress at building interfaces should be verified through detailed waterproofing and flashing design.

11.2.5 Rooftop Equipment and Access Constraints

Final framing geometry should be confirmed against field-measured rooftop mechanical equipment clearances and required maintenance access zones. Minor dimensional discrepancies could influence connection detailing or erection sequencing.

11.2.6 Temporary Conditions During Construction

The final structural model reflects completed structural behaviour. Temporary load cases during erection, including partially braced frames and crane-induced loads, would require evaluation by the installing contractor’s engineer to ensure stability during construction staging.

11.2.7 Risk Management

Risk management throughout the project focused on early identification of structural uncertainties, modelling limitations, and integration constraints. Weekly internal progress reviews were used to monitor technical risks and ensure that structurally critical tasks were prioritized. In the transition from design verification to implementation and to operation, there are several risks that should be addressed to ensure a safe final design.

The primary risks identified are summarized below.

11.2.7.1 Existing Structure Uncertainty

The design relies on available drawings and assumes properties of the existing structure at tie-in locations. Variations in member size, connection condition, corrosion state, or roof deck composition could affect load transfer assumptions.

Prior to implementation, field verification and selective exploratory investigation should be completed prior to final fabrication. If discrepancies are identified, localized reinforcement or revised connection detailing would be implemented.

11.2.7.2 Structural Modelling Limitations

The SAP2000 student version imposes model size limitations. There is also inherent modelling simplification in representing connection stiffness and boundary conditions.

To address this, structural modelling was initiated early in the design phase. Governing frame lines were isolated to confirm critical forces. Hand calculations were performed to validate key members. For implementation, final connection stiffness assumptions should be confirmed during detailed engineering.

11.2.7.3 Differential Movement and Compatibility

Differential deflection between the new atrium frame and the existing structure, as well as thermal expansion effects, may influence glazing performance and long-term seal durability.

To accommodate these effects, incorporate slip connections or expansion detailing at interfaces. Final glazing tolerances and movement allowances should be confirmed during detailed connection design.

11.2.7.4 Drainage and Waterproofing Performance

Improper integration with the existing roof drainage system could result in ponding, leakage, or long-term membrane deterioration.

As part of the mitigation strategy, confirm positive drainage slopes and redundant flow paths. Conduct detailed flashing and waterproofing coordination prior to construction. Consider water testing after installation.

11.2.7.5 Temporary Stability During Construction

The completed structural system differs from partially erected conditions. Temporary instability during installation, particularly prior to full bracing or glazing diaphragm action, presents a construction-stage risk.

During construction, temporary bracing and erection sequencing should be designed and verified by the contractor's engineer. Crane loading effects and staged load cases should be reviewed before installation.

11.2.7.6 Cost Escalation and Material Availability

Fluctuations in steel pricing, glazing lead times, or supply chain delays could affect project feasibility.

To address this, early identification of long-lead materials and allowance for cost contingency during budgeting. Maintain flexibility in member selection where structurally acceptable.

11.2.7.7 Rooftop Access and Operational Constraints

The building remains occupied during potential construction. Restricted crane access, pedestrian safety requirements, and coordination with rooftop mechanical equipment may impact schedule and sequencing.

A pre-construction logistics review should be conducted to confirm crane placement feasibility and safe access routes. Coordinate installation timing to minimize disruption to building occupants.

11.2.7.8 Prioritization Strategy

If unforeseen constraints arise, the following hierarchy governs decision-making:

1. Structural safety and code compliance
2. Water management and durability
3. Serviceability performance (deflection and vibration)
4. Constructability and schedule
5. Aesthetic refinements

This prioritization ensures that safety, long-term performance, and code compliance remain the primary drivers of all design decisions.

11.2.8 Risk Evaluation

Following the identification of several risks, a risk evaluation was conducted to identify potential technical, construction, and operational risks associated with the proposed design. The purpose of this assessment is to systematically identify uncertainties that may influence structural performance, constructability, cost, or operational functionality, and to outline mitigation strategies where appropriate.

Each risk was evaluated using the following two criteria:

1. Likelihood – the probability that the risk event may occur
2. Severity – the potential consequences if the risk event occurs

A risk score was calculated using the following formula:

$$Risk\ Score = Likelihood\ \times Severity$$

The resulting score allows risks to be categorized into qualitative levels that guide the recommended degree of monitoring and mitigation. This approach enables quick identification of higher-priority risks, while lower-priority risks remain documented during the entire implementation process.

11.2.8.1 Likelihood Rating

Likelihood describes the probability that a given risk may occur during design, construction, or the operation of the proposed atrium. The scores are summarized in Table 8 below:

Table 8: Description of likelihood ratings

Likelihood Rating	Description	Interpretation
1 – Rare	Highly unlikely to occur	Would require unusual circumstances
2 – Unlikely	Possible but not expected	Has occurred occasionally on similar projects
3 – Possible	Reasonable chance of occurring	May occur under certain conditions
4 – Likely	Expected to occur in some cases	Occurs regularly on comparable projects
5 – Almost Certain	Very high probability	Expected without mitigation measures

11.2.8.2 Severity Rating

Likelihood describes the probability that a given risk may occur during design, construction, or the operation of the proposed atrium. The scores are summarized in Table 9 below:

Table 9: Description of the severity of consequences

Severity Rating	Description	Impact
1 – Negligible	Minimal impact	Minor inconvenience or negligible cost impact
2 – Minor	Limited impact	Minor repair, small cost increase, or short delay
3 – Moderate	Noticeable impact	Localized redesign, moderate cost increase, or schedule delay
4 – Major	Significant impact	Major repair, substantial redesign, or construction delay
5 – Critical	Severe impact	Structural safety concern, major project disruption, or significant cost escalation

11.2.8.3 Risk Score Interpretation

Risk scores range from 1 – 25 and are categorized into four levels to guide the recommended management approach. The scores are summarized into Table 10 below:

Table 10: Description of risk scores

Risk Score	Risk Level	Recommended Action
1 – 4	Low	Acceptable risk. Monitor periodically; no additional mitigation required beyond standard engineering practice.
5 – 9	Moderate	Mitigation measures should be considered where practical. Risks should be reviewed during detailed design and construction planning.
10 – 16	High	Active mitigation required. Design modifications, verification procedures, or construction controls should be implemented
17 – 25	Critical	Immediate attention required. Risk must be reduced through redesign, additional investigation, or procedural controls prior to implementation.

11.2.8.4 Risk Monitoring and Management

Risk levels may evolve as additional information becomes available during detailed design, field investigations, and construction planning. As such, this evaluation should be considered an initial assessment intended to support decision-making and highlight areas requiring further verification.

Lower-level risks are documented to maintain awareness during the design process, while higher-level risks require targeted mitigation strategies or additional engineering review.

Mitigation measures generally aim to reduce the likelihood of occurrence through verification, detailing improvements, or construction controls, as the severity of consequences may be difficult to reduce once a failure mechanism exists.

11.2.8.5 Risk Evaluation Matrix

The following matrix (Table 11) summarizes the identified risks, assigned likelihood and severity ratings, resulting scores, and recommended mitigation strategies.

Table 11: Risk evaluation matrix

Risk ID	Risk	Likelihood	Severity	Score	Risk Level	Mitigation Strategy
R1	Existing Structure Uncertainty	3	4	12	High	Perform field verification and selective exploratory investigation at tie-in locations prior to fabrication. Revise connection detailing or implement localized reinforcement if discrepancies are identified
R2	Structural Modelling Limitations	2	3	6	Moderate	Validate governing member forces using hand calculations. Confirm connection stiffness assumptions and boundary conditions during detailed engineering
R3	Differential Movement and Compatibility	3	3	9	Moderate	Incorporate slip connections or expansion detailing at structural interfaces. Confirm glazing tolerances and allowable movements during detailed design
R4	Drainage and Waterproofing Performance	3	4	12	High	Verify drainage slopes and integrate flashing systems with the existing roof assembly. Conduct detailed waterproofing coordination and consider post-installation water testing
R5	Temporary Stability During Construction	2	5	10	High	Contractor's engineer to design temporary bracing and erection sequencing. Review staged loading conditions and crane loading effects prior to installation
R6	Cost Escalation and Material Availability	3	3	9	Moderate	Identify long-lead materials early and maintain flexibility in member selection where structurally acceptable. Include contingency allowances during budgeting
R7	Rooftop Access and Operational Constraints	3	3	9	Moderate	Conduct a pre-construction logistics review, confirm crane placement feasibility, and coordinate installation sequencing to minimize disruption to building occupants

11.3 Meetings

Queen’s Facilities had agreed to bi-weekly progress meetings to review design assumptions, confirm task completion, and align project priorities. Towards the submission of the Final Report, meetings were changed to be on an as-needed basis. Meetings were held in person or virtually as required. The team distributed agendas at least 24 hours in advance and recorded action items following each meeting. Keinar Widjaja served as the primary communication liaison with Queen’s Facilities and the TA, ensuring continuity of information and timely resolution of technical questions.

12.0 Conclusion

This report was prepared in response to Queen’s Facilities’ request to develop a feasible atrium concept over Alumni Way that enhances the usability of the space while maintaining structural feasibility and constructability. The objective of this project was to explore viable design options, evaluate material and system choices, and present a preliminary, proof-of-concept solution supported by analysis and structured decision-making.

The project team developed two design concepts and assessed different geometries and configurations using clearly defined performance criteria. Weighted evaluation matrices enabled a systematic comparison, leading to the selection of Design Concept 2 as the preferred option based on its relative advantages in constructability, serviceability, and overall feasibility. A similar approach was used in material selection, resulting in structural steel being identified as the primary load-resisting material, complemented by timber elements and insulated glazing units.

The analysis indicates that the proposed design is structurally feasible at a conceptual level and reasonably addresses key considerations such as constructability, cost drivers, maintenance requirements, sustainability, and user experience. These findings suggest that the atrium concept is a viable candidate for further development and aligns with the operational needs of the John Deutsch University Centre (JDUC).

However, important aspects—including detailed connection design, comprehensive lateral system validation, and verification of the existing structure—remain outside the scope of this study and are identified as critical next steps. As such, the results presented should be interpreted as a preliminary assessment rather than a finalized design.

Overall, the project objectives have been met within the scope of a conceptual design study. The work provides a code-informed and analytically supported foundation that can be used to guide subsequent detailed engineering, refinement, and potential implementation.

13.0 References

[1] P. S. and P. C. Government of Canada, "National Building Code of Canada 2020 Volume 1." Accessed: Nov. 04, 2025. [Online]. Available: https://publications.gc.ca/site/archivee-archived.html?url=https%3A%2F%2Fpublications.gc.ca%2Fcollections%2Fcollection_2022%2Fcnrc-nrc%2FNR24-28-2020-eng.pdf

[2] "Section 4 of the Ontario Building Code." Accessed: Nov. 04, 2025. [Online]. Available: https://www.buildingcode.online/section4.html

[3] "Heritage Study | Queen's Encyclopedia." Accessed: Nov. 04, 2025. [Online]. Available: https://www.queensu.ca/encyclopedia/h/heritage-study

[4] "Queen's Building Design Standards | Facilities." Accessed: Nov. 04, 2025. [Online]. Available: https://www.queensu.ca/facilities/building-design-standards

[5] Canada Green Building Council, "LEED," Canada Green Building Council (CAGBC). Accessed: Nov. 08, 2025. [Online]. Available: https://www.cagbc.org/our-work/certification/leed/

[6] "WELL - International WELL Building Institute." Accessed: Nov. 08, 2025. [Online]. Available: https://www.wellcertified.com/home

[7] "Ontario Heritage Act, R.S.O. 1990, c. O.18 | ontario.ca." Accessed: Nov. 08, 2025. [Online]. Available: https://www.ontario.ca/laws/statute/90o18

[8] J. Llewellyn and N. C. Specialist, "Publication 841, Guide to Nursery and Landscape Plant Production and IPM".

[9] H. E. Ilgın, "Analysis of the Main Architectur al and Structural Design Considerations in Tall Timber Buildings," *Buildings*, vol. 14, no. 1, Dec. 2023, doi: 10.3390/buildings14010043.

[10] "Check of steel connection components (CSA)." Accessed: Nov. 18, 2025. [Online]. Available: https://www.ideastatica.com/support-center/check-of-components-according-to-csa?

[11] "Glulam Design Specification".

[12] "Bending Moment Design." Accessed: Nov. 18, 2025. [Online]. Available: https://help.woodworks-software.com/WoodWorks/OnlineHelp/Sizer/4244.htm?

[13] "2426995.pdf | WebViewer." Accessed: Nov. 18, 2025. [Online]. Available: https://view-csagroup-org.proxy.queensu.ca/FCtNb4

[14] D. F. Lima, S. Duarte, J. M. Branco, and L. Nunes, "Mass Timber Buildings: The associated risks of rainwater exposure during construction in the Portuguese climate," *Journal of Building Engineering*, vol. 98, p. 111110, Dec. 2024, doi: 10.1016/j.jobe.2024.111110.

[15] M. Iannuzzi and G. S. Frankel, "The carbon footprint of steel corrosion," *npj Mater Degrad*, vol. 6, no. 1, p. 101, Dec. 2022, doi: 10.1038/s41529-022-00318-1.

[16] E. Lam, "Structural Engineering and Embodied Carbon," Canadian Architect. Accessed: Nov. 18, 2025. [Online]. Available: https://www.canadianarchitect.com/structural-engineering-and-embodied-carbon/

[17] F. Morris, S. Allen, and W. Hawkins, "On the embodied carbon of structural timber versus steel, and the influence of LCA methodology," *Building and Environment*, vol. 206, p. 108285, Dec. 2021, doi: 10.1016/j.buildenv.2021.108285.

[18] "XCarb® | ArcelorMittal." Accessed: Nov. 18, 2025. [Online]. Available: https://corporate.arcelormittal.com/climate-action/xcarb/

[19] "Code of practice for Use of Glass in Buildings".

[20] American Society of Civil Engineers, Construction Engineering Handbook, 2nd ed. Reston, VA, USA: ASCE, 2008

[21] R. G. Guggemos and A. Horvath, “Decision-support tool for assessing the environmental effects of constructing commercial buildings,” Journal of Architectural Engineering, vol. 11, no. 4, pp. 118–128, 2005.

[22] ASTM International, “Standard Guide for Selection of Sealants for Glazing Applications,” ASTM C1193, West Conshohocken, PA, USA.

[23] M. Pomponi and A. Moncaster, “Embodied carbon mitigation and reduction in the built environment – What does the evidence say?” Journal of Environmental Management, vol. 181, pp. 687–700, 2016.

[24] U.S. Department of Energy, Building Envelope Best Practices, Washington, DC, USA, 2015.

[25] World Steel Association, “Steel’s contribution to a low carbon future,” Brussels, Belgium, 2019.

Appendix A – Design Calculations

Snow Load Calculations for Design Concept 1

Formula:

$$S = I_s[\, S_s(C_b C_w C_s C_a) + S_r]$$

Constants:

- $I_s = 1.0$
- $S_s = 2.1$ kPa
- $S_r = 0.4$ kPa
- $C_w = 1.0$ (normal importance, not rural or north of treeline)
- $C_b = 0.8$

Determination of C_b**:**

a) Determined as:

i. $C_b = 0.8 \; for \; l_c \leq \frac{70}{C_w}$

ii. $C_b = 0.8 + \left[1 - (1 - 0.8C_w) \times \exp\left(\frac{l_c \times C_w - 70}{100}\right)\right] for \; l_c \leq \frac{70}{{C_w}^2}$

Where:

- $l_c = 2w - \frac{w^2}{l}$
- w = shorter dimension
- l = longer dimension

b) Reference: Table 4.1.6.2 – B

c) C_a equals 1 for any roof with mean height less than $1 + \frac{S_s}{\gamma}$ (in meters) above grade, where γ is the specific weight of snow (see Article 4.1.6.13)

Example Calculation:

Using approximate measurements:

- l ≈ 40 m (from JDUC over Mitchell Hall)
- w ≈ 35 m (along Alumni Way)

$$l_c = 2(35) - \frac{35^2}{40} = 39.375\ m$$

$$\frac{70}{C_w} = \frac{70}{1} = 70$$

$$Since\ l_c < \frac{70}{C_w}, then\ C_b = 0.8$$

Determination of C_s:

(OBC 4.1.6.2. 6) - Slippery Roofs (e.g., Glass Panels):

- a) $C_s = 1.0$ if slope $\alpha \leq 15°$
- b) $C_s = (60 - \alpha) / 45$ if $15° < \alpha < 60°$
- c) $C_s = 0$ if $\alpha > 60°$

Using geometry from the design:

- Roof slope angle (α) calculation:

$$tan(\alpha)\ = \frac{4}{40}$$

$$\alpha =\ tan^{-1}\left(\frac{4}{40}\right) = 5.7°$$

- Since $\alpha < 15°$, Cs = 1.0

Determination of C_a:

- $C_a = 1.0$ (Shed roof taller than all surrounding buildings)

Determination of C_s:

- Notes from Section 4.6.2 Sentence 8:
- $C_s = 1.0$ unless:
- a) drifting from higher roof
- b) roof projections
- c) gable, arched, or curved
- d) sliding snow from taller roof
- e) valleys
- f) melt water from adjacent roofs
- None of the above are applicable therefore $C_s = 1.0$

Wind Load Calculations for Design Concept 1

Formula:

$$p = I_w q C_e C_g C_p$$

Constants:

- I_w = 1.0 (normal importance, not rural area or north of treeline)
- q = 0.47 kPa (from Table C-2, NBCC 2020 — 1-in-50-year wind)
- C_e = 0.83

Determination of C_e:

- For open terrain (scattered buildings, trees, open water or shoreline):

a. $C_e = (\frac{h}{10})^{0.2} \geq 0.9$

- For rough terrain (suburban, urban, wooded, uninterrupted for 1 km or 20x building height)

b. $C_e = 0.7(\frac{h}{12})^{0.3} \geq 0.7$

Where:

- h = reference height above grade (in meters)

Using the buildings geometry, h = 21 m, and the building being in an urban area:

$$C_e = 0.7(\frac{h}{12})^{0.3} \geq 0.7$$

$$C_e = 0.7(\frac{21}{12})^{0.3} \approx 0.83$$

C_e = 0.83

Determination of C_g:

a) Whole building, main structural members: C_g = 2.0
b) External pressure on small elements: C_g = 2.5
c) Internal pressures: C_g = 2.0

- Use C_g = 2.0 for whole structure

Determination of C_p:

Use C_p = 1.0 to be conservative (no reduction)

NOTE: All values selected based on conservative assumptions and NBCC 2020 guidelines for wind load analysis.

Table 12: Relevant Load Combinations from Table 4.1.3.2.-A of the 2024 OBC

Case	Load Combination	
	Principal Loads	Companion Loads
1	1.4D	-
2	(1.25D or 0.9D) + 1.5L	1.0S or 0.4W
3	(1.25D or 0.9D) +1.5S	1.0L or 0.4W
4	(1.25D or 0.9D) + 1.4W	0.5L or 0.5S

Snow Load Calculations for Design Concept 2

Formula:

$$S = I_s[\, S_s(C_b C_w C_s C_a) + S_r]$$

Constants:

- I_s = 1.0 (normal importance; NBCC 2020 4.1.6.2.-A)
- S_s = 2.1 kPa (Kingston, ON; NBCC 2020 Subsection 1.1.3.)
- S_r = 0.4 kPa (Kingston, ON; NBCC 2020 Subsection 1.1.3.)
- C_w = 1.0 (Not rural or north of treeline; NBCC 2020 4.1.6.2 Sentences (3) and (4))
- C_b = 0.8

Determination of C_b**:**

Using approximate measurements:

- l ≈ 34.23 m (along Alumni Way)
- w ≈ 8.53 m (over Alumni Way)

$$l_c = 2(8.53) - \frac{8.53^2}{34.23} = 14.93\ m$$

$$\frac{70}{C_w} = \frac{70}{1} = 70$$

$$Since\ l_c < \frac{70}{C_w}, then\ C_b = 0.8$$

Determination of C_s**:**

(OBC 4.1.6.2. 6) - Slippery Roofs (e.g., Glass Panels):

- a) C_s = 1.0 if slope $\alpha \leq 15°$
- b) C_s = (60 - α) / 45 if $15° < \alpha < 60°$
- c) C_s = 0 if $\alpha > 60°$

Using geometry from the design:

- Roof slope angle (α) calculation:

$$sin(\alpha) = \frac{4.05}{7.15}$$

$$\alpha = tan^{-1}\left(\frac{4.05}{7.15}\right) = 34.5°$$

- Since $15° < \alpha < 60°$, Cs = (60 – 34.5) / 45 = 0.89

Determination of C_a:

- C_a = 1.25 ($20° < \alpha < 90°$; Assuming downwind)

<u>Initial Dead Load Calculations for Design Concept 2</u>

Assumptions:

- Initially neglecting self-weight of the structural material. This will be accounted for during the reiterative member selection process; assumption is to simplify the initial calculation.
- Standard 1-inch-thick plexiglass of typical density 1.18 g/cm^3

Calculation:

$$Dead\ Load = \left(9.81\frac{m}{s^2}\right)\left(1180\frac{kg}{m^3}\right)(0.0254\ m) = 0.294\ KPa$$

Primary Beams

NBCC 9.4.3.1:

Deflection limit:

$$\Delta_{max} = \frac{l}{240}$$

Applied load:

$$w = 4.77\ kPa * 5\ m = 23.85\ kN/m$$

Factored moment:

$$M_f = \frac{wl^2}{8}$$

Where:

- Uniformly distributed load, $w_f = 23.85$ kN/m
- Beam length, $l = 9300$ mm

$$M_f = \frac{(23.85)(9300^2)}{8} = 258\ kNm$$

Using the CSA steel beam selection tables, a W310x107 was initially selected.

- Moment resistance: 392 kN-m
- Self-weight: 1.05 kN/m

Updated UDL including self-weight:

$$w = 23.85 + 1.05 = 25.2\ kN/m$$

Updated factored moment:

$$M_f = \frac{(25.2)(9300^2)}{8} = 272\ kNm$$

Deflection check:

$$\Delta = \frac{5wl^4}{384EI}$$

Where:

- Uniformly distributed load, $w_f = 25.2$ kN/m
- Beam length, $l = 9300$ mm
- Modulus of elasticity, $E = 200{,}000$ MPa
- Moment of inertia (for W310x107), $I = 267 \times 10^6$ mm^4

$$\Delta = \frac{5(25.2)(9300^4)}{384(200{,}000)(267 \times 10^6)} = 45.6\ mm$$

Since 45.6 > 39 mm, the section fails deflection check.

Required moment of inertia:

$$I_{req} = \frac{5wl^4}{384E\Delta_{max}}$$

$$I_{req} = \frac{5(25.2)(9300^4)}{384(200{,}000)(39)} = 312 \ \times 10^6 \ mm^4$$

A W360x110 was selected:

- Mr = 372 kN-m
- I = 331 x 10^6 mm^4
- Deflection = 37.1 mm < 39 mm – OK

Girder

Applied load:

$$w = \ 4.77 \ kPa * 4.65 \ m = 22.2 \ kN/m$$

Try a W360x110:

- Self-weight: 1.08 kN/m
- Total UDL: 23.5 kN/m

Factored moment:

$$M_f = \frac{(23.5)(5000^2)}{8} = 73.5 \ kNm$$

Deflection:

$$\Delta = \frac{5(23.5)(5000^4)}{384(200{,}000)(331 \times 10^6)} = 3 \ mm$$

Both moment and deflection are acceptable.

Columns

Using Wood Design Manual Section 7.5.8:

$$P_r = \ \emptyset F_c A K_{Z_{cg}} K_c$$

Where:

- Material reduction factor, $\emptyset = 0.8$
- Adjusted compressive strength, F_c
- Cross-sectional area, A
- Size factor, $K_{Z_{cg}}$
- Slenderness factor, K_c

Adjusted compressive strength:

$$F_c = f_c K_D K_H K_{Sc} K_T$$

Where:

- Specified strength in compression parallel to grain, $f_c = 25.2$ MPa (for 24f-EX DFL)
- Duration factor, $K_D = 1.0$ for normal duration
- System factor, $K_H = 1.0$ for no system since columns are spaced too far apart
- Service condition factor, $K_{Sc} = 1.0$ for dry service condition (inside)
- Treatment factor, $K_T = 1.0$ for untreated timber

$$F_c = (25.2)(1.0)(1.0)(1.0)(1.0)$$

$$F_c = 25.2\ MPa$$

Cross-sectional area, A = 14820 mm^2 for 130x114 mm column.

Size factor:

$$K_{Z_{cg}} = 0.68(Z)^{-0.13} \ \leq 1.0$$

Where:

- Member volume, $Z = 0.03703$ m^3 for 2.5 m long 130x114 mm columns

$$K_{Z_{cg}} = 0.68(0.03703)^{-0.13} \ \leq 1.0$$

$$K_{Z_{cg}} = 1.0$$

Slenderness factor:

$$K_c = \left[1.0 + \frac{F_c K_{Z_{cg}} {C_c}^3}{35 E_{05} K_{SE} K_T}\right]^{-1}$$

Where:

- Slenderness ratio, Cc
- Modulus of elasticity, $E = 13100$ MPa (for 24f-EX DFL timber)
- Adjusted modulus of elasticity, $E_{05} = 0.87E = \ 11397$ MPa

Where slenderness ratio is the greater of:

$$C_c = \frac{Effective\ length\ associated\ with\ width}{member\ width}$$

$C_c = \frac{2500}{114} = 21.93$ (governing)

or

$$C_c = \frac{Effective\ length\ associated\ with\ depth}{member\ depth}$$

$$C_c = \frac{2500}{130} = 19.23$$

Substituting:

$$K_c = \left[1.0 + \frac{(25.2)(1.0)(21.93)^3}{35(11397)(1)(1)}\right]^{-1} = 0.60$$

Final compressive resistance:

$$P_r = \emptyset F_c A K_{Z_{cg}} K_c$$

$$P_r = (0.8)(25.2)(14820)(1.0)(0.60)$$

$$P_r = 179\ kN$$

Since the required axial resistance is approximately 100 kN, the selected 130x114 mm 24f-EX DFL glulam column is adequate.

Appendix B – Gantt Chart

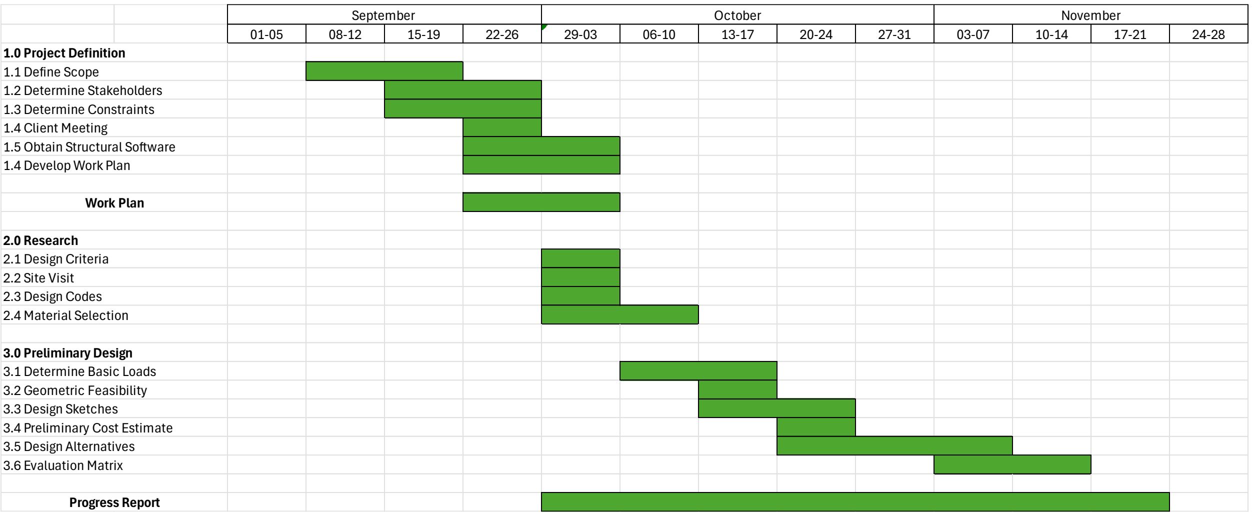


Figure 16: Gantt Chart Describing Tasks and Deliverables for September to November

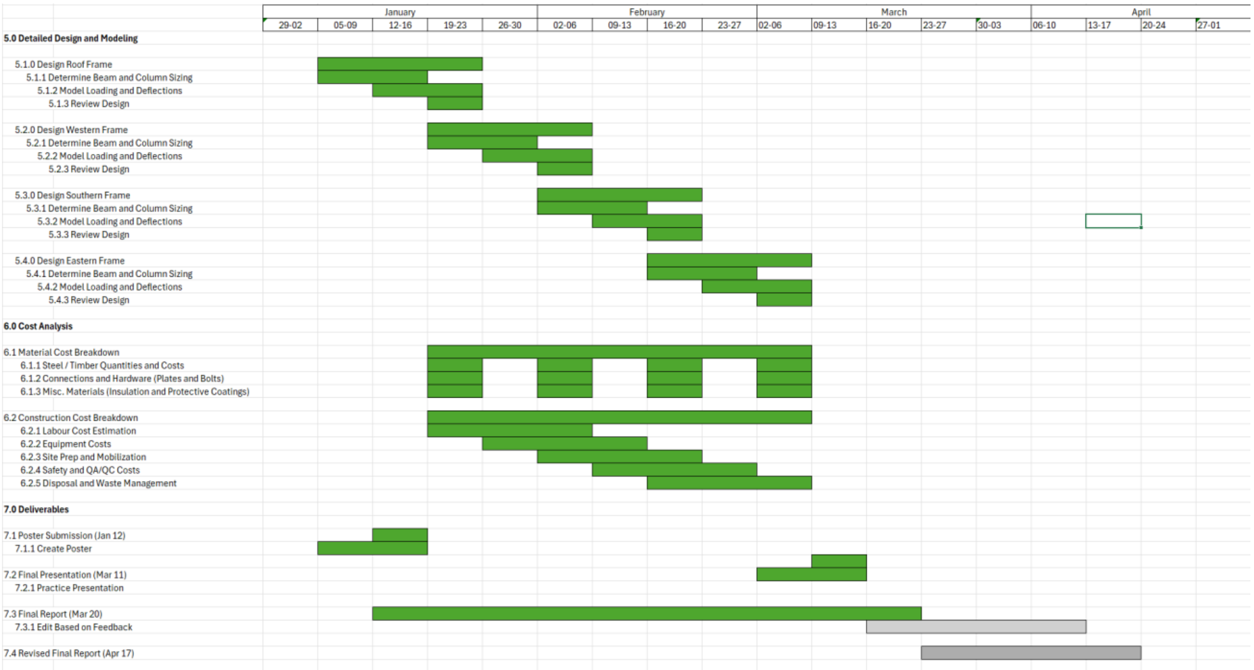


Figure 17: Gantt Chart Outlining Tasks and Deliverables for January to April

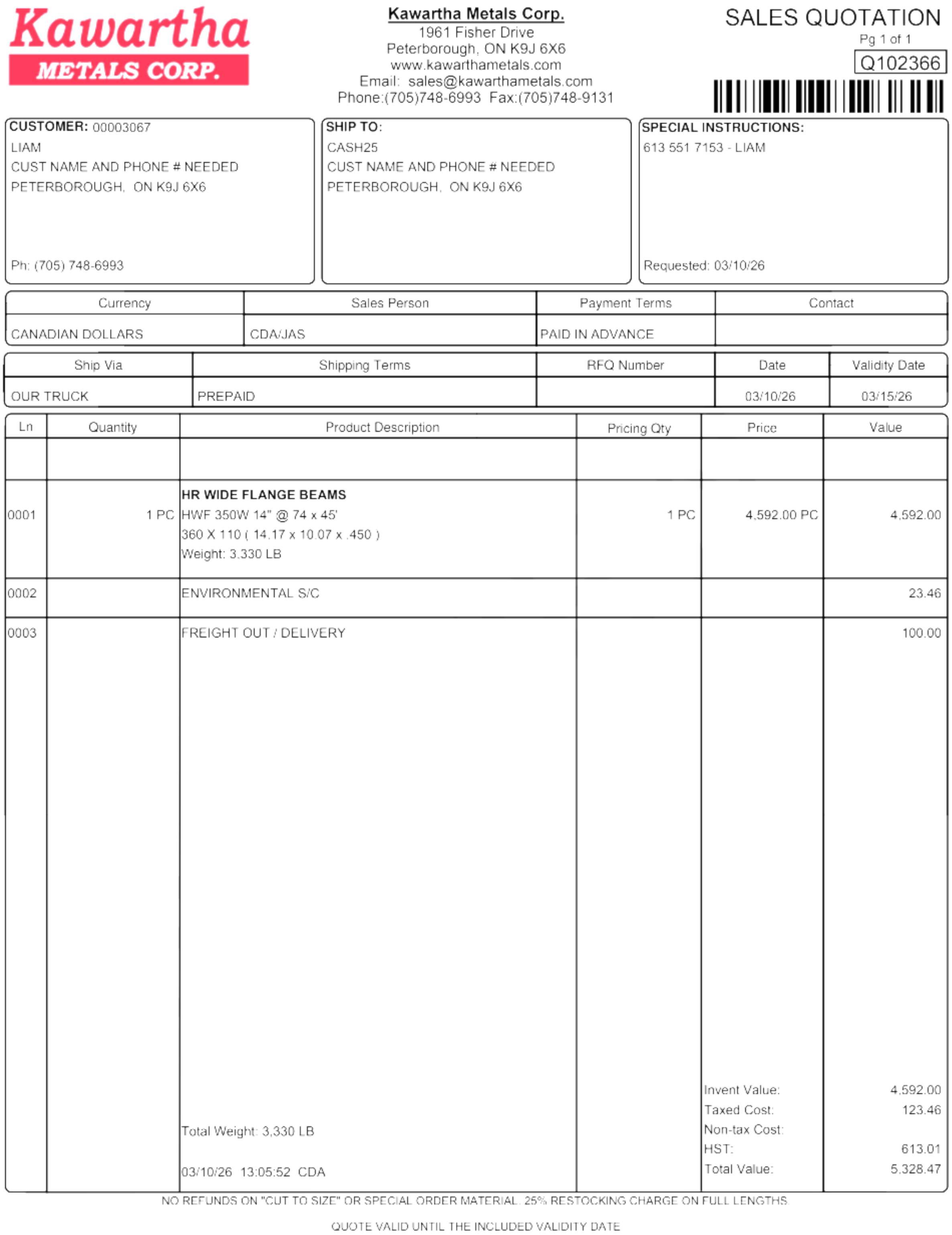
Appendix C – Supplementary Material

Figure 18 is the steel beam quote the project team received from Kawartha Metals, used to inform steel cost estimates in Section 7.1. The quote presents costs not only from the structural steel itself, but from environmental and delivery fees.

Figure 19 presents the plan view of the atrium's structural layout overlaid on the surrounding buildings. The adjacent buildings and bordering streets are labelled to provide site context, and a north arrow is included for orientation. The drawing identifies the spacing of the primary beams, the typical W360x110 steel section used for the beams and girder, and the 130x114 mm glulam columns supporting the system. The overall atrium footprint and key dimensions, including the 35 m span, are shown to illustrate how the structural layout fits within the site.

Figure 20 shows the elevation view of the atrium structure, taken as a cross-section between Mitchell Hall and the JDUC. The heights of both buildings relative to ground level are labelled to provide vertical context, along with the 9.3 m span of the primary beams and the 10 m separation between the buildings. The drawing identifies the W360x110 steel beams and the 130x114 mm glulam columns used to support the atrium. This elevation illustrates the vertical alignment of the structural members and the overall geometry of the atrium structure.

Figure 21 presents the embodied carbon rates of various structural materials from the Institution of Structural Engineers. This information was used to calculate embodied carbon estimates for the proposed design concept in Section 7.2.



Kawartha Metals Corp.
1961 Fisher Drive
Peterborough, ON K9J 6X6
www.kawarthametals.com
Email: sales@kawarthametals.com
Phone:(705)748-6993 Fax:(705)748-9131

SALES QUOTATION
Pg 1 of 1
Q102366

CUSTOMER: 00003067 LIAM CUST NAME AND PHONE # NEEDED PETERBOROUGH, ON K9J 6X6 Ph: (705) 748-6993	**SHIP TO:** CASH25 CUST NAME AND PHONE # NEEDED PETERBOROUGH, ON K9J 6X6	**SPECIAL INSTRUCTIONS:** 613 551 7153 - LIAM Requested: 03/10/26

Currency	Sales Person	Payment Terms	Contact
CANADIAN DOLLARS	CDA/JAS	PAID IN ADVANCE	

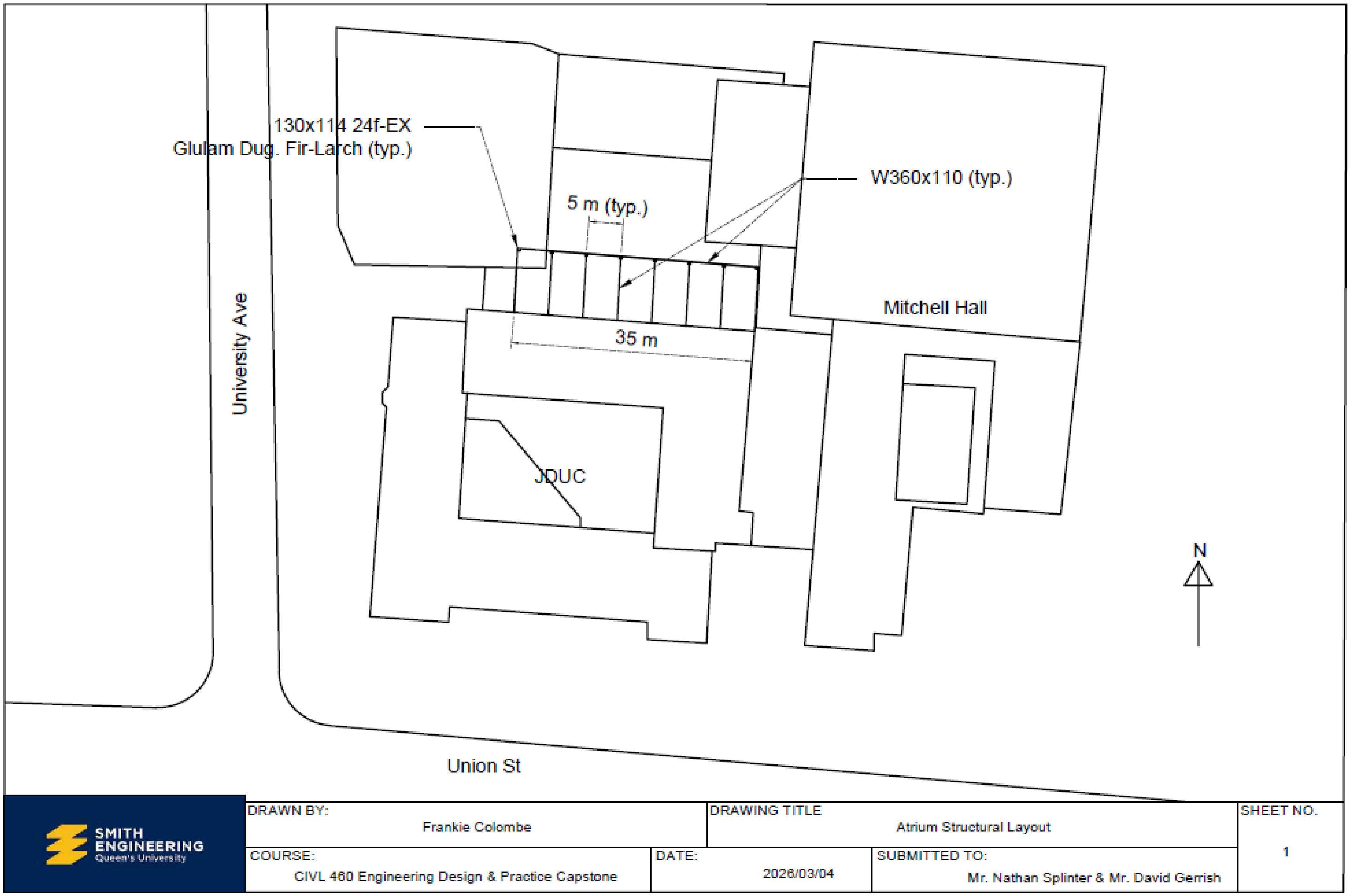
Ship Via	Shipping Terms	RFQ Number	Date	Validity Date
OUR TRUCK	PREPAID		03/10/26	03/15/26

Ln	Quantity	Product Description	Pricing Qty	Price	Value
0001	1 PC	**HR WIDE FLANGE BEAMS** HWF 350W 14" @ 74 x 45' 360 X 110 (14.17 x 10.07 x .450) Weight: 3.330 LB	1 PC	4,592.00 PC	4,592.00
0002		ENVIRONMENTAL S/C			23.46
0003		FREIGHT OUT / DELIVERY			100.00
		Total Weight: 3,330 LB 03/10/26 13:05:52 CDA		Invent Value: Taxed Cost: Non-tax Cost: HST: Total Value:	4,592.00 123.46 613.01 5,328.47

NO REFUNDS ON "CUT TO SIZE" OR SPECIAL ORDER MATERIAL. 25% RESTOCKING CHARGE ON FULL LENGTHS

QUOTE VALID UNTIL THE INCLUDED VALIDITY DATE

Figure 18: Steel Beam Quote



DRAWN BY: Frankie Colombe

DRAWING TITLE: Atrium Structural Layout

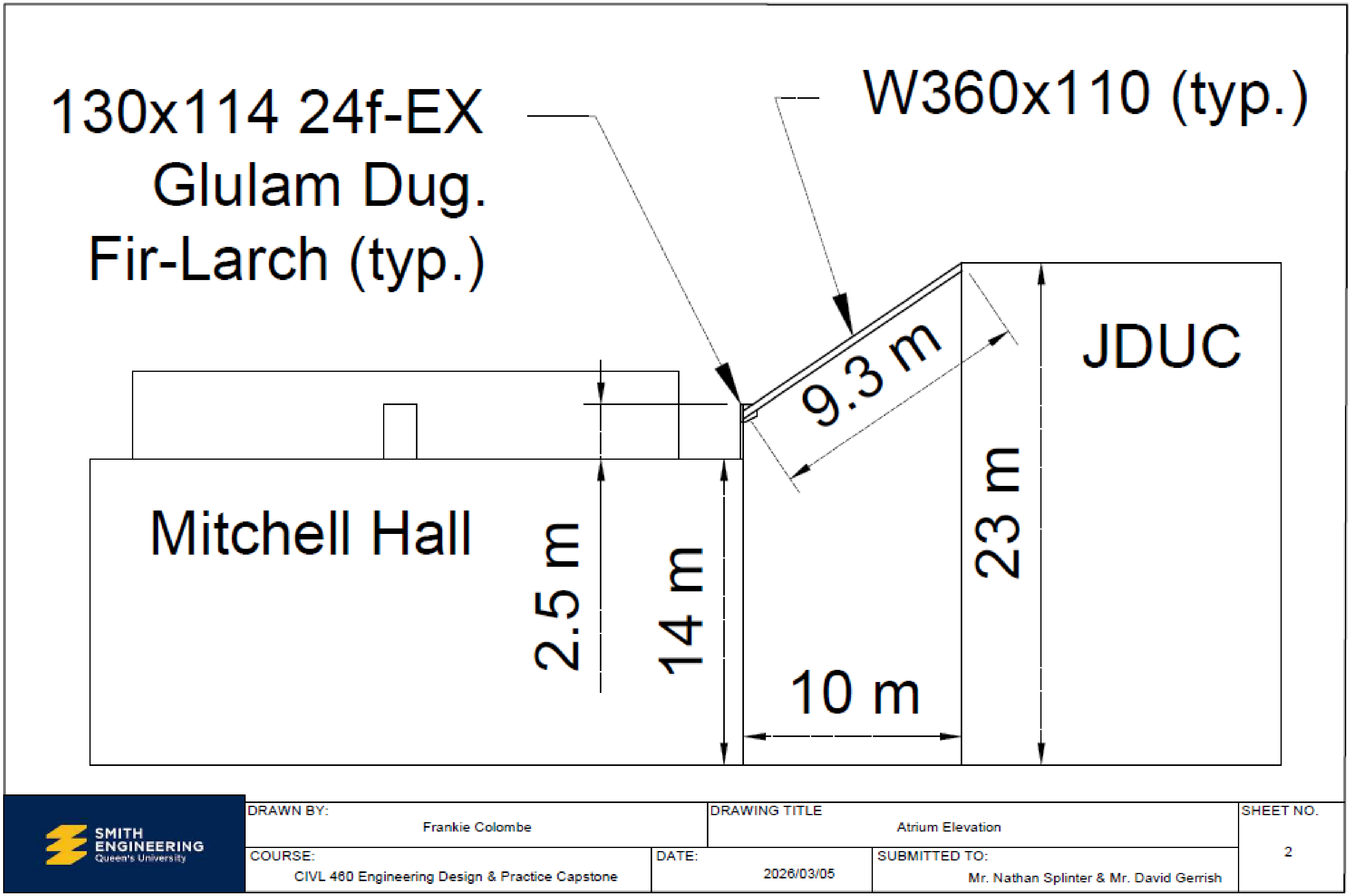
SHEET NO. 1

COURSE: CIVL 460 Engineering Design & Practice Capstone

DATE: 2026/03/04

SUBMITTED TO: Mr. Nathan Splinter & Mr. David Gerrish

Figure 19: Atrium structural layout plan view



DRAWN BY: Frankie Colombe

DRAWING TITLE: Atrium Elevation

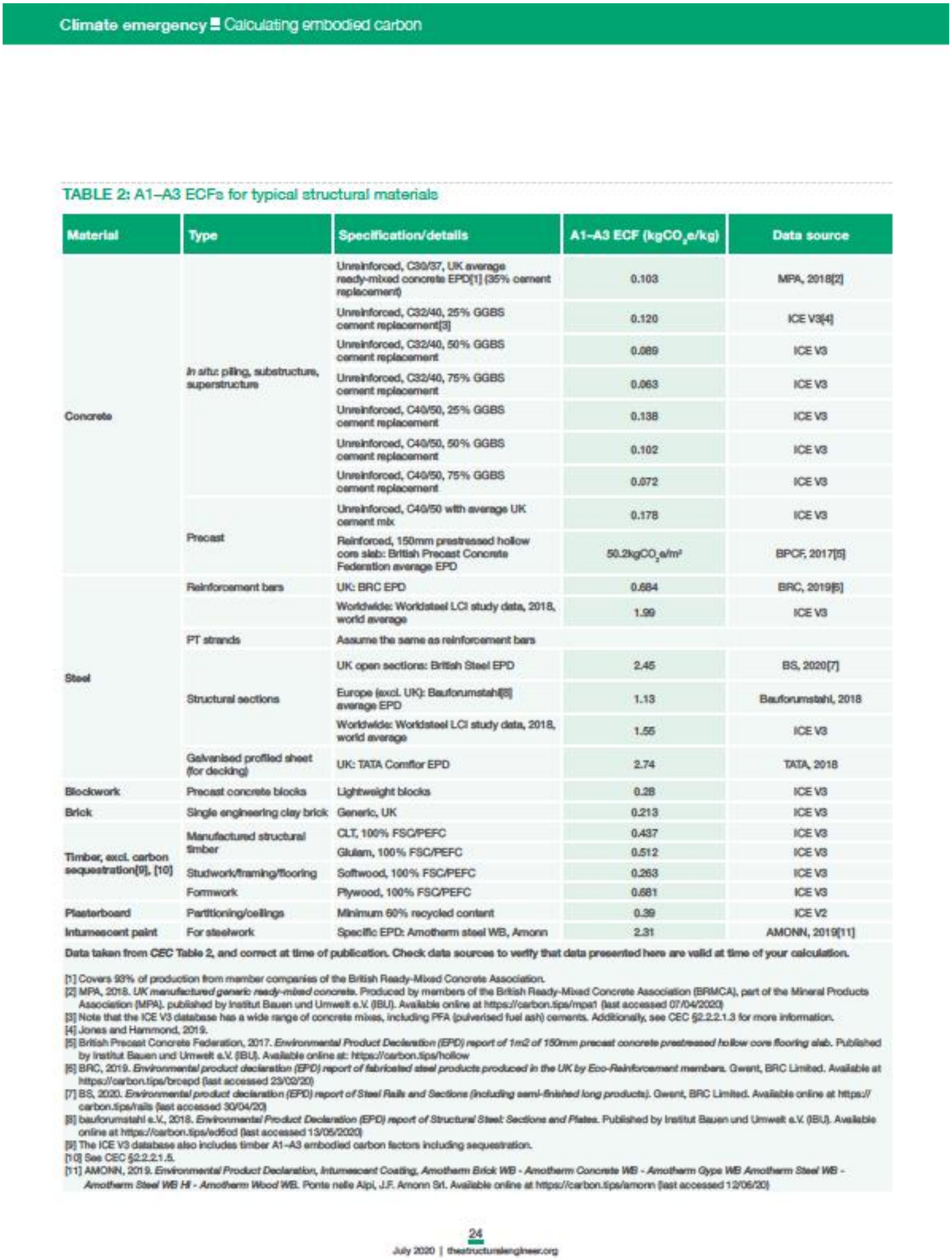
SHEET NO. 2

COURSE: CIVL 460 Engineering Design & Practice Capstone

DATE: 2026/03/05

SUBMITTED TO: Mr. Nathan Splinter & Mr. David Gerrish

Figure 20: Atrium structural layout elevation view



Climate emergency ▪ Calculating embodied carbon

TABLE 2: A1–A3 ECFs for typical structural materials

Material	Type	Specification/details	A1–A3 ECF ($kgCO_2e/kg$)	Data source
Concrete	*In situ*: piling, substructure, superstructure	Unreinforced, C30/37, UK average ready-mixed concrete EPD[1] (35% cement replacement)	0.103	MPA, 2018[2]
		Unreinforced, C32/40, 25% GGBS cement replacement[3]	0.120	ICE V3[4]
		Unreinforced, C32/40, 50% GGBS cement replacement	0.089	ICE V3
		Unreinforced, C32/40, 75% GGBS cement replacement	0.063	ICE V3
		Unreinforced, C40/50, 25% GGBS cement replacement	0.138	ICE V3
		Unreinforced, C40/50, 50% GGBS cement replacement	0.102	ICE V3
		Unreinforced, C40/50, 75% GGBS cement replacement	0.072	ICE V3
	Precast	Unreinforced, C40/50 with average UK cement mix	0.178	ICE V3
		Reinforced, 150mm prestressed hollow core slab: British Precast Concrete Federation average EPD	$50.2kgCO_2e/m^2$	BPCF, 2017[5]
Steel	Reinforcement bars	UK: BRC EPD	0.684	BRC, 2019[6]
		Worldwide: Worldsteel LCI study data, 2018, world average	1.99	ICE V3
	PT strands	Assume the same as reinforcement bars		
	Structural sections	UK open sections: British Steel EPD	2.45	BS, 2020[7]
		Europe (excl. UK): Bauforumstahl[8] average EPD	1.13	Bauforumstahl, 2018
		Worldwide: Worldsteel LCI study data, 2018, world average	1.55	ICE V3
	Galvanised profiled sheet (for decking)	UK: TATA Comflor EPD	2.74	TATA, 2018
Blockwork	Precast concrete blocks	Lightweight blocks	0.28	ICE V3
Brick	Single engineering clay brick	Generic, UK	0.213	ICE V3
Timber, excl. carbon sequestration[9], [10]	Manufactured structural timber	CLT, 100% FSC/PEFC	0.437	ICE V3
		Glulam, 100% FSC/PEFC	0.512	ICE V3
	Studwork/framing/flooring	Softwood, 100% FSC/PEFC	0.263	ICE V3
	Formwork	Plywood, 100% FSC/PEFC	0.681	ICE V3
Plasterboard	Partitioning/ceilings	Minimum 60% recycled content	0.39	ICE V2
Intumescent paint	For steelwork	Specific EPD: Amotherm steel WB, Amonn	2.31	AMONN, 2019[11]

Data taken from CEC Table 2, and correct at time of publication. Check data sources to verify that data presented here are valid at time of your calculation.

[1] Covers 93% of production from member companies of the British Ready-Mixed Concrete Association.

[2] MPA, 2018. *UK manufactured generic ready-mixed concrete*. Produced by members of the British Ready-Mixed Concrete Association (BRMCA), part of the Mineral Products Association (MPA). published by Institut Bauen und Umwelt e.V. (IBU). Available online at https://carbon.tips/mpa1 (last accessed 07/04/2020)

[3] Note that the ICE V3 database has a wide range of concrete mixes, including PFA (pulverised fuel ash) cements. Additionally, see CEC §2.2.2.1.3 for more information.

[4] Jones and Hammond, 2019.

[5] British Precast Concrete Federation, 2017. *Environmental Product Declaration (EPD) report of 1m2 of 150mm precast concrete prestressed hollow core flooring slab*. Published by Institut Bauen und Umwelt e.V. (IBU). Available online at: https://carbon.tips/hollow

[6] BRC, 2019. *Environmental product declaration (EPD) report of fabricated steel products produced in the UK by Eco-Reinforcement members*. Gwent, BRC Limited. Available at https://carbon.tips/brcepd (last accessed 23/03/20)

[7] BS, 2020. *Environmental product declaration (EPD) report of Steel Rails and Sections (including semi-finished long products)*. Gwent, BRC Limited. Available online at https:// carbon.tips/rails (last accessed 30/04/20)

[8] bauforumstahl e.V., 2018. *Environmental Product Declaration (EPD) report of Structural Steel: Sections and Plates*. Published by Institut Bauen und Umwelt e.V. (IBU). Available online at https://carbon.tips/ed6od (last accessed 13/05/2020)

[9] The ICE V3 database also includes timber A1–A3 embodied carbon factors including sequestration.

[10] See CEC §2.2.2.1.5.

[11] AMONN, 2019. *Environmental Product Declaration, Intumescent Coating, Amotherm Brick WB - Amotherm Concrete WB - Amotherm Gyps WB Amotherm Steel WB - Amotherm Steel WB HI - Amotherm Wood WB*. Ponte nelle Alpi, J.F. Amonn Srl. Available online at https://carbon.tips/amonn (last accessed 12/06/20)

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July 2020 | thestructuralengineer.org

Figure 21: Embodied Carbon Rates for Various Structural Materials by the Institution of Structural Engineers

Table 13: Summary of Preliminary Cost Estimation

Category	**Item**	**Total Mass**	**Total Length**	**Cost Rate**	**Cost**	**Embodied Carbon (kgCO2e)**	**Carbon Rate**	**Carbon Cost ($)**
Material	Structural Steel (W360x110)	15913 kg	144.4 m	$334.79/m	$49,000.00	25174.4	$110/tonne	$2,714.00
	Glulam Timber Columns (130x114 mm DFL 20F-EX)	166 kg	20 m	$103.74/m	$2,000.00	77.9	$110/tonne	$8.00
	Insulated Glazing Units (IGU)	14100 kg	-	$323/m^2	$152,000.00	-	-	-
Labour and Equipment	Personnel	-	-	$200 - 300/hr	-	-	-	-
	Crane Service	-	-	$169/hr	-	-	-	-
Total	-	-	-	$369/hr - $469/hr	$203,000	-	-	$2,722.00
				$203,000+ $369-469/hr				

Appendix D – Meeting Minutes

Table 14: Meeting Minutes for September 24th, 2025

Date and time	24-09-2025 11:00 AM – 11:30 AM EST
Location	355 King St W – Room 246
Attendees	David Gerrish Brooke Maurier Dean Martin Frankie Colombe Liam Macdonell Keinar Widjaja
Agenda	1. Introductions 2. Discuss project details 3. Clearly define project scope
Questions and Notes	What is the final deliverable? What does the final product look like? - Progress report; propose design options: cost evaluation, evaluation matrices, etc. - Final report: fully fleshed out design and implementation proposal. Is there a theoretical budget? What are some foreseeable expenses we should know about? - If presenting options, produce cost projections for each design. - Possibly base budget off similar projects and receive approval from PPS. Establishing constraint will guide design choices. Are there key stakeholders and constraints we should know about? - Few different users in area. Higher levels are grad residents. Consider construction, ideally complete it during summer season. AMS based in JDUC. Users of nearby facilities and buildings.

	Will we be able to visit the site via rooftop? - Yes to site visit. Will we be able to receive the "as built" drawings for the JDUC and possibly Mitchell Hall - Yes, will look into obtaining them. Liam asked if there are structural modelling for us to use? - Revit through Queen's? Will investigate. Heritage design? - Use atrium from JDUC to model base design, in terms of heritage. Room for new design. Look into what City of Kingston requires for heritage design. Frequency of meetings? - Biweekly to start, see how it goes. Schedule meetings for major deliverables: workplan and progress report. Construction plan should be included within final report. PPS has a contact that can approve or deny feasibility of construction plan. Look into ground improvements. Add more plants, possible precipitation management. Redistributing rainwater into planters? Possibly investigate heating the space. Feasibility analysis to evaluate this. Varying roof elevations will be a design challenge. Need access to small corridor in rear, contains condenser unit for AC that should remain outside. Group will need to design a solution that separates the corridor from covered area: wall and door. HVAC considerations: adding ducts to the existing intake/exhaust vents. Will need to integrate this into atrium design.

	Glass material considerations. David mentioned Plexiglas degradation: discolouration. Should consider and evaluate options, as well as maintenance options.
Decisions	- Design should be enclosed, no pigeons inside.
Action Items (What's next)	- Work Plan meeting next Wednesday at 11:00 AM. - Add Brooke Maurier, David Gerrish, and Nathan Splinter to Teams group (complete). - Brooke Maurier is looking into as-builts. - Group O is reaching out to Ian for Revit access via Queen's. - Potential on-site meeting next week depending on client availability.

Table 15: Meeting minutes for October 22nd, 2025

Date and time	22-10-2025 11:00 AM – 11:30 AM EST
Location	355 King St W – Room 246
Attendees	David Gerrish Brooke Maurier Dean Martin Frankie Colombe Liam MacDonell Keinar Widjaja
Agenda	• Go Over Proposed Timeline into Progress Report • Questions & Updates
Questions and Notes	• Going over timeline for Progress Report • 2 design options, "add-ons" to be added in Final Report. In Progress Report, client will select one of the two design options • Costing: based on material list; David usually refers to other comparable projects to come up with cost estimates. Cost should be reasonable
Decisions	• Two preliminary designs, two material selections (steel & timber)
Action Items (What's next)	• Continue with preliminary design • Determine load combinations • Determine estimate of section sizes

Table 16: Meeting minutes for November 19th, 2025

Date and time	19-11-2025 11:00 AM – 11:30 AM EST
Location	Microsoft Teams
Attendees	Nathan Splinter Brooke Maurier

	Dean Martin Frankie Colombe Liam MacDonell Keinar Widjaja
Agenda	• Review Preliminary Design Choices • Feedback from Client; Design Direction
Questions and Notes	• Nathan: asking about considering roof loads, especially when snow slides down; to do a full snow loading analysis later on in design; snow retention add-on for the design • Modelling is limited in terms of software so we will use SAP2000 to model deflections; cost analysis to come about once we have member sizing based on deflections • To see a full 3D render in Final Report; to see the design integrated into the existing buildings • Nathan: to have a formal presentation at the end of the year to senior leadership, to potentially try and pitch project idea to them and continue with the project • Nathan: as design progresses and we might need more work, he can see about a cost consultant to help • To provide pros and cons for the choice between steel vs. timber: cost, embodied carbon, constructability, durability • Brooke: have we worked on the landscaping below yet? • Nathan: would like to see comments about landscaping or space utilization on the progress report. Currently only an egress option; list all possible options for the use of the space below, possible reuses • Liam: what plants do would you generally want to see? • Nathan: looking for native species, maybe vertical climbers/growers, not ones that expand and take up too much space, maybe requiring less maintenance. Queen’s usually looks at perennials for flowers indoors
Action Items (What’s next)	• Add section on possible landscaping options or solutions • Add section on possible uses for the space in the hallway • WEM for design options and material selection • See about 3D rendering options

Table 17: Meeting minutes for November 26th, 2025

Date and time	26-11-2025 11:00 AM – 11:30 AM EST
Location	Microsoft Teams
Attendees	David Gerrish Brooke Maurier Dean Martin Frankie Colombe Liam MacDonell

	Keinar Widjaja
Agenda	1. Review Progress Report 2. Go over next steps
Questions and Notes	- David: There may be louvres and ventilation near the mechanical building Does the NBCC require you to account for snow loads if you have heated panels? Is it all or nothing for one material? Are you looking for our input for a decision? Do we have a lifespan on the poly-carbonate panels? When evaluating sustainability, we should consider the life span of the materials. - Brooke: Let us know if you need additional information about the surrounding buildings. - Dean: If we wanted to pursue a mixed design, we would recommend wood columns and steel beams since we want to minimize deflections (glass has low deflection tolerance). - Frankie: - Liam: Lifespan on glazing depends on exposure…within 15-20 years. - Keinar: • Went over design selection for the comparison between conceptual design #1 vs. #2. Design option #2 is the team's preferred design as it simplifies size, loading, and connections.
Decisions	Send decision making list to Queen's Facilities. • Begin next phase of the project.
Action Items (What's next)	• Detailing • QA/QC

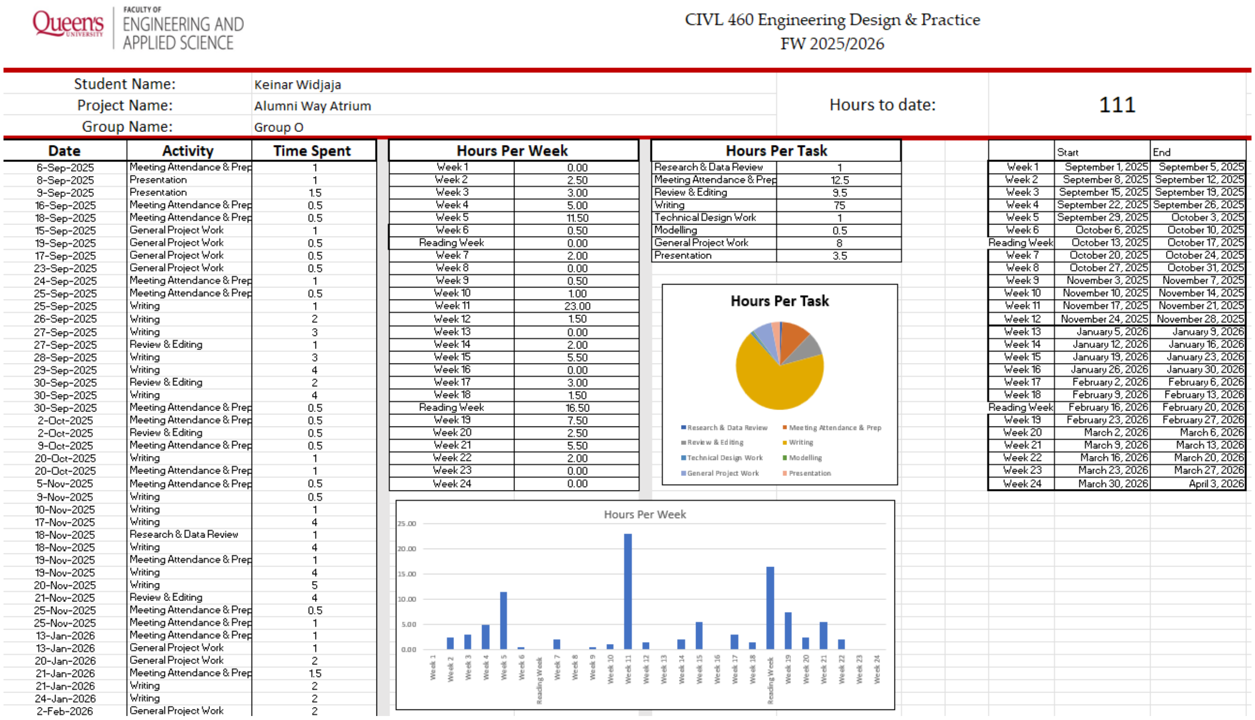
Table 18: Meeting minutes for January 21, 2026

Date and time	21-01-2026 11:00 AM – 11:30 AM EST
Location	Microsoft Teams
Attendees	David Gerrish Brooke Maurier Dean Martin Frankie Colombe Liam MacDonell Keinar Widjaja
Agenda	1. Advocate for Design Concept 2 2. Who designed JDUC & Mitchell Hall? 3. Is there anyone we can speak to about existing structures
Questions and Notes	• If there are specific questions, reach out to David and he will find someone to ask • Look at the drawings provided by Brooke and David, is there sufficient information? • The buildings we are looking at were not touched structurally • JDUC residence was constructed in the 60’s • ARC was about 25 years ago • The NW section was renovated, let Brooke know if there are drawings we need and don’t have for this section • If the drawings aren’t available – can we make assumptions? • Talked about feasibility of design 1, need to go through mechanical room to access roof • Limitations with SAP2000 student version – the model would not be accurate for such a large structure • Look into timber for columns and beams o Would really like structural members to be made of wood o Has embodied carbon, less carbon footprint o Is it suitable for deflections with glass paneling on top? • Is carbon analysis part of the scope? o If not, see if we can discuss within the report. If possible, put some numbers to it o Incorporate into the cost analysis/budget? o Comment on it when looking at materials
Decisions	• Proceed with Design Concept 2
Action Items (What’s next)	• Transfer progress report into final • Make edits as suggested by Zaid • Work on structural design for next meeting

	○ Pick spacing and size members accordingly - Look into existing buildings for capacity, etc.

Appendix E – Timesheet

Keinar:



CIVL 460 Engineering Design & Practice
FW 2025/2026

Student Name:	Keinar Widjaja
Project Name:	Alumni Way Atrium
Group Name:	Group O

Hours to date: 111

Date	Activity	Time Spent
6-Sep-2025	Meeting Attendance & Prep	1
8-Sep-2025	Presentation	1
9-Sep-2025	Presentation	1.5
16-Sep-2025	Meeting Attendance & Prep	0.5
18-Sep-2025	Meeting Attendance & Prep	0.5
15-Sep-2025	General Project Work	1
19-Sep-2025	General Project Work	0.5
17-Sep-2025	General Project Work	0.5
23-Sep-2025	General Project Work	0.5
24-Sep-2025	Meeting Attendance & Prep	1
25-Sep-2025	Meeting Attendance & Prep	0.5
25-Sep-2025	Writing	1
26-Sep-2025	Writing	2
27-Sep-2025	Writing	3
27-Sep-2025	Review & Editing	1
28-Sep-2025	Writing	3
29-Sep-2025	Writing	4
30-Sep-2025	Review & Editing	2
30-Sep-2025	Writing	4
30-Sep-2025	Meeting Attendance & Prep	0.5
2-Oct-2025	Meeting Attendance & Prep	0.5
2-Oct-2025	Review & Editing	0.5
9-Oct-2025	Meeting Attendance & Prep	0.5
20-Oct-2025	Writing	1
20-Oct-2025	Meeting Attendance & Prep	1
5-Nov-2025	Meeting Attendance & Prep	0.5
9-Nov-2025	Writing	0.5
10-Nov-2025	Writing	1
17-Nov-2025	Writing	4
18-Nov-2025	Research & Data Review	1
18-Nov-2025	Writing	4
19-Nov-2025	Meeting Attendance & Prep	1
19-Nov-2025	Writing	4
20-Nov-2025	Writing	5
21-Nov-2025	Review & Editing	4
25-Nov-2025	Meeting Attendance & Prep	0.5
25-Nov-2025	Meeting Attendance & Prep	1
13-Jan-2026	Meeting Attendance & Prep	1
13-Jan-2026	General Project Work	1
20-Jan-2026	General Project Work	2
21-Jan-2026	Meeting Attendance & Prep	1.5
21-Jan-2026	Writing	2
24-Jan-2026	Writing	2
2-Feb-2026	General Project Work	2

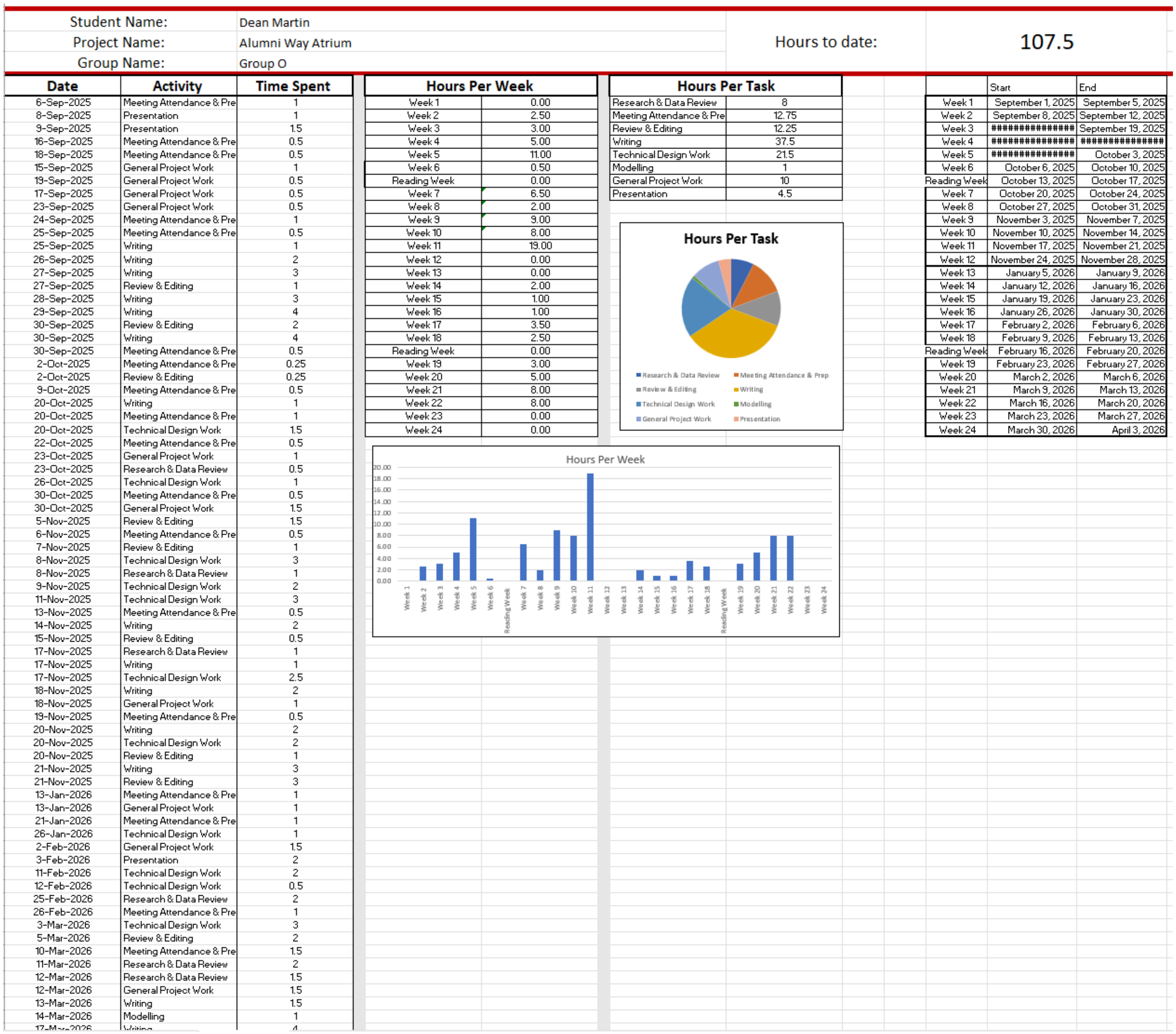
Hours Per Week	
Week 1	0.00
Week 2	2.50
Week 3	3.00
Week 4	5.00
Week 5	11.50
Week 6	0.50
Reading Week	0.00
Week 7	2.00
Week 8	0.00
Week 9	0.50
Week 10	1.00
Week 11	23.00
Week 12	1.50
Week 13	0.00
Week 14	2.00
Week 15	5.50
Week 16	0.00
Week 17	3.00
Week 18	1.50
Reading Week	16.50
Week 19	7.50
Week 20	2.50
Week 21	5.50
Week 22	2.00
Week 23	0.00
Week 24	0.00

Hours Per Task	
Research & Data Review	1
Meeting Attendance & Prep	12.5
Review & Editing	9.5
Writing	75
Technical Design Work	1
Modelling	0.5
General Project Work	8
Presentation	3.5

	Start	End
Week 1	September 1, 2025	September 5, 2025
Week 2	September 8, 2025	September 12, 2025
Week 3	September 15, 2025	September 19, 2025
Week 4	September 22, 2025	September 26, 2025
Week 5	September 29, 2025	October 3, 2025
Week 6	October 6, 2025	October 10, 2025
Reading Week	October 13, 2025	October 17, 2025
Week 7	October 20, 2025	October 24, 2025
Week 8	October 27, 2025	October 31, 2025
Week 9	November 3, 2025	November 7, 2025
Week 10	November 10, 2025	November 14, 2025
Week 11	November 17, 2025	November 21, 2025
Week 12	November 24, 2025	November 28, 2025
Week 13	January 5, 2026	January 9, 2026
Week 14	January 12, 2026	January 16, 2026
Week 15	January 19, 2026	January 23, 2026
Week 16	January 26, 2026	January 30, 2026
Week 17	February 2, 2026	February 6, 2026
Week 18	February 9, 2026	February 13, 2026
Reading Week	February 16, 2026	February 20, 2026
Week 19	February 23, 2026	February 27, 2026
Week 20	March 2, 2026	March 6, 2026
Week 21	March 9, 2026	March 13, 2026
Week 22	March 16, 2026	March 20, 2026
Week 23	March 23, 2026	March 27, 2026
Week 24	March 30, 2026	April 3, 2026

Figure 22: Timesheet for Keinar Widjaja

Dean:



Student Name:	Dean Martin
Project Name:	Alumni Way Atrium
Group Name:	Group O

Hours to date: 107.5

Date	Activity	Time Spent
6-Sep-2025	Meeting Attendance & Pre	1
8-Sep-2025	Presentation	1
9-Sep-2025	Presentation	1.5
16-Sep-2025	Meeting Attendance & Pre	0.5
18-Sep-2025	Meeting Attendance & Pre	0.5
15-Sep-2025	General Project Work	1
19-Sep-2025	General Project Work	0.5
17-Sep-2025	General Project Work	0.5
23-Sep-2025	General Project Work	0.5
24-Sep-2025	Meeting Attendance & Pre	1
25-Sep-2025	Meeting Attendance & Pre	0.5
25-Sep-2025	Writing	1
26-Sep-2025	Writing	2
27-Sep-2025	Writing	3
27-Sep-2025	Review & Editing	1
28-Sep-2025	Writing	3
29-Sep-2025	Writing	4
30-Sep-2025	Review & Editing	2
30-Sep-2025	Writing	4
30-Sep-2025	Meeting Attendance & Pre	0.5
2-Oct-2025	Meeting Attendance & Pre	0.25
2-Oct-2025	Review & Editing	0.25
9-Oct-2025	Meeting Attendance & Pre	0.5
20-Oct-2025	Writing	1
20-Oct-2025	Meeting Attendance & Pre	1
20-Oct-2025	Technical Design Work	1.5
22-Oct-2025	Meeting Attendance & Pre	0.5
23-Oct-2025	General Project Work	1
23-Oct-2025	Research & Data Review	0.5
26-Oct-2025	Technical Design Work	1
30-Oct-2025	Meeting Attendance & Pre	0.5
30-Oct-2025	General Project Work	1.5
5-Nov-2025	Review & Editing	1.5
6-Nov-2025	Meeting Attendance & Pre	0.5
7-Nov-2025	Review & Editing	1
8-Nov-2025	Technical Design Work	3
8-Nov-2025	Research & Data Review	1
9-Nov-2025	Technical Design Work	2
11-Nov-2025	Technical Design Work	3
13-Nov-2025	Meeting Attendance & Pre	0.5
14-Nov-2025	Writing	2
15-Nov-2025	Review & Editing	0.5
17-Nov-2025	Research & Data Review	1
17-Nov-2025	Writing	1
17-Nov-2025	Technical Design Work	2.5
18-Nov-2025	Writing	2
18-Nov-2025	General Project Work	1
19-Nov-2025	Meeting Attendance & Pre	0.5
20-Nov-2025	Writing	2
20-Nov-2025	Technical Design Work	2
20-Nov-2025	Review & Editing	1
21-Nov-2025	Writing	3
21-Nov-2025	Review & Editing	3
13-Jan-2026	Meeting Attendance & Pre	1
13-Jan-2026	General Project Work	1
21-Jan-2026	Meeting Attendance & Pre	1
26-Jan-2026	Technical Design Work	1
2-Feb-2026	General Project Work	1.5
3-Feb-2026	Presentation	2
11-Feb-2026	Technical Design Work	2
12-Feb-2026	Technical Design Work	0.5
25-Feb-2026	Research & Data Review	2
26-Feb-2026	Meeting Attendance & Pre	1
3-Mar-2026	Technical Design Work	3
5-Mar-2026	Review & Editing	2
10-Mar-2026	Meeting Attendance & Pre	1.5
11-Mar-2026	Research & Data Review	2
12-Mar-2026	Research & Data Review	1.5
12-Mar-2026	General Project Work	1.5
13-Mar-2026	Writing	1.5
14-Mar-2026	Modelling	1
17-Mar-2026	Writing	4

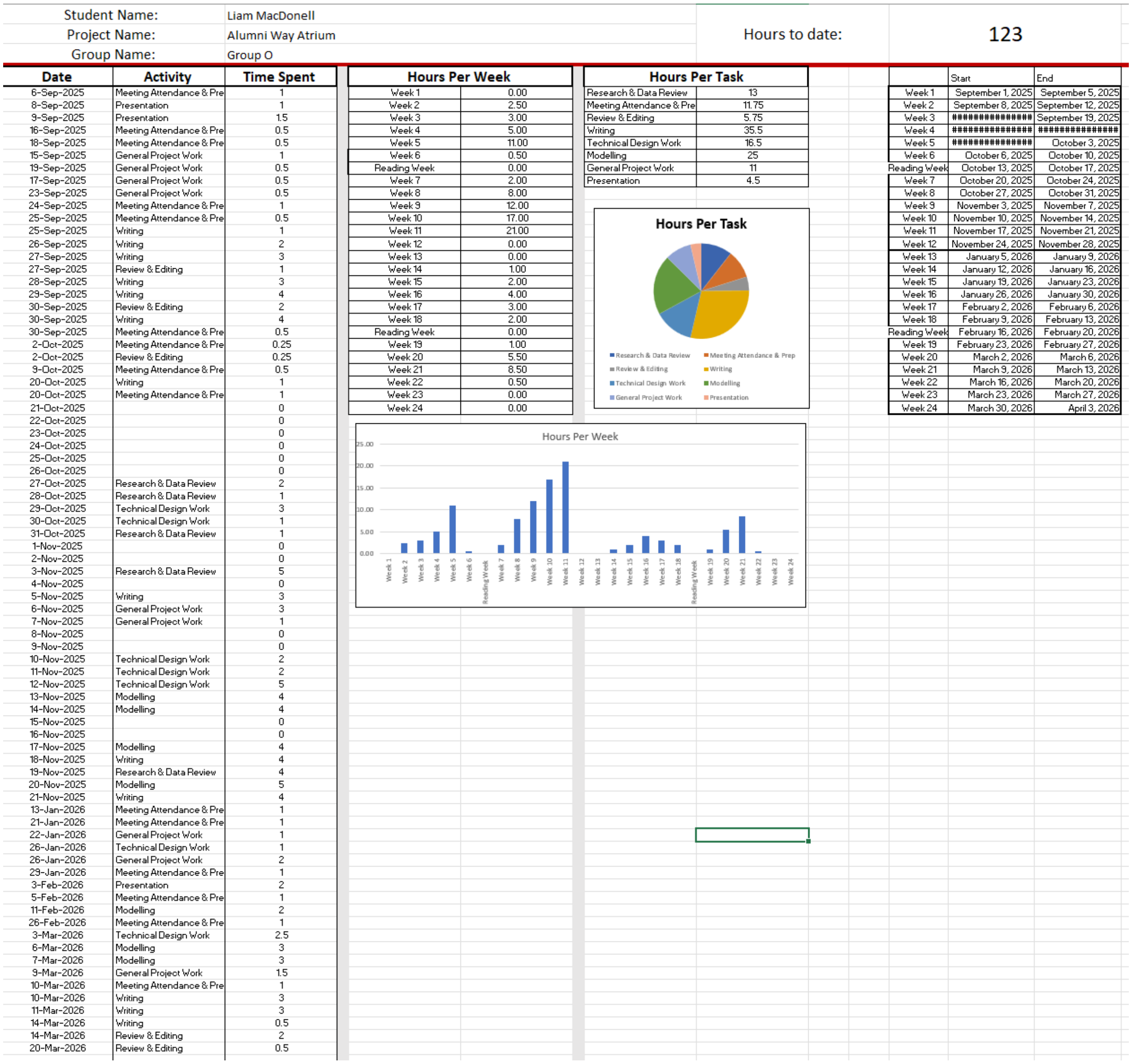
Hours Per Week	
Week 1	0.00
Week 2	2.50
Week 3	3.00
Week 4	5.00
Week 5	11.00
Week 6	0.50
Reading Week	0.00
Week 7	6.50
Week 8	2.00
Week 9	9.00
Week 10	8.00
Week 11	19.00
Week 12	0.00
Week 13	0.00
Week 14	2.00
Week 15	1.00
Week 16	1.00
Week 17	3.50
Week 18	2.50
Reading Week	0.00
Week 19	3.00
Week 20	5.00
Week 21	8.00
Week 22	8.00
Week 23	0.00
Week 24	0.00

Hours Per Task	
Research & Data Review	8
Meeting Attendance & Pre	12.75
Review & Editing	12.25
Writing	37.5
Technical Design Work	21.5
Modelling	1
General Project Work	10
Presentation	4.5

	Start	End
Week 1	September 1, 2025	September 5, 2025
Week 2	September 8, 2025	September 12, 2025
Week 3	###############	September 19, 2025
Week 4	###############	###############
Week 5	###############	October 3, 2025
Week 6	October 6, 2025	October 10, 2025
Reading Week	October 13, 2025	October 17, 2025
Week 7	October 20, 2025	October 24, 2025
Week 8	October 27, 2025	October 31, 2025
Week 9	November 3, 2025	November 7, 2025
Week 10	November 10, 2025	November 14, 2025
Week 11	November 17, 2025	November 21, 2025
Week 12	November 24, 2025	November 28, 2025
Week 13	January 5, 2026	January 9, 2026
Week 14	January 12, 2026	January 16, 2026
Week 15	January 19, 2026	January 23, 2026
Week 16	January 26, 2026	January 30, 2026
Week 17	February 2, 2026	February 6, 2026
Week 18	February 9, 2026	February 13, 2026
Reading Week	February 16, 2026	February 20, 2026
Week 19	February 23, 2026	February 27, 2026
Week 20	March 2, 2026	March 6, 2026
Week 21	March 9, 2026	March 13, 2026
Week 22	March 16, 2026	March 20, 2026
Week 23	March 23, 2026	March 27, 2026
Week 24	March 30, 2026	April 3, 2026

Figure 23: Timesheet for Dean Martin

Liam:



Student Name:	Liam MacDonell
Project Name:	Alumni Way Atrium
Group Name:	Group O

Hours to date: 123

Date	Activity	Time Spent
6-Sep-2025	Meeting Attendance & Pre	1
8-Sep-2025	Presentation	1
9-Sep-2025	Presentation	1.5
16-Sep-2025	Meeting Attendance & Pre	0.5
18-Sep-2025	Meeting Attendance & Pre	0.5
15-Sep-2025	General Project Work	1
19-Sep-2025	General Project Work	0.5
17-Sep-2025	General Project Work	0.5
23-Sep-2025	General Project Work	0.5
24-Sep-2025	Meeting Attendance & Pre	1
25-Sep-2025	Meeting Attendance & Pre	0.5
25-Sep-2025	Writing	1
26-Sep-2025	Writing	2
27-Sep-2025	Writing	3
27-Sep-2025	Review & Editing	1
28-Sep-2025	Writing	3
29-Sep-2025	Writing	4
30-Sep-2025	Review & Editing	2
30-Sep-2025	Writing	4
30-Sep-2025	Meeting Attendance & Pre	0.5
2-Oct-2025	Meeting Attendance & Pre	0.25
2-Oct-2025	Review & Editing	0.25
9-Oct-2025	Meeting Attendance & Pre	0.5
20-Oct-2025	Writing	1
20-Oct-2025	Meeting Attendance & Pre	1
21-Oct-2025		0
22-Oct-2025		0
23-Oct-2025		0
24-Oct-2025		0
25-Oct-2025		0
26-Oct-2025		0
27-Oct-2025	Research & Data Review	2
28-Oct-2025	Research & Data Review	1
29-Oct-2025	Technical Design Work	3
30-Oct-2025	Technical Design Work	1
31-Oct-2025	Research & Data Review	1
1-Nov-2025		0
2-Nov-2025		0
3-Nov-2025	Research & Data Review	5
4-Nov-2025		0
5-Nov-2025	Writing	3
6-Nov-2025	General Project Work	3
7-Nov-2025	General Project Work	1
8-Nov-2025		0
9-Nov-2025		0
10-Nov-2025	Technical Design Work	2
11-Nov-2025	Technical Design Work	2
12-Nov-2025	Technical Design Work	5
13-Nov-2025	Modelling	4
14-Nov-2025	Modelling	4
15-Nov-2025		0
16-Nov-2025		0
17-Nov-2025	Modelling	4
18-Nov-2025	Writing	4
19-Nov-2025	Research & Data Review	4
20-Nov-2025	Modelling	5
21-Nov-2025	Writing	4
13-Jan-2026	Meeting Attendance & Pre	1
21-Jan-2026	Meeting Attendance & Pre	1
22-Jan-2026	General Project Work	1
26-Jan-2026	Technical Design Work	1
26-Jan-2026	General Project Work	2
29-Jan-2026	Meeting Attendance & Pre	1
3-Feb-2026	Presentation	2
5-Feb-2026	Meeting Attendance & Pre	1
11-Feb-2026	Modelling	2
26-Feb-2026	Meeting Attendance & Pre	1
3-Mar-2026	Technical Design Work	2.5
6-Mar-2026	Modelling	3
7-Mar-2026	Modelling	3
9-Mar-2026	General Project Work	1.5
10-Mar-2026	Meeting Attendance & Pre	1
10-Mar-2026	Writing	3
11-Mar-2026	Writing	3
14-Mar-2026	Writing	0.5
14-Mar-2026	Review & Editing	2
20-Mar-2026	Review & Editing	0.5

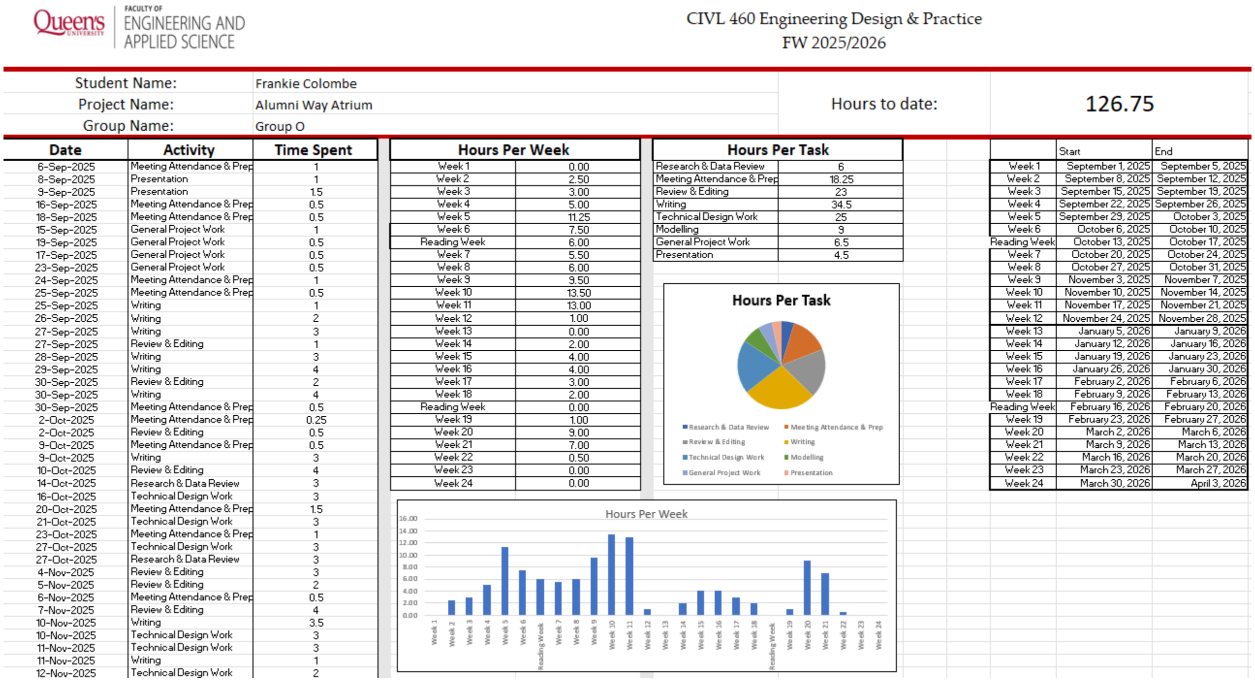
Hours Per Week	
Week 1	0.00
Week 2	2.50
Week 3	3.00
Week 4	5.00
Week 5	11.00
Week 6	0.50
Reading Week	0.00
Week 7	2.00
Week 8	8.00
Week 9	12.00
Week 10	17.00
Week 11	21.00
Week 12	0.00
Week 13	0.00
Week 14	1.00
Week 15	2.00
Week 16	4.00
Week 17	3.00
Week 18	2.00
Reading Week	0.00
Week 19	1.00
Week 20	5.50
Week 21	8.50
Week 22	0.50
Week 23	0.00
Week 24	0.00

Hours Per Task	
Research & Data Review	13
Meeting Attendance & Pre	11.75
Review & Editing	5.75
Writing	35.5
Technical Design Work	16.5
Modelling	25
General Project Work	11
Presentation	4.5

	Start	End
Week 1	September 1, 2025	September 5, 2025
Week 2	September 8, 2025	September 12, 2025
Week 3	###############	September 19, 2025
Week 4	###############	###############
Week 5	###############	October 3, 2025
Week 6	October 6, 2025	October 10, 2025
Reading Week	October 13, 2025	October 17, 2025
Week 7	October 20, 2025	October 24, 2025
Week 8	October 27, 2025	October 31, 2025
Week 9	November 3, 2025	November 7, 2025
Week 10	November 10, 2025	November 14, 2025
Week 11	November 17, 2025	November 21, 2025
Week 12	November 24, 2025	November 28, 2025
Week 13	January 5, 2026	January 9, 2026
Week 14	January 12, 2026	January 16, 2026
Week 15	January 19, 2026	January 23, 2026
Week 16	January 26, 2026	January 30, 2026
Week 17	February 2, 2026	February 6, 2026
Week 18	February 9, 2026	February 13, 2026
Reading Week	February 16, 2026	February 20, 2026
Week 19	February 23, 2026	February 27, 2026
Week 20	March 2, 2026	March 6, 2026
Week 21	March 9, 2026	March 13, 2026
Week 22	March 16, 2026	March 20, 2026
Week 23	March 23, 2026	March 27, 2026
Week 24	March 30, 2026	April 3, 2026

Figure 24: Timesheet for Liam MacDonell

Frankie:



CIVL 460 Engineering Design & Practice
FW 2025/2026

Student Name:	Frankie Colombe
Project Name:	Alumni Way Atrium
Group Name:	Group O

Hours to date: 126.75

Date	Activity	Time Spent
6-Sep-2025	Meeting Attendance & Prep	1
8-Sep-2025	Presentation	1
9-Sep-2025	Presentation	1.5
16-Sep-2025	Meeting Attendance & Prep	0.5
18-Sep-2025	Meeting Attendance & Prep	0.5
15-Sep-2025	General Project Work	1
19-Sep-2025	General Project Work	0.5
17-Sep-2025	General Project Work	0.5
23-Sep-2025	General Project Work	0.5
24-Sep-2025	Meeting Attendance & Prep	1
25-Sep-2025	Meeting Attendance & Prep	0.5
25-Sep-2025	Writing	1
26-Sep-2025	Writing	2
27-Sep-2025	Writing	3
27-Sep-2025	Review & Editing	1
28-Sep-2025	Writing	3
29-Sep-2025	Writing	4
30-Sep-2025	Review & Editing	2
30-Sep-2025	Writing	4
30-Sep-2025	Meeting Attendance & Prep	0.5
2-Oct-2025	Meeting Attendance & Prep	0.25
2-Oct-2025	Review & Editing	0.5
9-Oct-2025	Meeting Attendance & Prep	0.5
9-Oct-2025	Writing	3
10-Oct-2025	Review & Editing	4
14-Oct-2025	Research & Data Review	3
16-Oct-2025	Technical Design Work	3
20-Oct-2025	Meeting Attendance & Prep	1.5
21-Oct-2025	Technical Design Work	3
23-Oct-2025	Meeting Attendance & Prep	1
27-Oct-2025	Technical Design Work	3
27-Oct-2025	Research & Data Review	3
4-Nov-2025	Review & Editing	3
5-Nov-2025	Review & Editing	2
6-Nov-2025	Meeting Attendance & Prep	0.5
7-Nov-2025	Review & Editing	4
10-Nov-2025	Writing	3.5
10-Nov-2025	Technical Design Work	3
11-Nov-2025	Technical Design Work	3
11-Nov-2025	Writing	1
12-Nov-2025	Technical Design Work	2

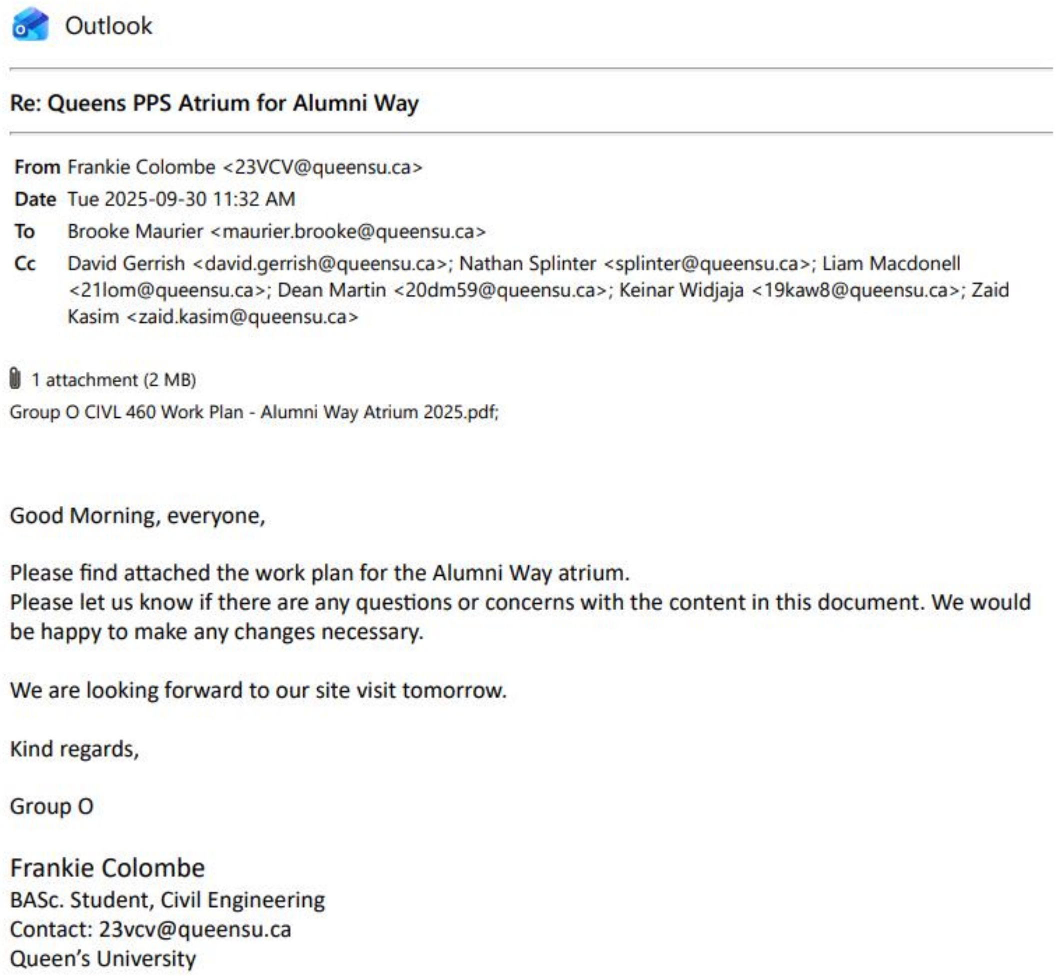
Hours Per Week	
Week 1	0.00
Week 2	2.50
Week 3	3.00
Week 4	5.00
Week 5	11.25
Week 6	7.50
Reading Week	6.00
Week 7	5.50
Week 8	6.00
Week 9	9.50
Week 10	13.50
Week 11	13.00
Week 12	1.00
Week 13	0.00
Week 14	2.00
Week 15	4.00
Week 16	4.00
Week 17	3.00
Week 18	2.00
Reading Week	0.00
Week 19	1.00
Week 20	9.00
Week 21	7.00
Week 22	0.50
Week 23	0.00
Week 24	0.00

Hours Per Task	
Research & Data Review	6
Meeting Attendance & Prep	18.25
Review & Editing	23
Writing	34.5
Technical Design Work	25
Modelling	9
General Project Work	6.5
Presentation	4.5

	Start	End
Week 1	September 1, 2025	September 5, 2025
Week 2	September 8, 2025	September 12, 2025
Week 3	September 15, 2025	September 19, 2025
Week 4	September 22, 2025	September 26, 2025
Week 5	September 29, 2025	October 3, 2025
Week 6	October 6, 2025	October 10, 2025
Reading Week	October 13, 2025	October 17, 2025
Week 7	October 20, 2025	October 24, 2025
Week 8	October 27, 2025	October 31, 2025
Week 9	November 3, 2025	November 7, 2025
Week 10	November 10, 2025	November 14, 2025
Week 11	November 17, 2025	November 21, 2025
Week 12	November 24, 2025	November 28, 2025
Week 13	January 5, 2026	January 9, 2026
Week 14	January 12, 2026	January 16, 2026
Week 15	January 19, 2026	January 23, 2026
Week 16	January 26, 2026	January 30, 2026
Week 17	February 2, 2026	February 6, 2026
Week 18	February 9, 2026	February 13, 2026
Reading Week	February 16, 2026	February 20, 2026
Week 19	February 23, 2026	February 27, 2026
Week 20	March 2, 2026	March 6, 2026
Week 21	March 9, 2026	March 13, 2026
Week 22	March 16, 2026	March 20, 2026
Week 23	March 23, 2026	March 27, 2026
Week 24	March 30, 2026	April 3, 2026

Figure 25: Timesheet for Frankie Colombe

Appendix F – Acknowledgement Email



Re: Queens PPS Atrium for Alumni Way

From Frankie Colombe <23VCV@queensu.ca>
Date Tue 2025-09-30 11:32 AM
To Brooke Maurier <maurier.brooke@queensu.ca>
Cc David Gerrish <david.gerrish@queensu.ca>; Nathan Splinter <splinter@queensu.ca>; Liam Macdonell <21lom@queensu.ca>; Dean Martin <20dm59@queensu.ca>; Keinar Widjaja <19kaw8@queensu.ca>; Zaid Kasim <zaid.kasim@queensu.ca>

1 attachment (2 MB)
Group O CIVL 460 Work Plan - Alumni Way Atrium 2025.pdf;

Good Morning, everyone,

Please find attached the work plan for the Alumni Way atrium.
Please let us know if there are any questions or concerns with the content in this document. We would be happy to make any changes necessary.

We are looking forward to our site visit tomorrow.

Kind regards,

Group O

Frankie Colombe
BASc. Student, Civil Engineering
Contact: 23vcv@queensu.ca
Queen’s University

Figure 26: Acknowledgement email between Group O and Queen's Facilities, enclosing the Work Plan which serves as a term of reference and a binding agreement