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100 Eton Road, Lindfield

LINDFIELD LEARNING VILLAGE

BUSHFIRE EVACUATION ANALYSIS

REPORT 2018/321 R4.0

REVISION CONTROL

Report No.	Issue Date	Report Details		
2018/321 R4.0	02/09/2019	Description:	Original Report	
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		Verified by:	Harriet Peel (Senior Fire Safety Engineer)	
		Approved and Issued by:	Carlos Quaglia (Managing Director, C10 - BPB0334)	
2018/321 DRAFT R4.0	23/07/19	Description:	Draft Report	
2018/321 DRAFT R4.0	18/07/19	Description:	Draft Report	

EXECUTIVE SUMMARY

This Fire Engineering Report relates to the Bushfire Evacuation Strategy of the proposed re-development of the Lindfield Learning Village at 100 Eton Road, Lindfield. Stephen Grubits & Associates Pty Ltd prepared this report at the request of NSW Department of Education and School Infrastructure NSW to support the preparation of a Bushfire Design Report.

Lindfield Learning Village is situated at the former University of Technology Sydney site at 100 Eton Road, Lindfield. The project consists of converting the existing university buildings to school facilities for students from Kindergarten to Year 12.

The proposed school is located on bushfire prone land. The purpose of this report is to document the outcome of an internal evacuation assessment of the building. The occupants within the building are to egress into a refuge area under a bushfire scenario. This assessment considers a scenario when all three stages of the building have been completed.

This report is not a performance-based solution assessment. It is expected that the Bushfire Consultant would utilise the timeframes presented in this report as an input to form part of a Bushfire Evacuation Plan within the Bushfire Design Report.

As an outcome of this engineering assessment, it has been demonstrated that 2520 occupants are expected to move into the refuge area, namely the Auditorium and BAL-FZ area in 650 s with the given conditions represented in this model. The above-mentioned time only considers the movement phase of the evacuation. Cue phase and pre-movement phase is not considered in this report and is to be appropriately determined by a bushfire consultant as part of the Evacuation Plan.

TABLE OF CONTENTS

LIST OF ACRONYMS

AS	Australian Standard
BCA	National Construction Code Series Volume One, Building Code of Australia
IFEG	International Fire Engineering Guidelines
SGA	Stephen Grubits & Associates Pty Ltd

1. INTRODUCTION

This Fire Engineering Report relates to the Bushfire Evacuation Strategy of the proposed re-development of the Lindfield Learning Village at 100 Eton Road, Lindfield. Stephen Grubits & Associates Pty Ltd prepared this report at the request of NSW Department of Education and School Infrastructure NSW to support the preparation of a Bushfire Design Report.

Lindfield Learning Village is situated at the former University of Technology Sydney site at 100 Eton Road, Lindfield. The project consists of converting the existing university buildings to school facilities for students from Kindergarten to Year 12.

The proposed school is located on bushfire prone land. The purpose of this report is to document the outcome of an internal evacuation assessment of the building. The occupants within the building are to egress into a refuge area under a bushfire scenario. This assessment considers a scenario when all three stages of the building has been complete.

2. LIMITATIONS & ASSUMPTIONS

1. The scope of this report is limited to the technical assessment to quantify the expected time for occupants to egress into a refuge space during a bushfire event. The assessment is not applicable to any other part of the wider project.
2. This report is not a performance-based solution in itself. It is expected that a Bushfire Consultant would utilise the timeframes in this report to form part of a Bushfire Design Report and inform the Evacuation Plan.
3. This report analyses a potential bushfire event, however it does not aim to investigate and quantify the probability associated with such an event.
4. Stephen Grubits & Associates have not specifically reviewed AS 3959 for applicability to the design of the subject building. It is assumed that the aforementioned standard has been agreed upon by stakeholders as representing the accepted level of safety, and that the subject building meets the requirements of these standards.
5. This Evacuation Plan does not consider and may not be appropriate for fires within the building.

3. DESIGN DOCUMENTATION

The following drawing sets have been reviewed for the preparation of this report. Refer to Appendix A for the drawings.

Table 1 – Design Documentation (Drawings)

Title / Description	Drawing No.	Revision	Issued By	Issued Date
DA-2-000 COVER SHEET	DA-2-000	A	DesignInc Sydney	12/06/2019
DA-2-100 SITE PLAN	DA-2-100	A	DesignInc Sydney	12/06/2019
DA-2-101 INDICATIVE CONSTRUCTION TRAFFIC MANAGEMENT PLAN	DA-2-101	A	DesignInc Sydney	12/06/2019
DA-2-200 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 0	DA-2-200	A	DesignInc Sydney	12/06/2019
DA-2-201 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 1	DA-2-201	A	DesignInc Sydney	12/06/2019
DA-2-202 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 2	DA-2-202	A	DesignInc Sydney	12/06/2019
DA-2-203 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 3	DA-2-203	A	DesignInc Sydney	12/06/2019
DA-2-204 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 4	DA-2-204	A	DesignInc Sydney	12/06/2019
DA-2-205 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 5	DA-2-205	A	DesignInc Sydney	12/06/2019
DA-2-206 PHASE 2 & 3 – PROPOSED FLOOR PLAN LEVEL 6	DA-2-206	A	DesignInc Sydney	12/06/2019
DA-2-300 NORTH & SOUTH BUILDING ELEVATION	DA-2-300	A	DesignInc Sydney	12/06/2019
DA-2-301 EAST & WEST BUILDING ELEVATION	DA-2-301	A	DesignInc Sydney	12/06/2019

4. BUILDING DESCRIPTION

4.1. GENERAL CHARACTERISTICS

Lindfield Learning Village is situated at the former University of Technology Sydney site at 100 Eton Road, Lindfield. The project consists of converting the existing university buildings to school facilities for students from Year 1 to Year 12, as well as administration and support facility. There are three stages to the conversion and construction works, namely Stages 1, 2 and 3. This report relates to all three stages.

The development is proposed to contain classrooms, learning rooms, offices, lecture theatres and an Auditorium.

4.2. BCA REFERENCE CRITERIA

For the purposes of information, the following BCA criteria have been identified to be applicable to the subject building based on the BCA report by Modern Building Certifiers (BCA Design Compliance Report, dated 12th June 2019):

Table 2 – BCA Reference Criteria

Building Classification	Class 5, 7a, 7b, 9b
Rise in Storeys	Max. 6
Type of Construction	A
Effective Height	<25 m

4.3. OCCUPANT CHARACTERISTICS

Occupants within the building would comprise of students, staff and visitors. It is considered that occupants would have a range of mobility levels. Characteristics are as follows:

- Staff and students are expected to be awake and fully conscious, and familiar with the building and its layout.
- Visitors are expected to be awake and fully conscious, however they may not be familiar with the building and its layout. Visitors are likely to be accompanied by staff in the event of emergency who will be familiar with the building and its layout.
- A number of teachers/staff assumed to have emergency training, including specific training on the evacuation plan for a bushfire event.

5. METHODOLOGY

5.1. CALCULATION

Calculation method implemented in this assessment to identify the total evacuation time has been adopted from Sub-system E, Chapter 2.8 of the International Fire Engineering Guidelines (IFEG) (1).

In order to determine the overall time required for occupants to reach a place of safety, any analysis must consider the time that an occupant requires to become aware for a fire alarm or other cue, the time to respond to an alarm or cue of a fire event as well as the required time for that occupant to travel to a safe place. These phases form Required Safe Egress Time (RSET) and are described below.

- Cue phase, which is the time taken from effective ignition of a fire to the time of a cue to occupants that indicates the possible occurrence of a fire. Cues alerting occupants to the occurrence of a fire would generally be sight or smell of smoke or fire and alarm sounds. In the event of a fire from outside of the building (e.g. bushfire), different response to the hazard is expected. The cue phase is to be appropriately determined by a bushfire consultant.
- Pre-movement phase, which extends from the occurrence of cue to the time when the movement of evacuating occupants from the affected areas has started. This period covers the time for occupants to assimilate the cue, resolve any ambiguity, undertake pre-evacuation actions such as gathering belongings, and commence evacuation. The degree of training and familiarity with the surroundings, as well as the general nature of the population, have an impact on reaction time.
- Movement phase, extends from the time occupants initiate movement until a safe place has been reached. This phase can be calculated on the basis of human walking speed affected by crowding.

The assessment in this report only simulates the movement phase of the occupant evacuation within the subject building. Cue phase and pre-movement phase is not considered in this report and is to be appropriately determined by a bushfire consultant as part of the Evacuation Plan.

A description of a methodology used to estimate the phases named above can be found in Appendix D.

To predict the movement phase of the occupant evacuation, a flow model known as 'Pathfinder' egress simulation software by Thunderhead Engineering USA (2) has been used.

5.2. FIRE HAZARDS AND SCENARIOS

Fire hazards may be present within or outside the subject building. Fire hazards and scenarios within the building are not addressed within this report. In general, the internal fire hazards and management is to be addressed in the fire engineering design for the buildings (documented within the Fire Engineering report for the compliance with the BCA).

It is considered that the worst-credible fire scenario necessitating occupants to take refuge within the building (to which this report is applicable) is a bushfire outside the building due to nature of location of the subject building.

The fire scenario considered in this report is a bushfire from Lane Cove National Park located to the periphery of the East, South and West boundaries of the subject building.

(1) International Fire Engineering Guidelines – Australian Building Codes Board, 2005, Edition 2005

(2) Pathfinder 2016 – Thunderhead Engineering Consultants Inc,

6. FIRE ENGINEERING BRIEF

6.1. GENERAL

The Fire Engineering Brief (FEB) is a documented process that defines the scope of work for the engineering analysis. Its purpose is to set down the basis, as agreed by all the relevant stakeholders, on which the engineering analysis will be undertaken. This includes agreement on the objectives and analysis methods.

6.2. PROJECT STAKEHOLDERS

The relevant stakeholders for the project are as follows:

Table 3 – Project Stakeholders

Stakeholders Role	Company
Client/Owner	NSW Department of Education
Architect	DesignInc
Bushfire Consultant	BlackAsh Bushfire Consulting
Fire Brigade	Rural Fire Services NSW
Fire Safety Engineer	Stephen Grubits & Associates

6.3. FEB PROCESS

The FEB was conducted by way of the following:

1. Briefing from the client to Stephen Grubits & Associates with regards to the technical issues and client objectives relating to the subject building.
2. Meetings amongst stakeholders of the project with regards to the subject building's bushfire evacuation strategy, including expected school population, bushfire exposure and location of students.
3. In-house discussions between key staff at Stephen Grubits & Associates with regards to the proposed objectives.

7. INTERNAL EVACUATION ASSESSMENT

7.1. INTRODUCTION

The internal evacuation is expected to occur within the building. In other words, occupants are not expected to egress externally to an open space or to a road. This is due to the potential risk of high radiant heat flux from a bushfire which may adversely impact occupants from egressing i.e. causing burn.

The number of students enrolled in the school is limited to 2000 students. However, for the purpose of modelling and considering conservatism into assessment, 520 occupants have been added who represent teachers, staff members, and visitors to the main building of the school. The total value of 2520 represents occupants in the main building of the school.

In addition, the simulation considers occupants of intermittent nature in the gymnasium (e.g. visitors from other schools), who may be occupying the gymnasium of the subject premises on a daily or weekly basis during school hours. In the event of bushfire, 300 additional occupants in the gymnasium (in addition to 2,520 occupants in the main building) are to evacuate into the main building when considered necessary. The simulation will assess whether these additional occupants are able to travel to a refuge area without adversely impacting the normal internal evacuation (e.g. cause of crowding).

Therefore, the simulation of internal evacuation determines the time taken for the movement phase of internal evacuation of 2520 occupants within the main building as well as 300 additional occupants egressing from the gymnasium to a refuge area in the main building.

7.2. OBJECTIVE

The objective of this internal evacuation assessment is to determine the travel time to the refuge area from all of the normally occupied parts of the building.

7.3. METHODOLOGY

The approach used to formulate this fire engineering assessment is as follows:

Table 4 – Methodology

Assessment Method	Other verification methods accepted by appropriate authority
Type of Analysis	Quantitative, Deterministic

Pathfinder [3] software developed by Thunderhead Engineering USA has been used to model internal evacuation. Refer to Appendix E for further information on '*Pathfinder*'.

7.4. EGRESS ANALYSIS

7.4.1. General

In the event of a bushfire emergency, where external evacuation to a safe place outside the school is not possible, all occupants within the building are expected to evacuate to the designated refuge area, which is the Auditorium (that interconnects from Level 4 to Level 6) and Level 5 BAL-FZ areas, namely the Cafeteria and Office Area. Moreover, the occupants in the Gymnasium are to evacuate into the main building via the 'external bridge' when necessary. The refuge areas are marked on the drawings in Appendix A.

3 *Pathfinder 2017*– Thunderhead Engineering Consultants Inc – 2017.

The egress analysis is intended to inform the internal evacuation plan. The model is based on routed and controlled plan intended for optimal evacuation time. It is expected that these routes are included in the bushfire training provided to teachers/staff and that teachers/staff guide students along the evacuation routes whenever possible. The occupants during evacuation are assumed to adhere to the evacuation plan to egress to the refuge area within the time as predicted in the model.

For occupants whose ability to evacuate promptly may be impaired (due to injury or disability), a specific plan for these occupants must be developed outside of this report.

7.4.2. Inputs & Considerations

It is considered that inputs to a simulation are essential in order to obtain a reliable and credible outcome. The following inputs have been obtained from relevant stakeholders and research:

- The simulation model has been based on Computer Aided-Design (CAD) of the subject building provided by the architect of this project. As such, it is considered to be a realistic model in regards to dimension of the building, width of doors and the height of each storey has been reflected in the simulation.
- There are no more than 30 students per classroom and a teacher/staff in charge of these students. The number of teacher/staff per class may be increased for younger students (e.g. number of teachers may be more than one for Kindergarten and junior years).
- Studies suggest that an average unrestricted walking speed is 1.25 m/s [(4)]. For the purpose of the analysis, a slower average walking speed of 1.0 m/s has been used for conservatism.
- The movement speed of occupant when going up or down the stair is reduced to a fraction of their level travel speed based on the incline of the stairway.
- The flow and velocity of occupant passing through a door may be affected by the width of the door and the density of population requiring to pass through the door.
- The evacuation is to immediately begin on Level 1 to Level 3 of the main building where occupants on Level 1 to Level 3 must be advised to travel to the entrance to the Auditorium on Level 4 and approximately 200 students (or 7 designated classrooms) located South-East of Level 3 are to be selected by a relevant authority to seek refuge in Level 6 Auditorium area.
- In order to minimise the impact of crowding, occupants on Level 4 to Level 6 are advised to begin their evacuation 400 seconds (or 6 min 40 s) after occupants on Level 1 to Level 3 have started to evacuate. These occupants on Level 4 to Level 6 are advised to travel to Level 5 BAL-FZ area (Cafeteria and Office Area on Level 5).
- The maximum permissible number of occupants in a refuge area has been estimated in accordance with Table D1.13 of the BCA 2019 by calculating the approximate floor area from architectural drawings. It is expected that occupants would be standing in the refuge area in an orderly manner and therefore, 0.3 m^2 per person (the area per person prescribed for 'Standing Viewing Area') is considered appropriate as a minimum floor area per person. However, considering practicability, the likelihood of furniture and the need for occupants to be able to move swiftly out of the refuge when directed, the maximum permissible number of occupants allowed in a refuge area for the purpose of the egress model has been determined to be lower than what has been prescribed in the BCA DTS Provisions to allow comfortable room space between occupants. Where fixed seatings are available, number of seats will determine the maximum occupant capacity of that area. Table 5 outlines the maximum permissible number of occupants in each refuge area.

[4] G.Proulx, "Movement of People: The Evacuation Timing", Chapter 13 in SFPE Handbook of Fire Protection Engineering, 3rd Edition, National Fire Protection Association and the Society of Fire Protection Engineers, U.S.A, 2002 – p.3-342 – 3-359.

- The gymnasium is expected to be occupied on a daily basis by students enrolled at Lindfield Learning Village (i.e. Physical Education classes or competitive sports), or as conservatively assumed by the model, some additional occupants are expected from other schools or visitors. Occupants from the gymnasium are to cross the 'external bridge' to the refuge area in the main building if deemed safe to do so by a relevant authority.

The relevant inputs of the model are tabulated in Table 5.

<table>
<tr><th colspan="2">Pathfinder Input</th><th colspan="2">Input Value</th></tr>
<tr><td rowspan="7">Number of occupants (Refer to Appendix B)</td><td>Level 1</td><td colspan="2">270</td></tr>
<tr><td>Level 2</td><td colspan="2">630</td></tr>
<tr><td>Level 3</td><td colspan="2">570</td></tr>
<tr><td>Level 4</td><td colspan="2">680</td></tr>
<tr><td>Level 5</td><td colspan="2">290</td></tr>
<tr><td>Level 6</td><td colspan="2">80</td></tr>
<tr><td>Gymnasium</td><td colspan="2">300*</td></tr>
<tr><td rowspan="7">Occupant destination (Refer to drawings in Appendix A)</td><td>Level 1</td><td colspan="2">Go-to "Auditorium (Level 4) – Stage"</td></tr>
<tr><td>Level 2</td><td colspan="2">Go-to "Auditorium (Level 4) – Stage, Lower Seatings & Auditorium (Level 5) - Upper Seatings"</td></tr>
<tr><td>Level 3</td><td colspan="2">Go-to "Auditorium (Level 4) – Stage, Lower Seatings, Auditorium (Level 5) - Upper Seatings & Auditorium (Level 6)"</td></tr>
<tr><td>Level 4</td><td colspan="2">Go-to "BAL-FZ (Cafeteria & Office Area)"</td></tr>
<tr><td>Level 5</td><td colspan="2">Go-to "BAL-FZ (Cafeteria & Office Area)"</td></tr>
<tr><td>Level 6</td><td colspan="2">Go-to "BAL-FZ (Cafeteria & Office Area)"</td></tr>
<tr><td>Gymnasium</td><td colspan="2">Go-to "BAL-FZ (Cafeteria)"</td></tr>
<tr><td colspan="2">Movement speed (level surface)</td><td colspan="2">1 m/s</td></tr>
<tr><td colspan="2">Body Shape</td><td colspan="2">Cylinder: shoulder width = 45.58cm</td></tr>
<tr><td rowspan="3">Maximum Permissible Capacity of Occupants</td><td>Level 4 – BAL-FZ Auditorium Stage</td><td>Total Floor Area ≈ 350 m^2</td><td>Maximum permissible in the model: 570</td></tr>
<tr><td>Level 4 – BAL-FZ Auditorium Lower Seatings</td><td>As per number of seats</td><td>Maximum permissible in the model: 440</td></tr>
<tr><td>Level 5 – BAL-FZ Auditorium</td><td>As per number of seats</td><td>Maximum permissible in the model: 230</td></tr>
</table>

	Upper Seatings		
	Level 6 – BAL-FZ Auditorium	As per number of seats	Maximum permissible in the model: 200
	Level 5 – BAL-FZ (Office Area)	Total Floor Area ≈ 450 m^2	Maximum permissible in the model: 280
	Level 5 – BAL-FZ (Cafeteria Area)	Total Floor Area ≈ 1100 m^2	Maximum permissible in the model: 800 (+ 300 from the gymnasium)

Table 5 – Inputs to Pathfinder Software

*Note: Input value of additional 300 occupants represent people occupying the gymnasium at the time of evacuation.

7.4.3. Simulation Output

The Pathfinder simulation has demonstrated that all occupants would reach the refuge area in 650 s with the inputs and considerations outlined in the previous section. The results of modelling are shown in Appendix C.

7.5. RECOMMENDATIONS

The simulation has demonstrated that internal evacuation would take approximately 650 s to evacuate 2520 occupants in various rooms of the 7 storeys building to the refuge areas (Auditorium (that interconnects from Level 4 to Level 6) as well as BAL-FZ areas on Level 5). Moreover, it has been determined that additional 300 occupants in the gymnasium are not likely to adversely impact the evacuation of the main building. The above time only considers the movement phase of the evacuation.

The recommended evacuation plans are shown in Appendix F. It is recommended that occupants adhere to the evacuation plans to achieve similar travel time as the evacuation plans reflect what has been considered in the analysis and the outcomes of the model.

It is to be noted that simulation may not reflect all possible events. Therefore, a discussion to account for possibility of unfavourable events occurring should be made such that the margin of safety of occupants is augmented.

Therefore following considerations are to be further incorporated into the Evacuation Plan:

1) Distribution of students: Students may not be within their classrooms as represented in the simulation and could potentially be spread out throughout the building during break-time (e.g. recess and lunch). The likelihood of 'controlled' evacuation plan as per training may not occur and thus potentially delaying the evacuation.
2) Inherent variability in population: Population within a school may vary especially during events involving students and/or local community. The population within the simulation does not account for events being held within the school where the number of occupants within the subject building may exceed 2520.

3) Cue and Pre-movement Phase: In order to determine the total evacuation time, cue and pre-movement phases of evacuation are to be appropriately determined and included in the Evacuation Plan.
4) Evacuation Procedures: A specific evacuation plan is to be established in such a way to correctly allocate each classroom to a designated refuge area. The following items are recommended to be included in the Bushfire Evacuation Plan:
    a. The evacuation is to immediately begin on Level 1 to Level 3 of the main building where occupants on Level 1 to Level 3 must be advised to travel to the entrance to the Auditorium on Level 4 and approximately 200 students (or 7 designated classrooms) located South-East of Level 3 are to be selected by a relevant authority to seek refuge in Level 6 Auditorium area.
    b. In order to minimise the impact of crowding, occupants on Level 4 to Level 6 are advised to begin their evacuation 400 seconds (or 6 min 40 s) after occupants on Level 1 to Level 3 have started to evacuate. These occupants on Level 4 to Level 6 are advised to travel to Level 5 BAL-FZ area (Cafeteria and Office Area on Level 5).
    c. The training should be in accordance with the evacuation plan to mitigate any delays and possibly reduce the total evacuation time.
5) Evacuation from the gymnasium: Occupants in the gymnasium require indication whether it is safe to cross the 'external bridge' where fire in vicinity to the gymnasium may endanger occupants that are required to evacuate externally via the external bridge.
6) Change in design & population: Should a change in design of the building or population of the building, a re-assessment will be needed to verify consistency with the analysis contained in this report.

The "Bushfire Evacuation Plan" should provide sufficient conservatism, as agreed with stakeholders, to take account of these variabilities, and any variabilities in the cue and pre-movement.

8. SUMMARY

As an outcome of this engineering assessment, it has been demonstrated that, once occupants begin to move, 2520 occupants are expected to move into the refuge area namely Auditorium and BAL-FZ area, in 650 s with the given conditions represented in this model. The above-mentioned time only considers the movement phase of the evacuation. Cue phase and pre-movement phase is not considered in this report and is to be appropriately determined by a bushfire consultant as part of the Evacuation Plan.

9. REFERENCES

G. Proulx, "Movement of People: The Evacuation Timing", Chapter 13 in SFPE Handbook of Fire Protection Engineering, 3rd Edition, National Fire Protection Association and the Society of Fire Protection Engineers, U.S.A, 2002 – p.3-342 – 3-359.

International Fire Engineering Guidelines, Edition 2005, Australian Building Codes Board.

National Construction Code Series, Guide to Volume 1, Building Code of Australia 2016, Australian Building Codes Board.

National Construction Code Series, Volume 1 Amendment 1, Building Code of Australia 2016, Australian Building Codes Board.

Pathfinder 2017– Thunderhead Engineering Consultants Inc – 2017

APPENDIX A. DRAWINGS – REFUGE AREA

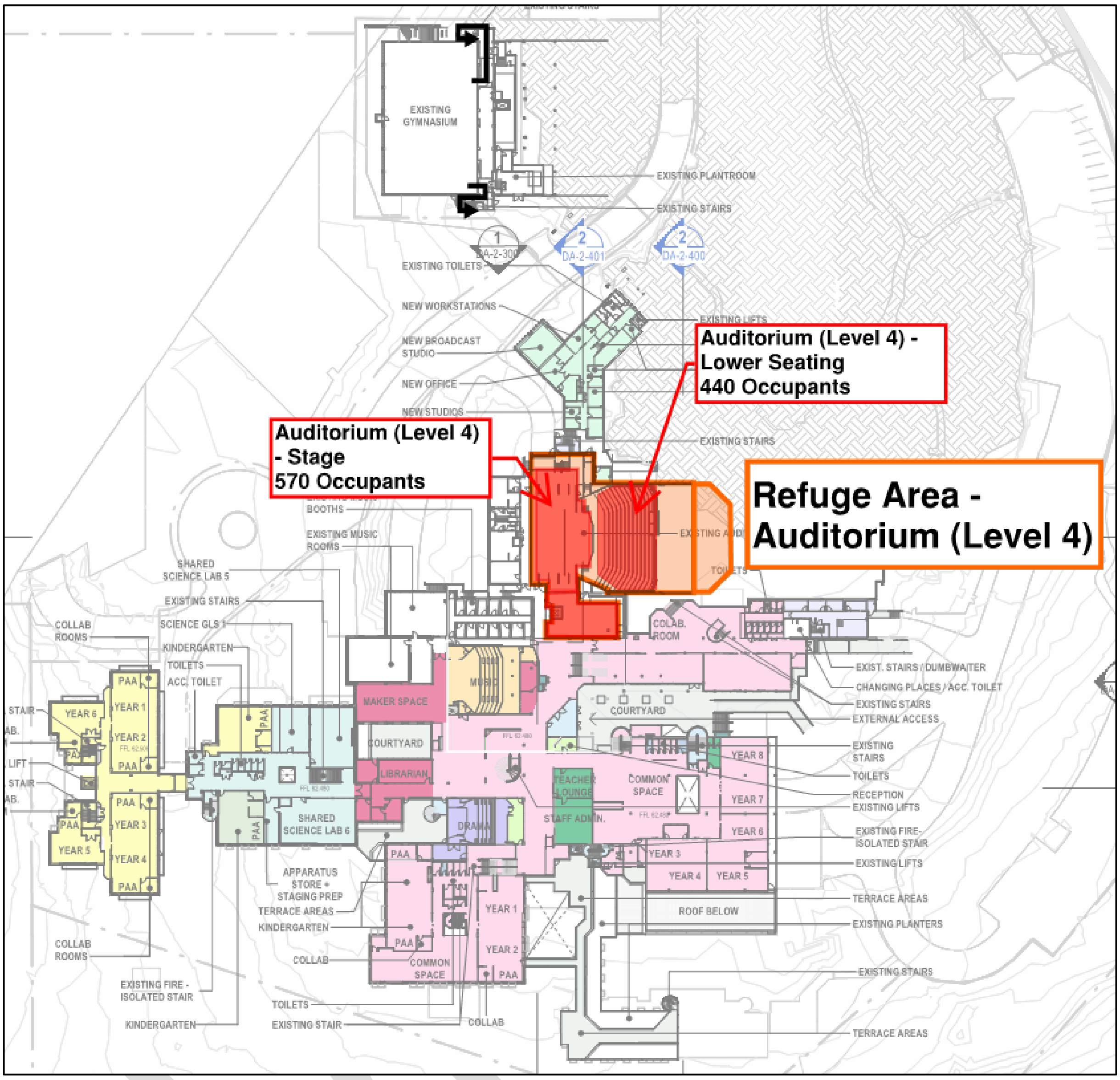

Figure 1 – Refuge Area on Level 4 (Auditorium)

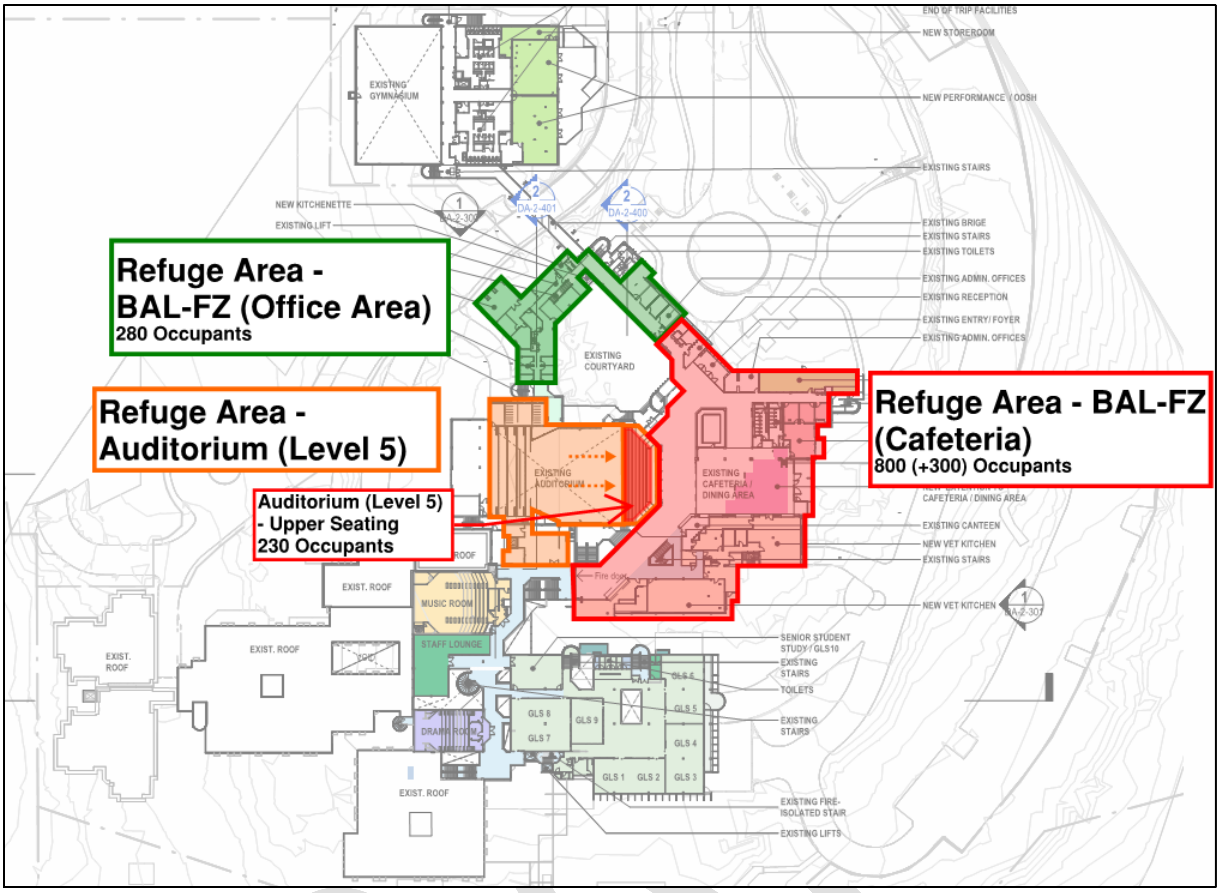

Figure 2 – Refuge Area on Level 5 (Auditorium Area and BAL-FZ Refuge Area)

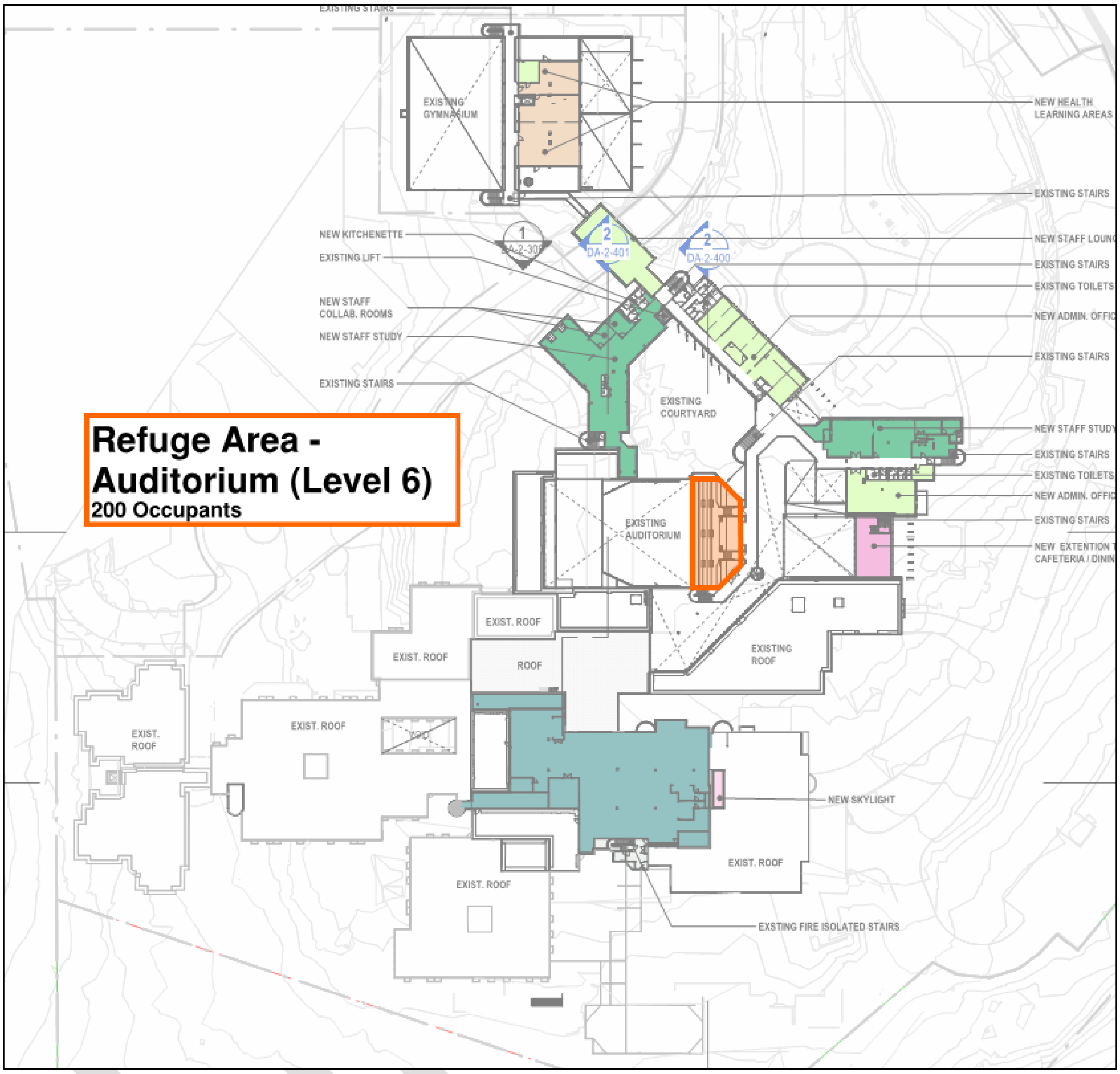

Figure 3 – Refuge Area on Level 6 (Auditorium)

APPENDIX B. NUMBER OF OCCUPANTS

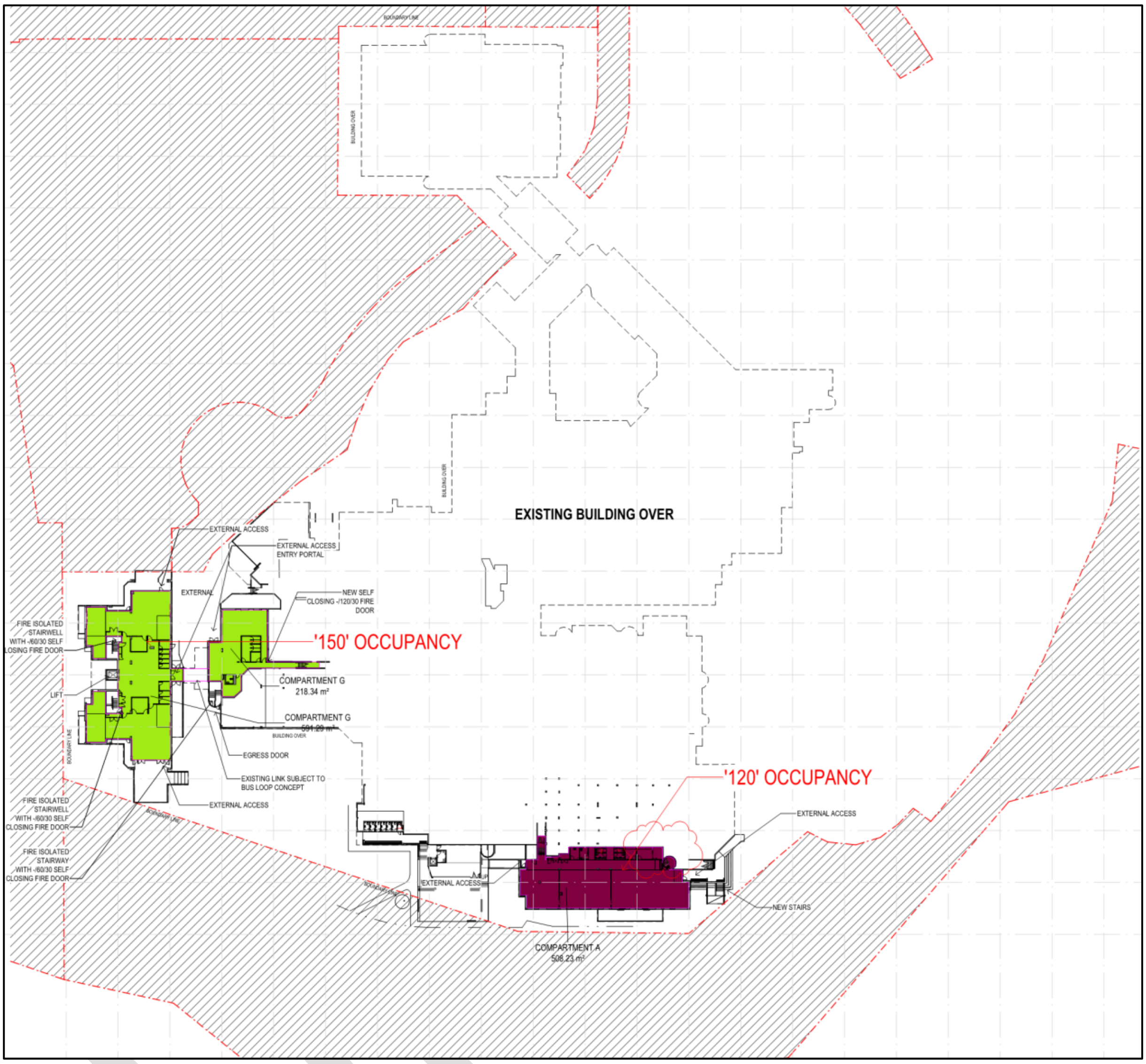

Figure 4 – Number of enrolled students on Level 1.

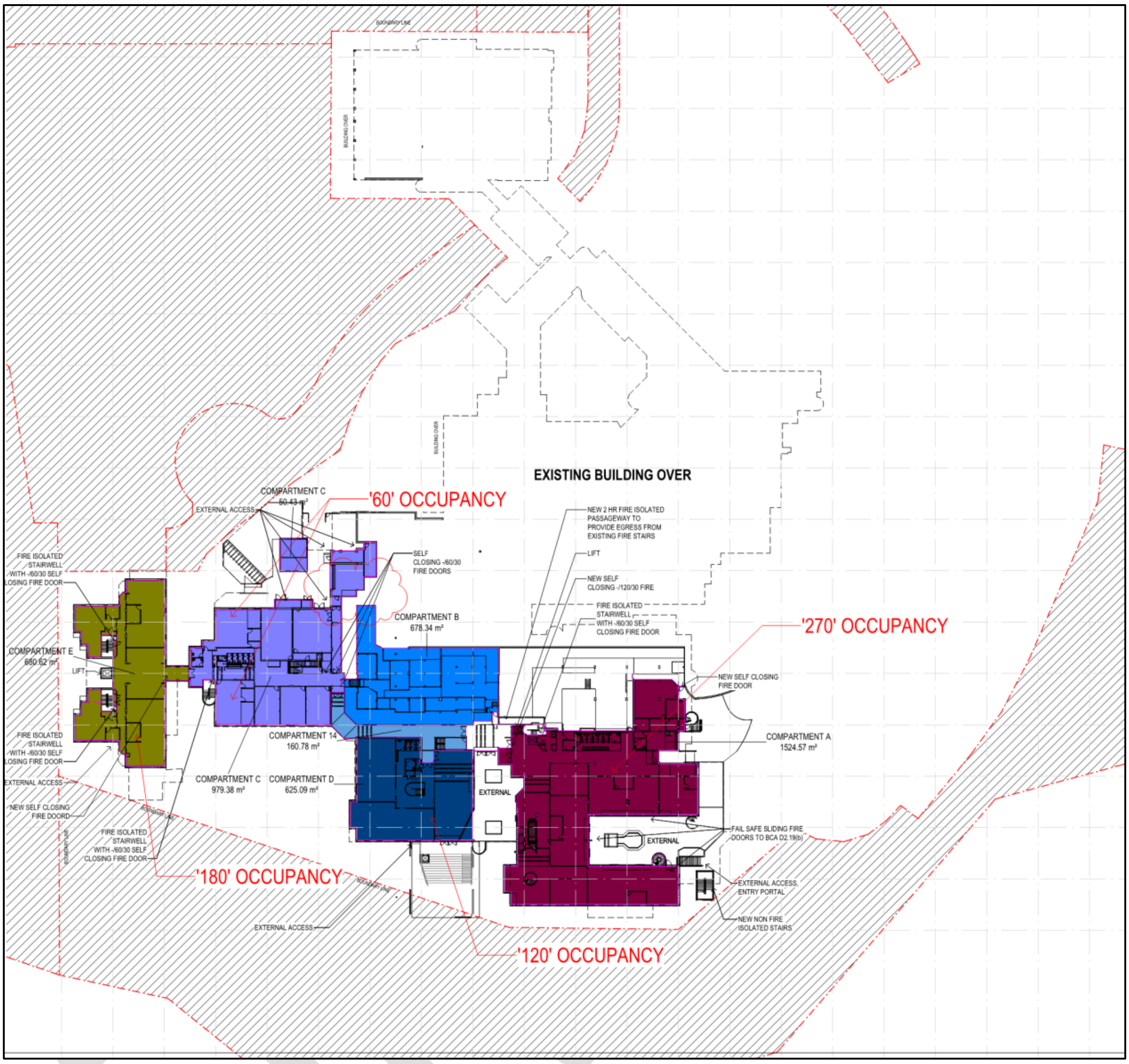

Figure 5 – Number of enrolled students on Level 2.

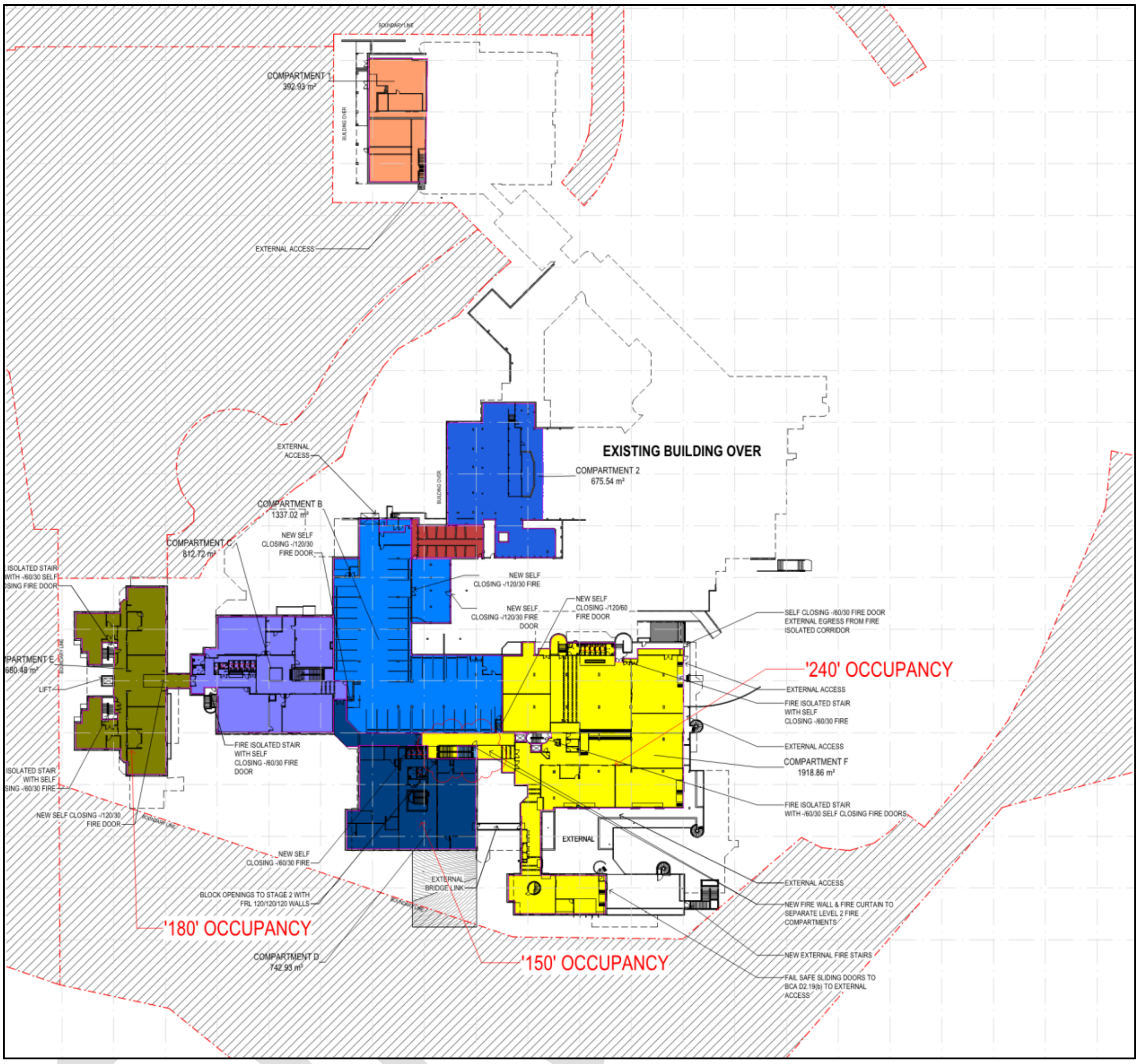

Figure 6 – Number of enrolled students on Level 3.

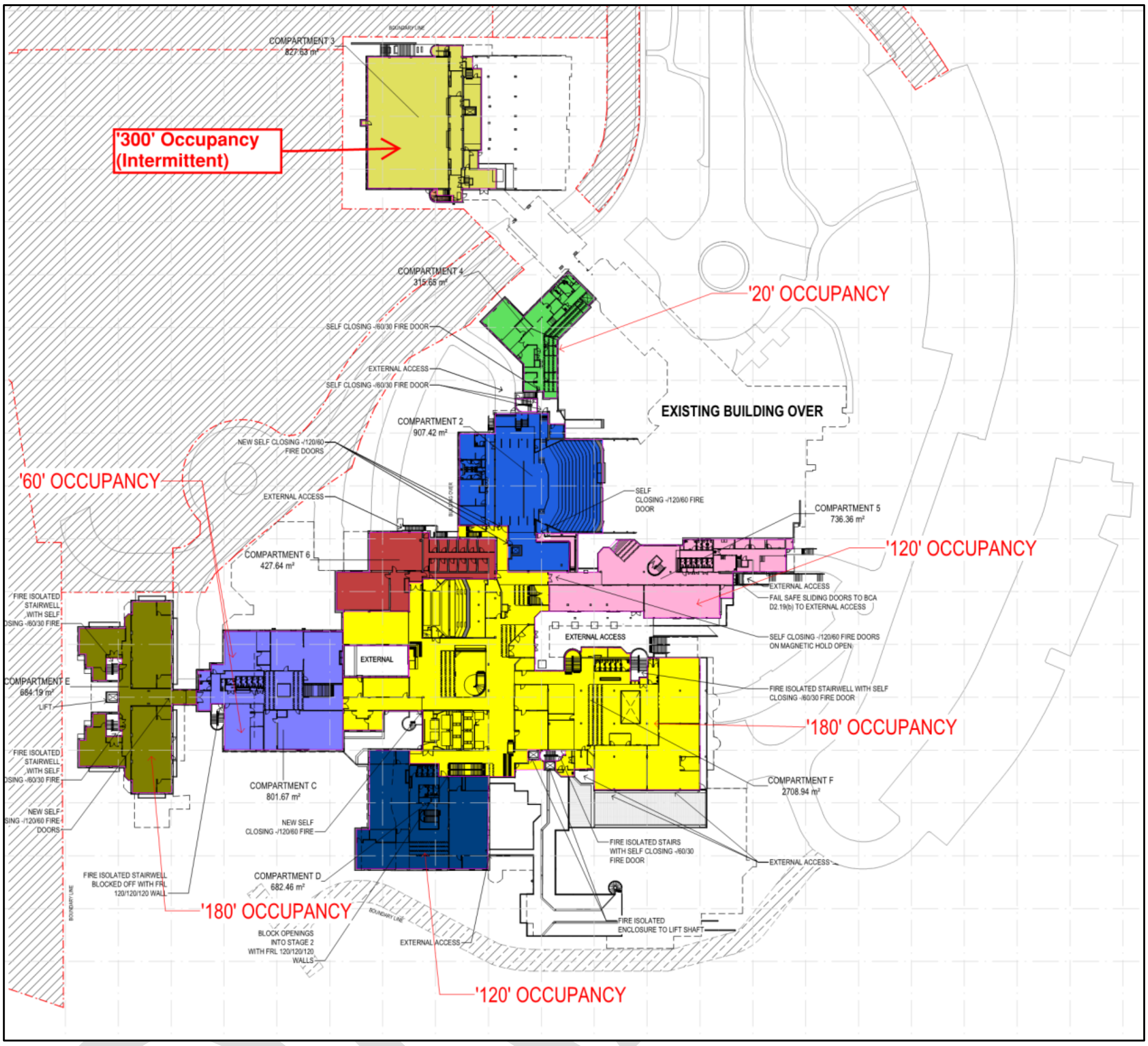

Figure 7 – Number of enrolled students on Level 4.

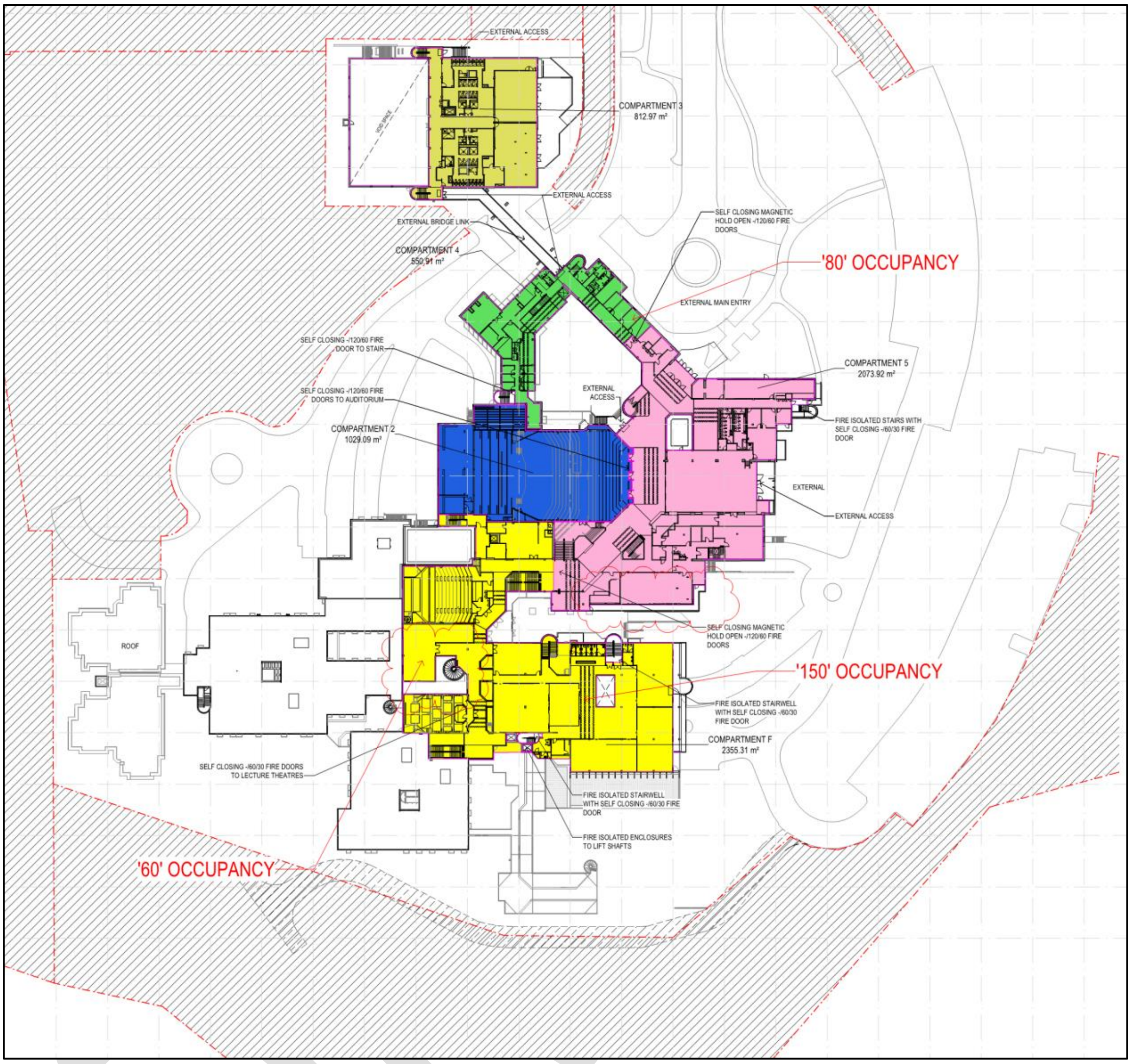

Figure 8 – Number of enrolled students on Level 5.

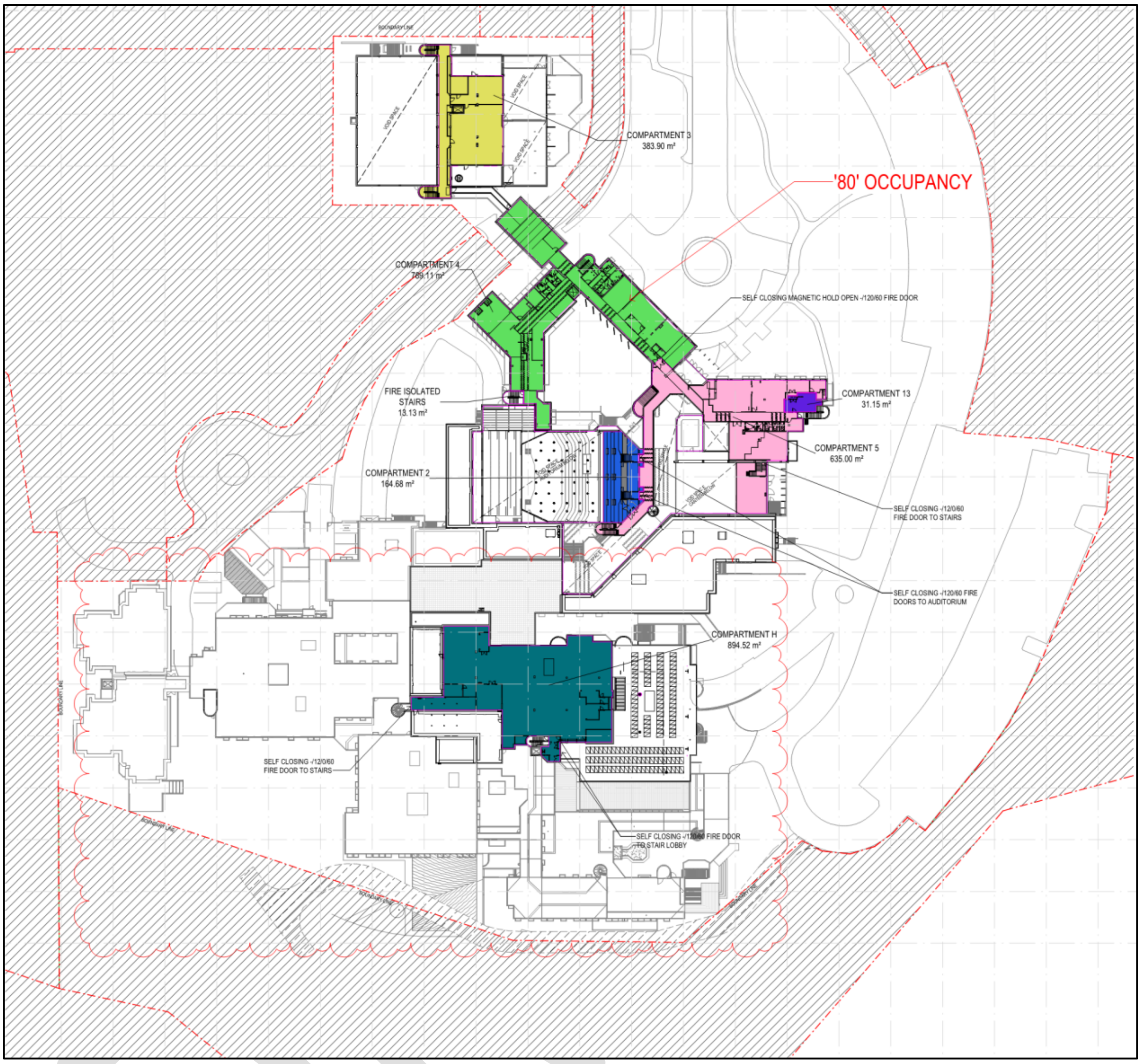

Figure 9 – Number of enrolled students on Level 6.

APPENDIX C. PATHFINDER RESULTS – TIME-LINE OF OCCUPANT EVACUATION

C.1 LEVEL 1

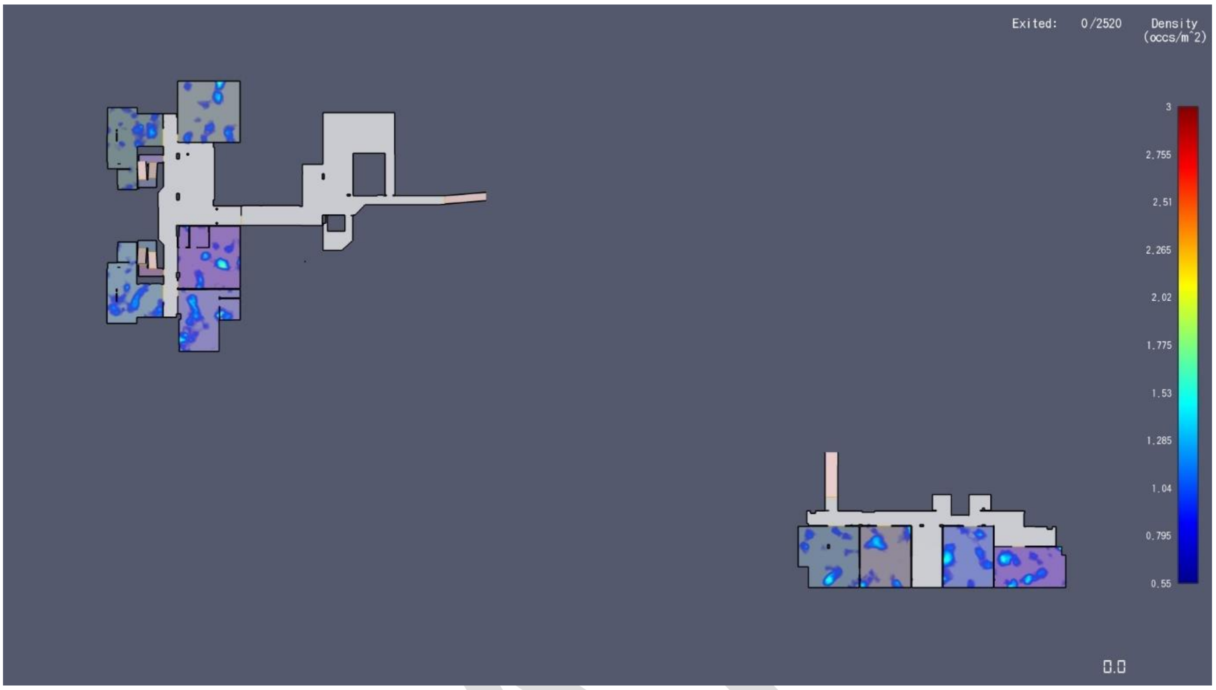

Figure 10 – Occupant density on Level 1 at 0 s.

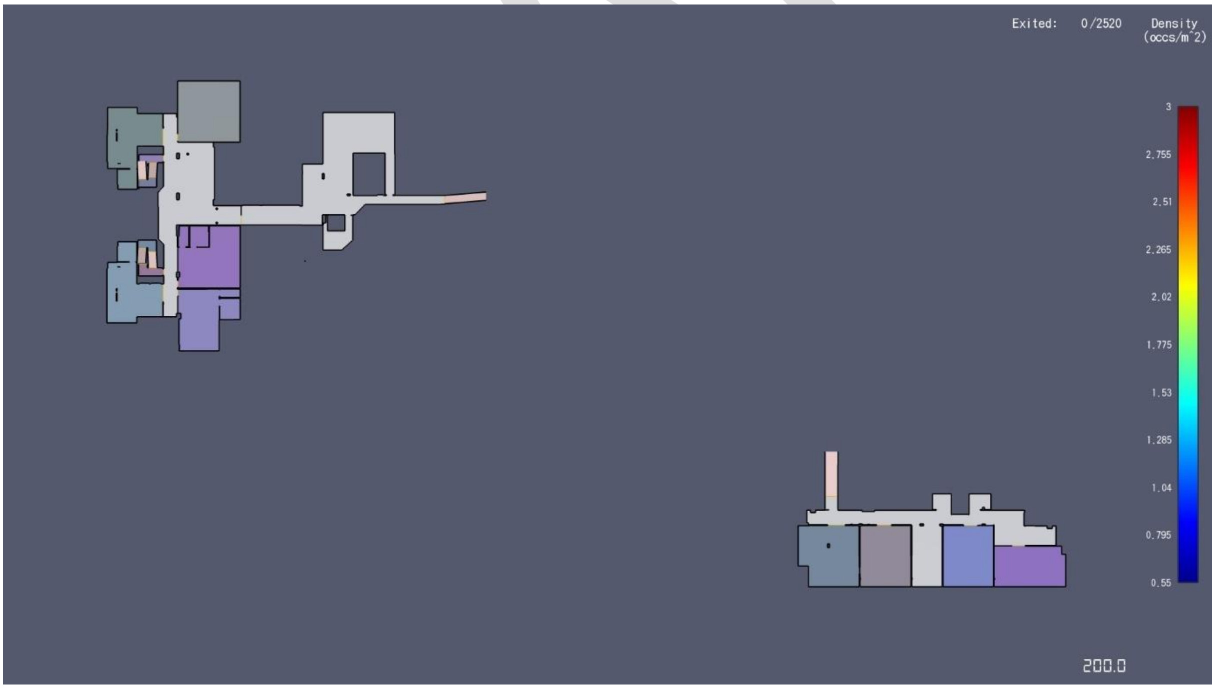

Figure 11 – Occupant density on Level 1 at +200 s.

C.2 LEVEL 2

Figure 12 – Occupant density on Level 2 at 0 s.

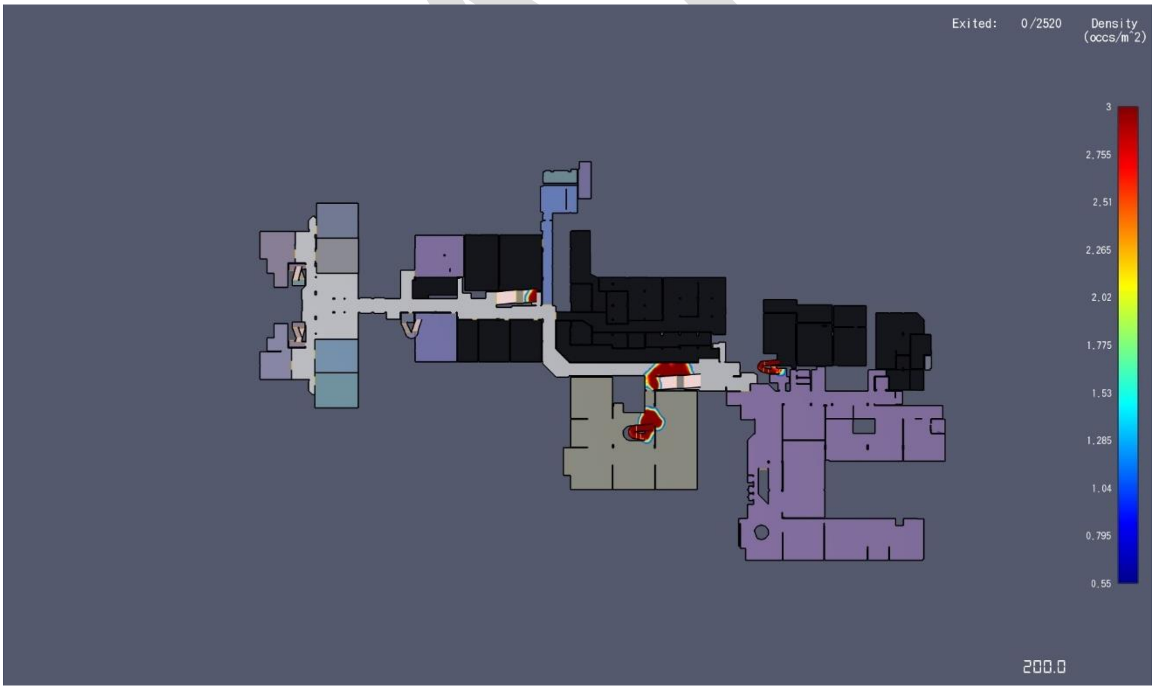

Figure 13 – Occupant density on Level 2 at 200 s.

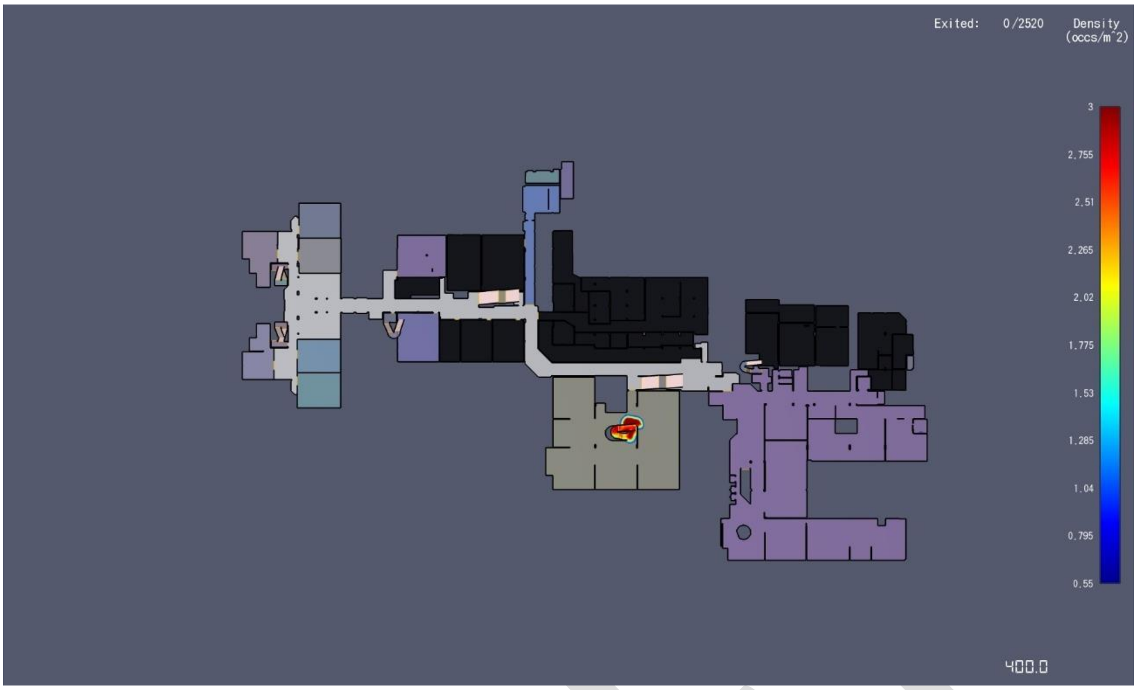

Figure 14 – Occupant density on Level 2 at 400 s.

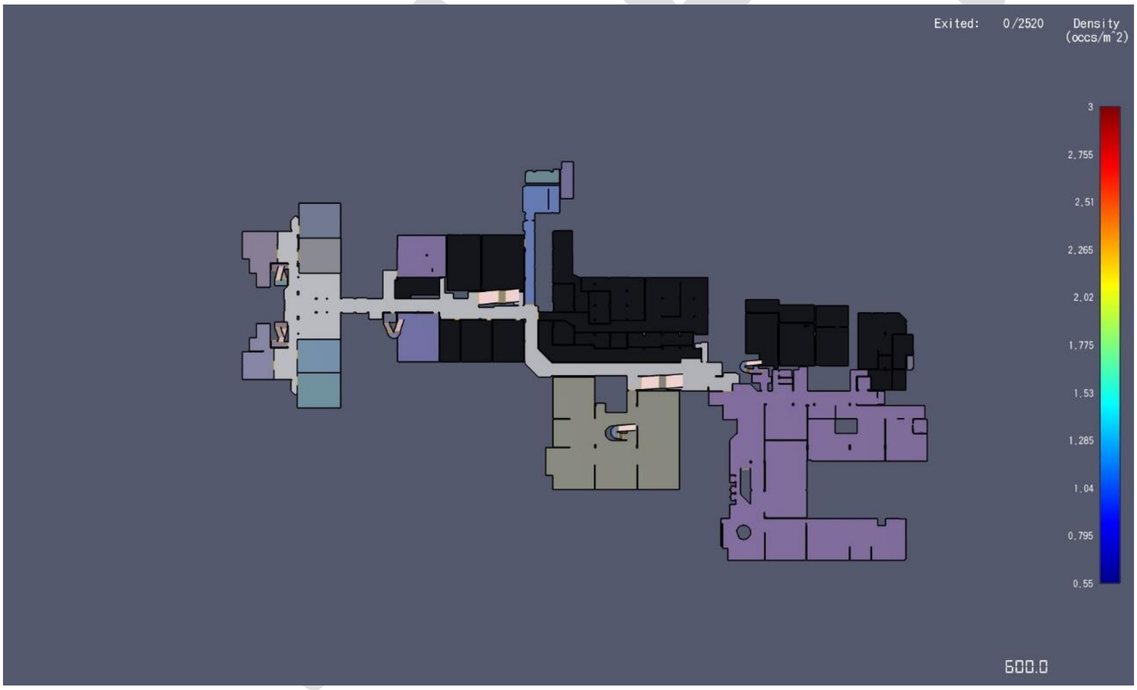

Figure 15 – Occupant density on Level 2 at 600 s.

C.3 LEVEL 3

Figure 16 – Occupant density on Level 3 at 0 s.

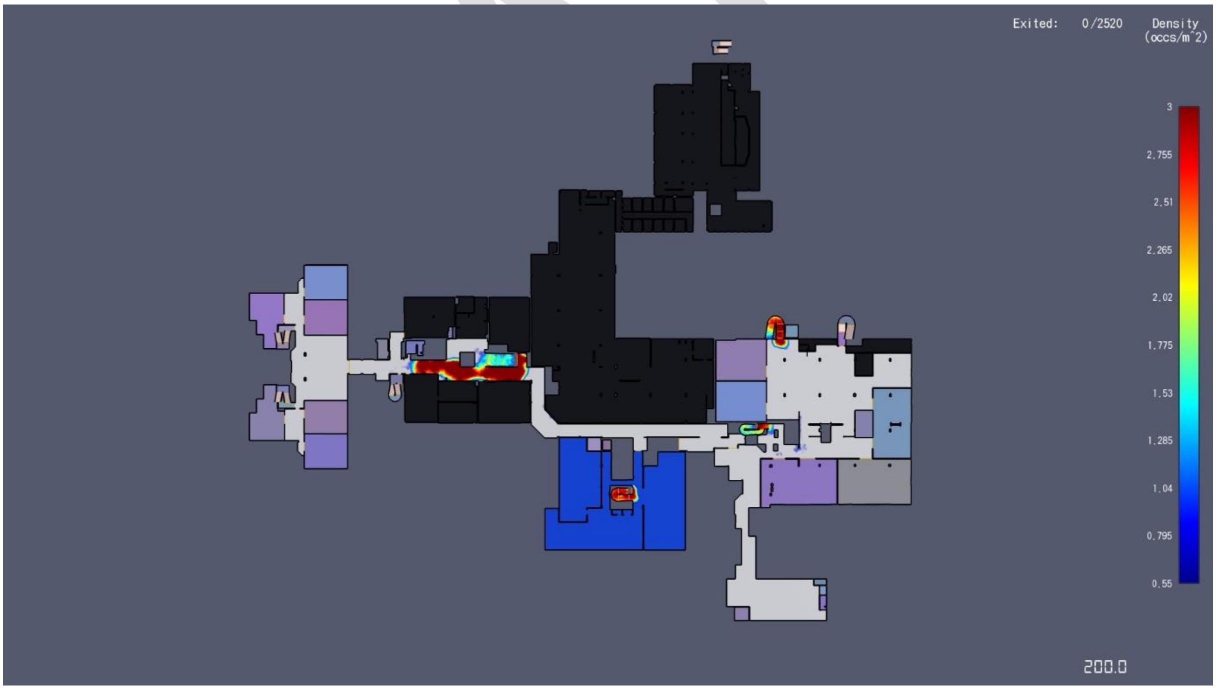

Figure 17 – Occupant density on Level 3 at 200 s.

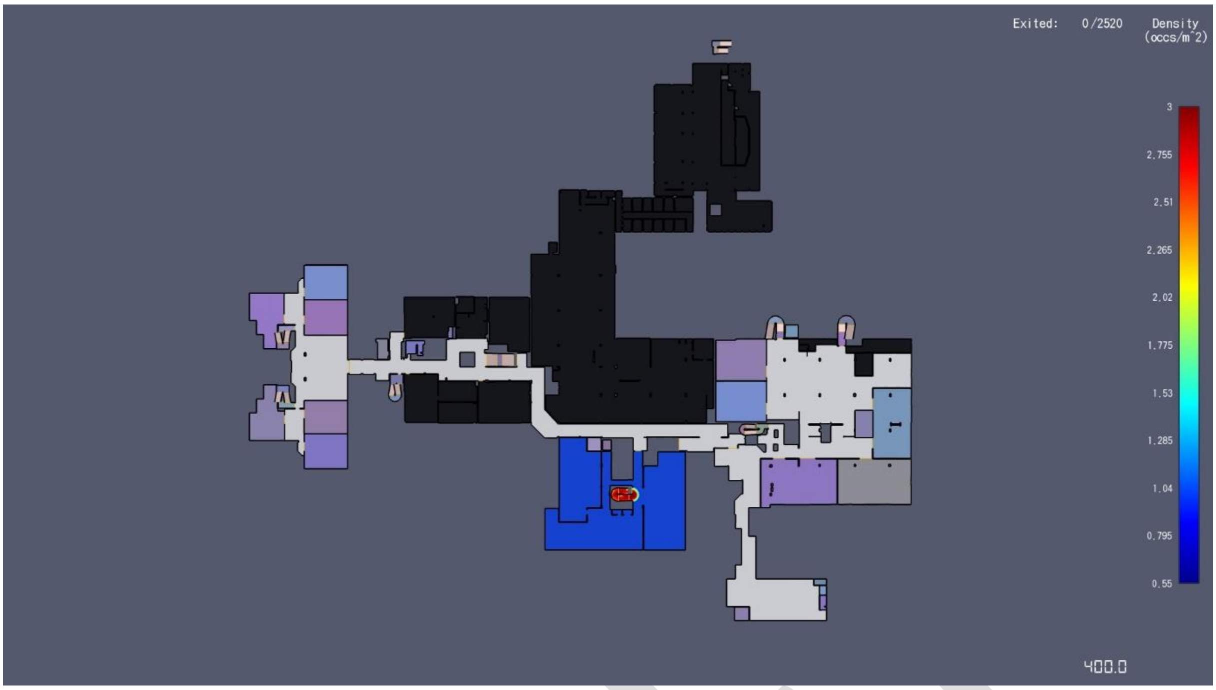

Figure 18 – Occupant density on Level 3 at 400 s.

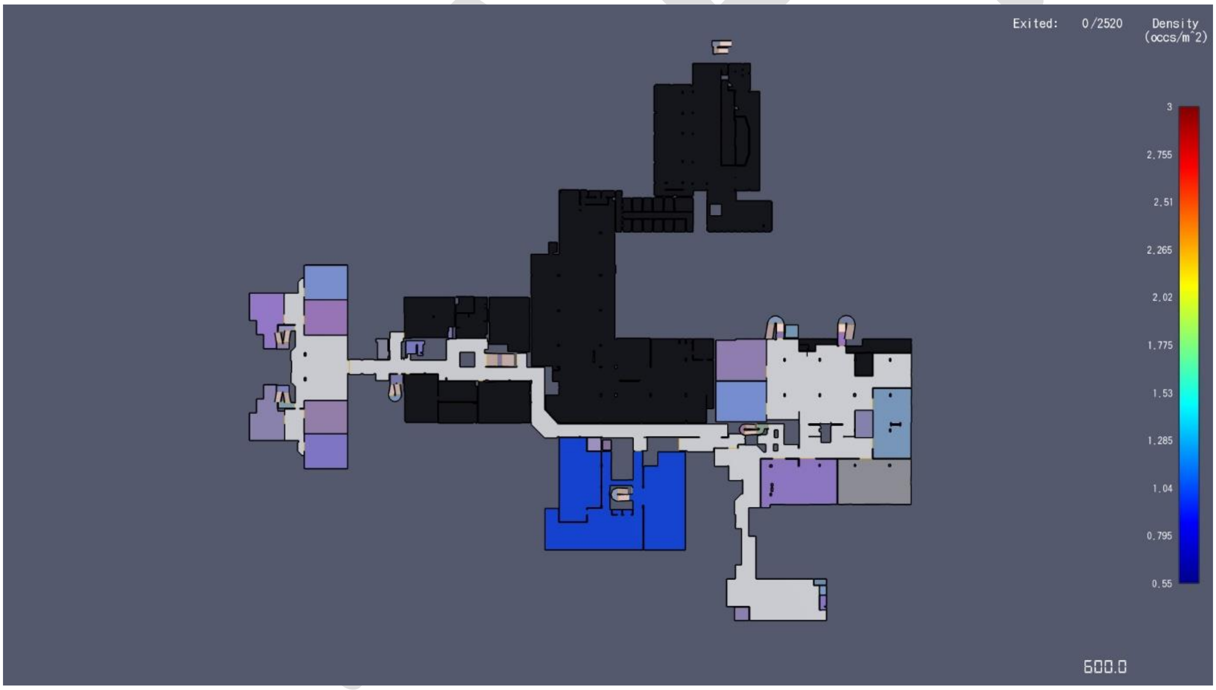

Figure 19 – Occupant density on Level 3 at 600 s.

C.4 LEVEL 4

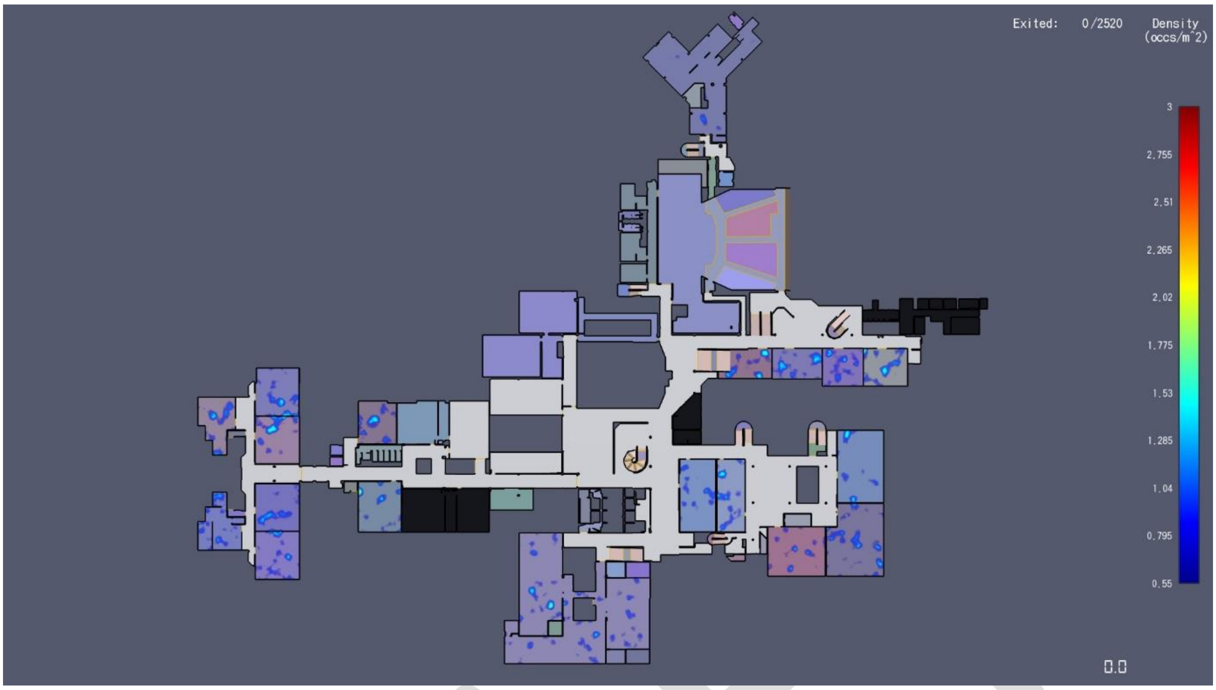

Figure 20 – Occupant density on Level 4 at 0 s.

Figure 21 – Occupant density on Level 4 at 200 s.

Figure 22 – Occupant density on Level 4 at 400 s.

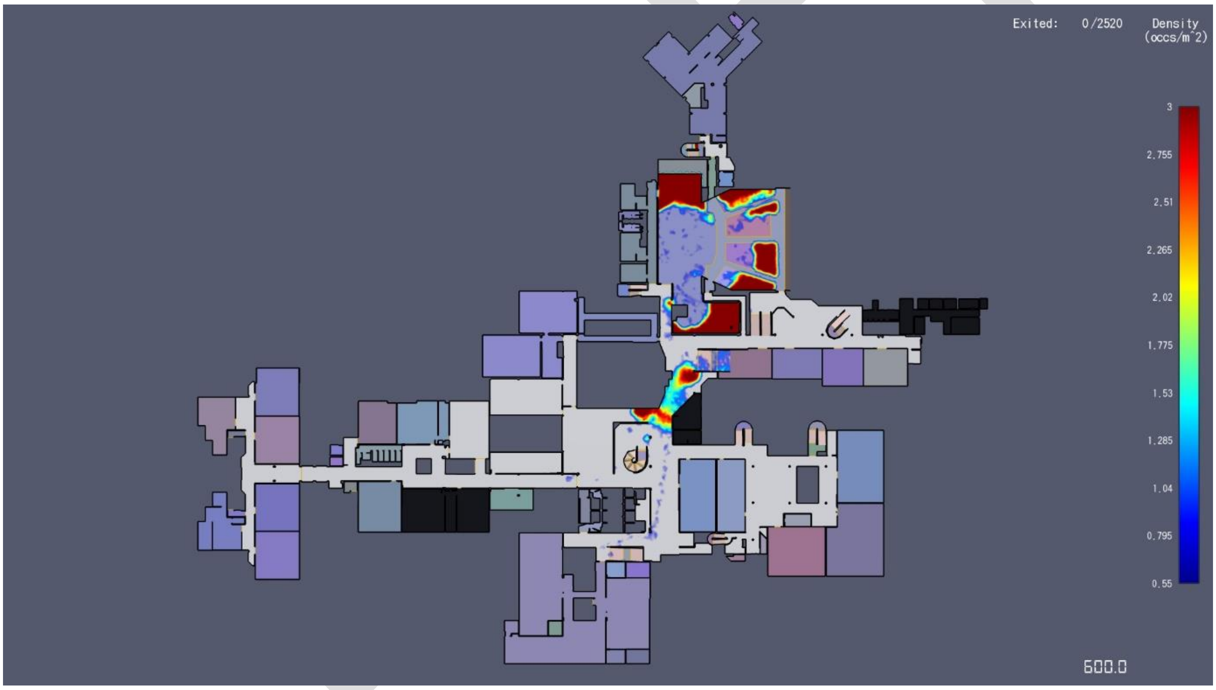

Figure 23 – Occupant density on Level 4 at 600 s.

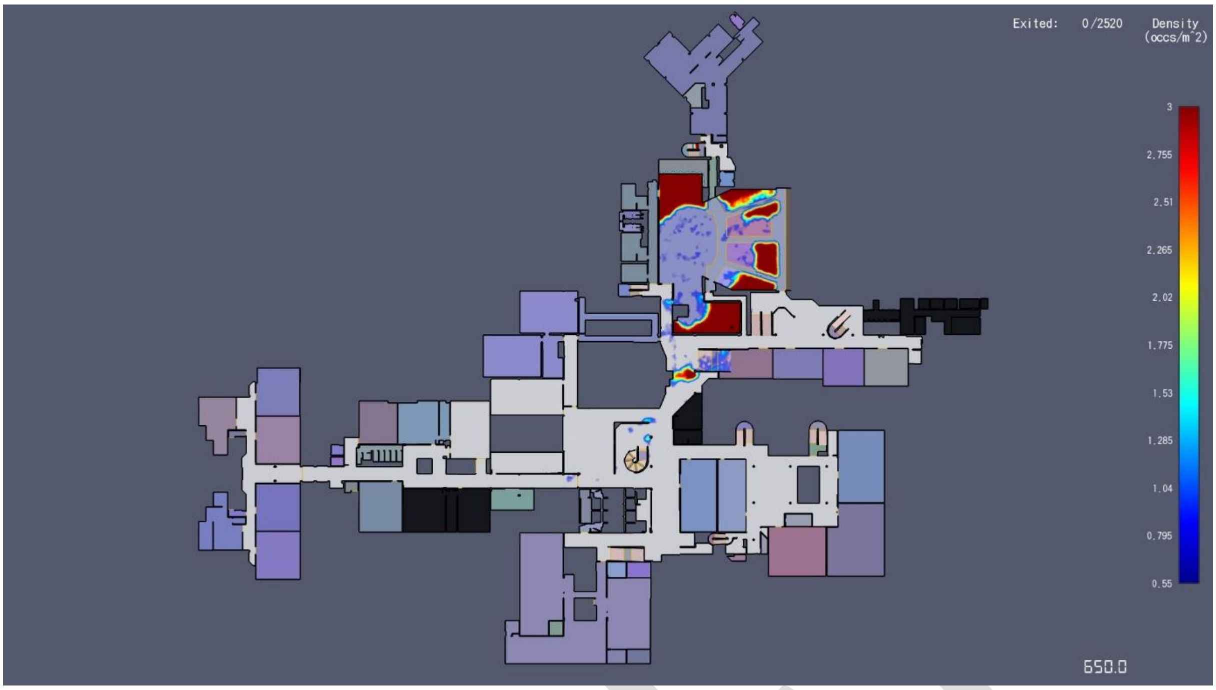

Figure 24 – Occupant density on Level 4 at 650 s.

C.5 LEVEL 5

Figure 25 – Occupant density on Level 5 at 0 s.

Figure 26 – Occupant density on Level 5 at 200 s.

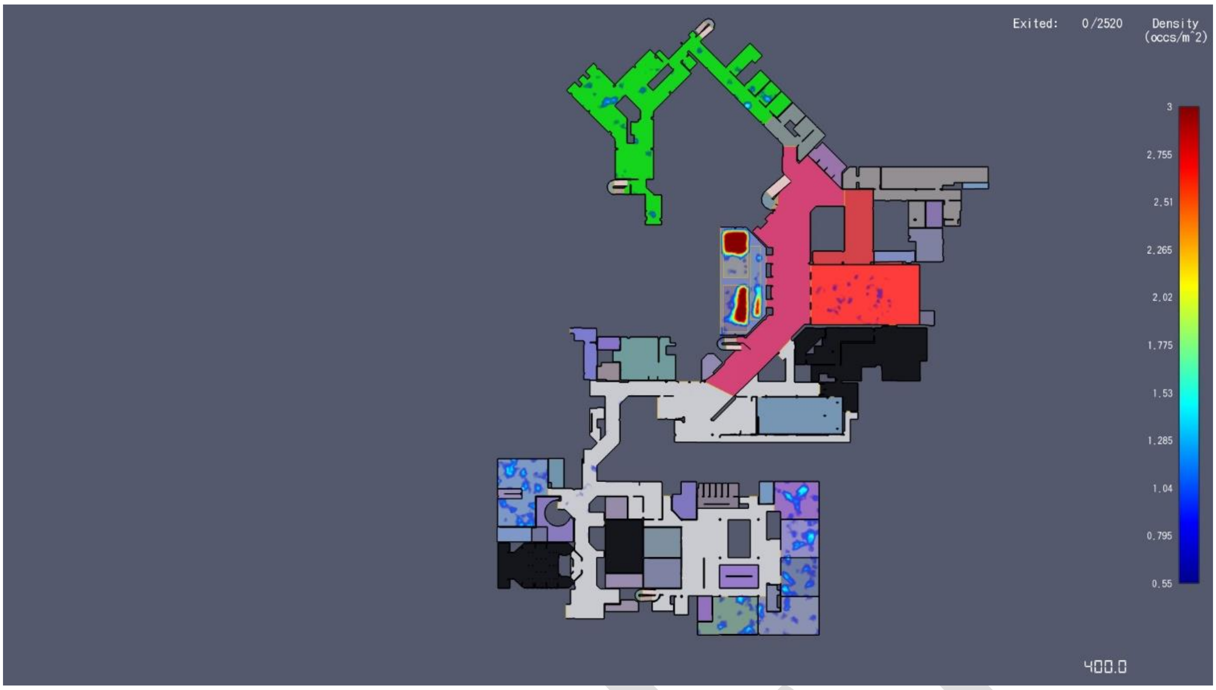

Figure 27 – Occupant density on Level 5 at 400 s.

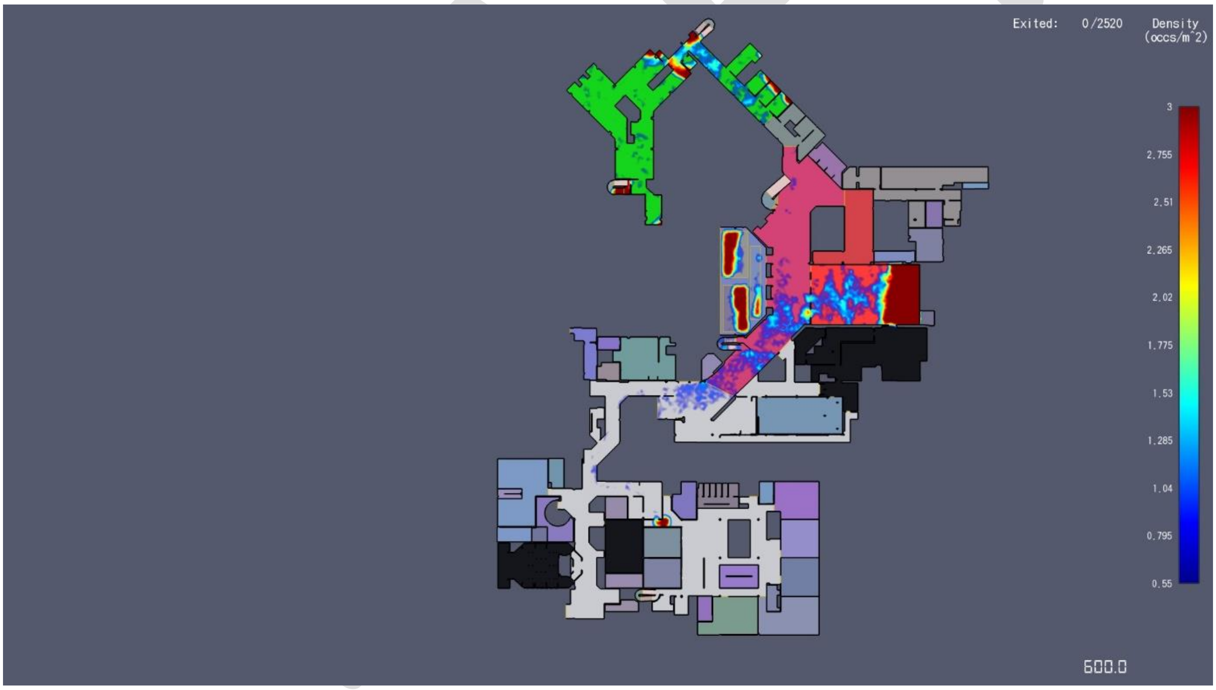

Figure 28 – Occupant density on Level 5 at 600 s.

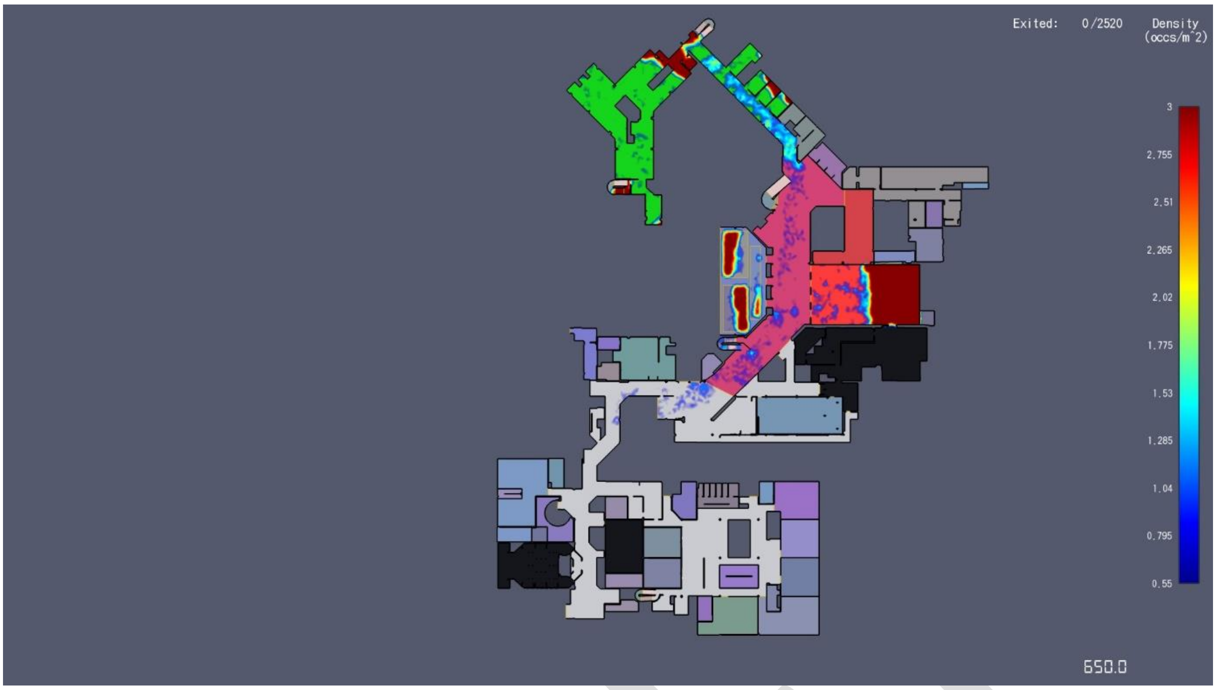

Figure 29 – Occupant density on Level 5 at 650 s.

C.6 LEVEL 6

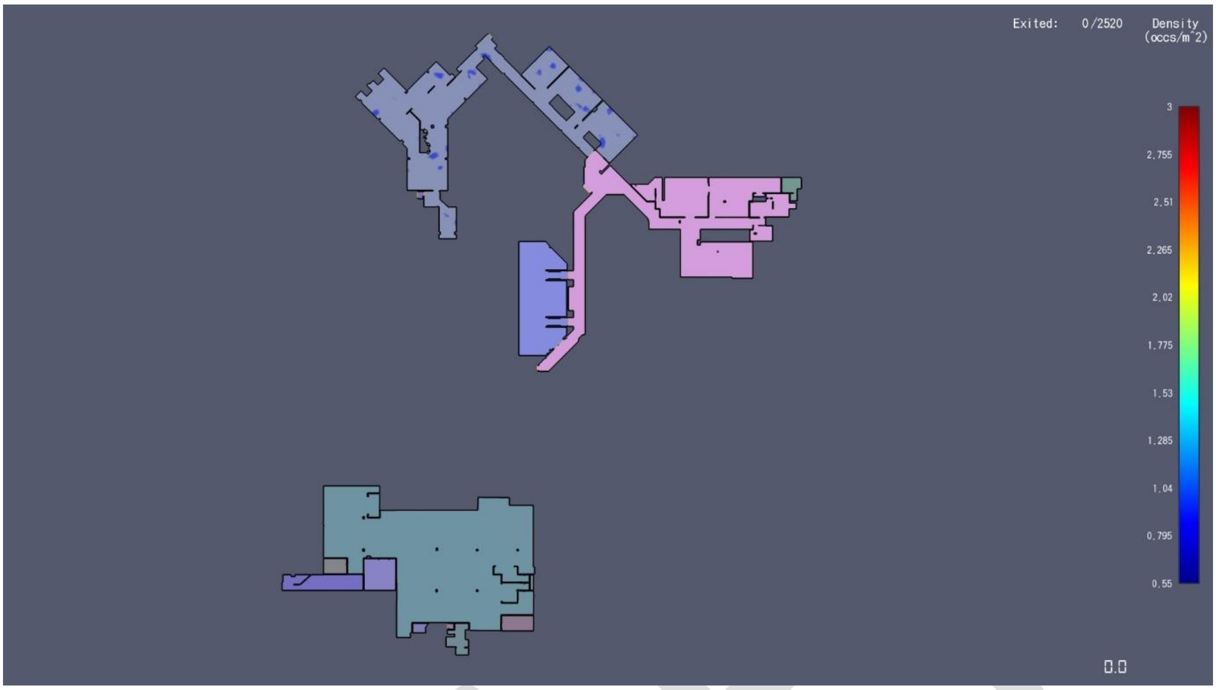

Figure 30 – Occupant density on Level 6 at 0 s.

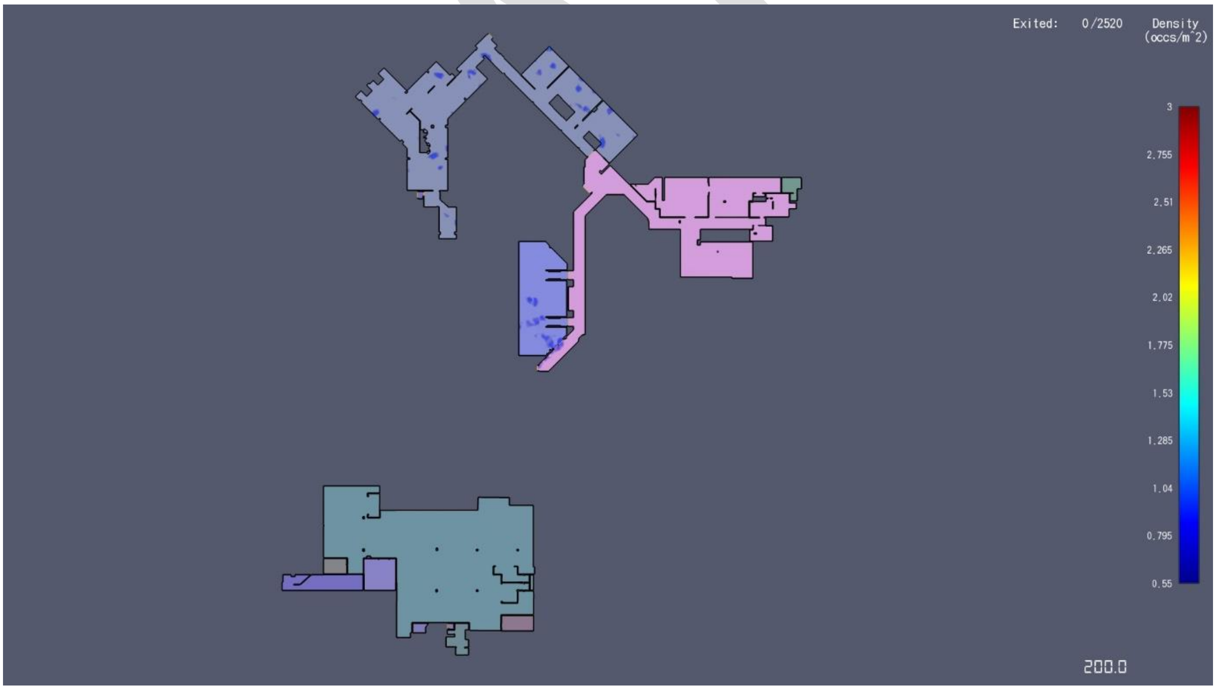

Figure 31 – Occupant density on Level 6 at 200 s.

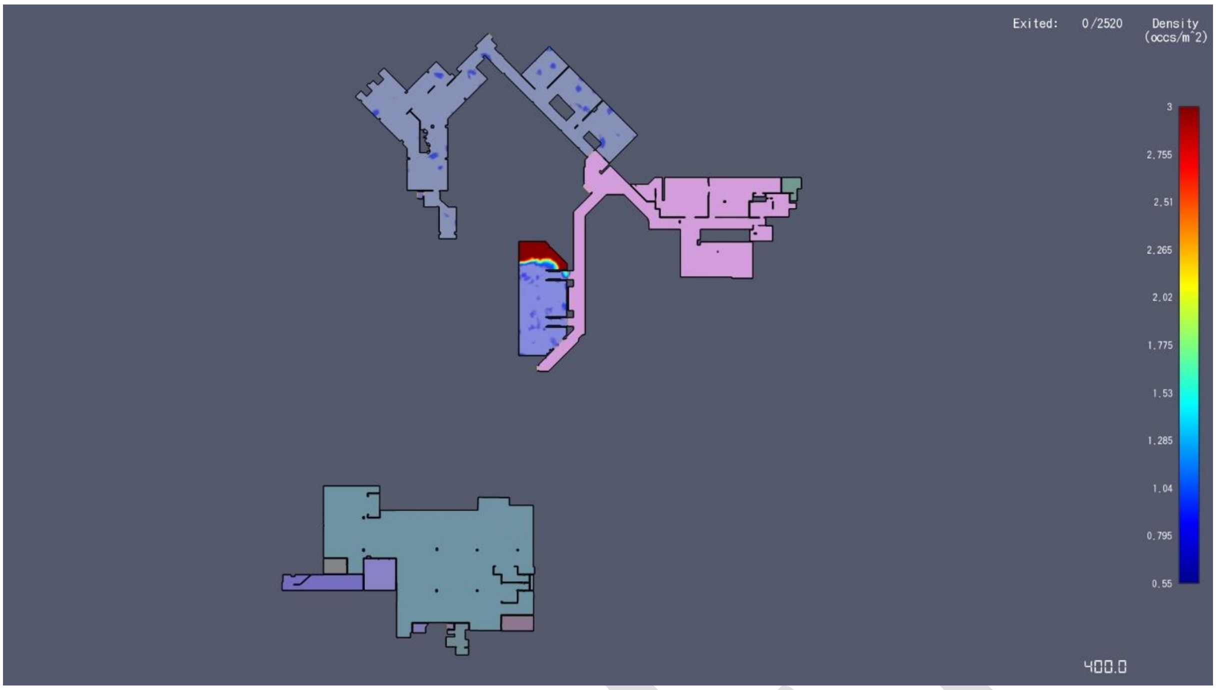

Figure 32 – Occupant density on Level 6 at 400 s.

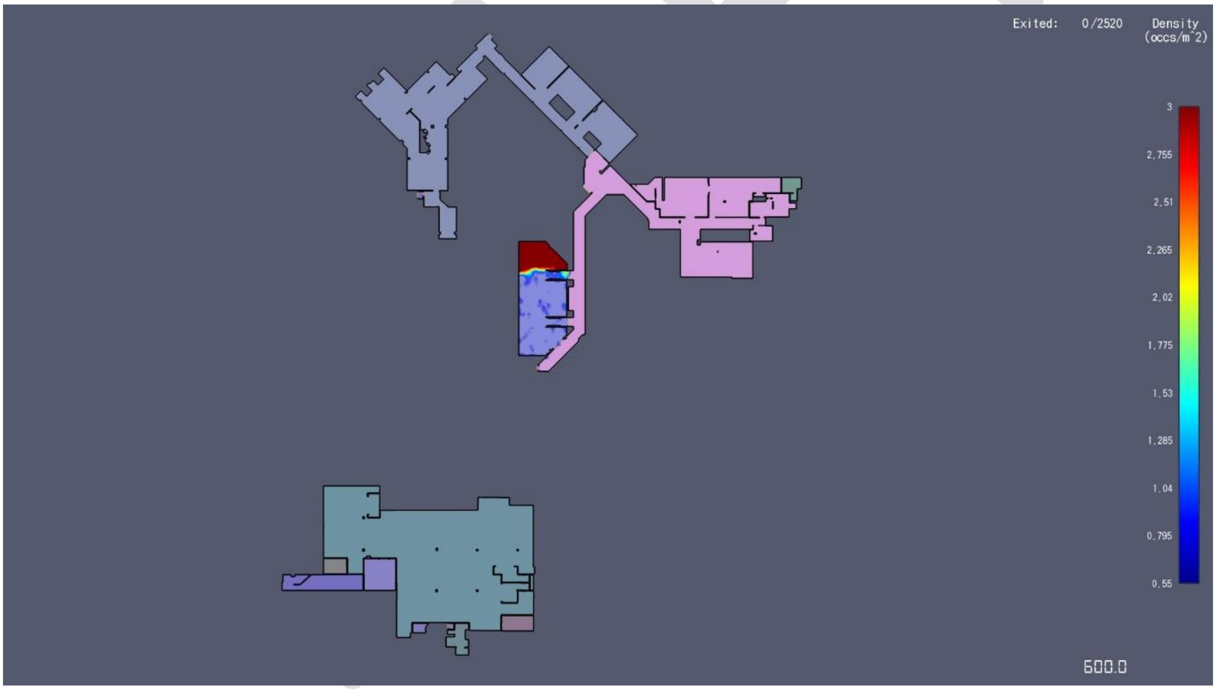

Figure 33 – Occupant density on Level 6 at 600 s.

APPENDIX D. EGRESS ANALYSIS

D.1 METHODOLOGY

The egress analysis determines time that an occupant requires to respond to an alarm or cue of a fire event and secondly, the required time for that occupant to reach a safe place.

The RSET and ASET are measured from the same point of origin of the fire, that is, from the time of effective ignition. In this manner both can be compared later. The RSET is the sum of the three phases described below:

- Cue phase, taken from effective ignition of a fire to the time of a cue that indicates the possible occurrence of a fire. In the absence of an alarm, the formation of a visible smoke layer under the ceiling can be taken as a reasonable cue for awake occupants [(5)]. In this regard, visible smoke covering approximately 10% of the ceiling height may serve as a cue for detection.
- Pre-movement phase, which extends from the occurrence of cue to the time when the action of evacuating occupants from the affected areas has started. The degree of training and familiarity with the surroundings, as well as the general nature of the population, have an impact on reaction time. This period covers the time for occupants to assimilate the cue, resolve any ambiguity, undertake pre-evacuation actions and commence evacuation.
- Movement phase, extends from the time occupants initiated movement until a safe place has been reached. This phase can be calculated on the basis of human walking speed affected by crowding.

D.2 CUE TIMES (T_C)

Cues alerting occupants to the occurrence of a fire would generally be:

- direct visual contact with the flame and/or smoke plume;
- warning from other occupants able to see the flame and/or smoke plume;
- the hot smoke layer at ceiling level developing to a sufficient depth so as to become noticeable, i.e. - 10% of ceiling height;
- building occupant warning system activated by sprinkler operation or smoke detector operation;
- break-glass alarm activation.

Cue times are determined based upon the activation of the smoke detectors, which would activate prior to the operation of the sprinklers.

Smoke detectors are to be located in all areas. The spacing between smoke detectors are assumed to follow the requirements of AS1670.1.

D.3 PRE-MOVEMENT TIMES (T_{PM})

D.3.1. General

Pre-movement time is the time taken between when the cue was first received and the start of the action of evacuating occupants from the affected areas. Pre-movement time can be broken down into two components, response time (T_r) and delay time (T_d).

[5] Humans are the best detectors of fire when awake and familiar with their environment, due to their ability to sense fire at lower concentrations of combustible products than the most sophisticated detection systems (Fire Engineering Guidelines 1996, p. 11).

D.3.2. Occupant Response Time (T_r)

Occupants response time involves the process of interpreting the automatic or intrinsic cue and identifying it as a cause for evacuation. The response time is dependent upon the type of cue.

D.3.3. Occupant Delay Time (T_d)

Following the time for the occupants to interpret the cue and identify it as a cause for evacuation, the occupants may undertake actions such as fighting the fire, investigating to obtain further information prior to begin moving toward the exits.

D.3.4. Total Pre-Movement Time (T_{pm})

Occupants are expected to be awake and fully conscious but may be unfamiliar with the building layout and exit locations. Due to the unique egress procedures in the building staff would be required to have emergency training.

Published document 7974-6:2004, published by British Standards, addresses the human factors in occupants egress and provides a table of suggested pre-movement times for different building types and occupant categories [6]. Under the definitions of the Published Document, the David Jones building is considered to be a Category B2 behaviour scenario (Occupants awake, unfamiliar with the layout and at a high density) [7] with Building Level 3 (large complex building) [8] and Management Level 1 (highly trained staff) [9]. This equates to the earliest occupant beginning egress at 90 s after the cue has been received.

Due to the limited exit width, significant queueing occurs at the exits during egress. Therefore it is not considered necessary to determine the likely spread of pre-movement times for the building as occupants beginning egress at later times would end up joining the queue.

D.4 MOVEMENT TIME (T_M)

This section describes the evaluation of the times necessary for movement of occupants to a safe area. The occupant movement times are to be determined using program '*Pathfinder*' [10] developed by Thunderhead Engineering USA. A walking speed of approximately 1 m/s and occupant 'steering' simulation mode is adopted in the evacuation simulations. Refer to Appendix E for further information on '*Pathfinder*'.

6 Table C.1, *PD 7974-6:2004*
7 Table 1, *PD 7974-6:2004*, Pg. 9.
8 Section 5.2.3, *PD 7974-6:2004.*, Pg. 10
9 Section 5.2.4, *PD 7974-6:2004.*, Pg. 11
10 *Pathfinder 2017*– Thunderhead Engineering Consultants Inc – 2017.

APPENDIX E. BRIEF INTRODUCTION OF PATHFINDER SOFTWARE

E.1.1. Introduction

Pathfinder is an agent based egress and human movement simulator. It provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis.

Pathfinder includes a graphical user interface that is used primarily to create and run simulation models. Pathfinder also includes a second program designed specifically for high-performance visualization of 3D time history.

E.1.2. Model Representation

The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data.

Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator, but are represented implicitly because occupants cannot move in places where no navigation mesh has been created.

Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow.

Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between stairways and the connecting doors.

Occupants are modelled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc).

E.1.3. Simulation Modes

Pathfinder supports two movement simulation modes. In "Steering" mode, doors do not act to limit the flow of occupants, but occupants use the steering system to maintain a reasonable separation distance. In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density.

APPENDIX F. EVACUATION PLANS – PATH OF TRAVEL

F.1 OCCUPANTS ON LEVEL 1

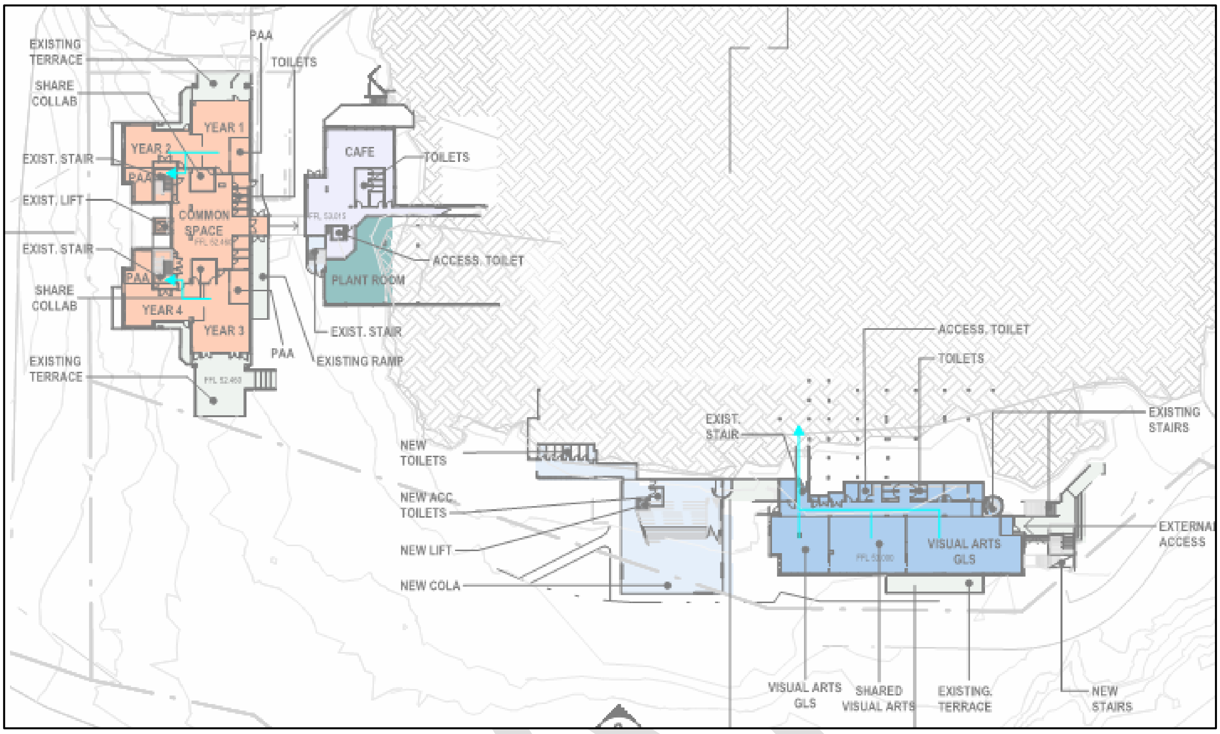

Figure 34 – Path of travel by Occupants on Level 1 from Level 1 to Level 2 (shown in sky blue colour arrows).

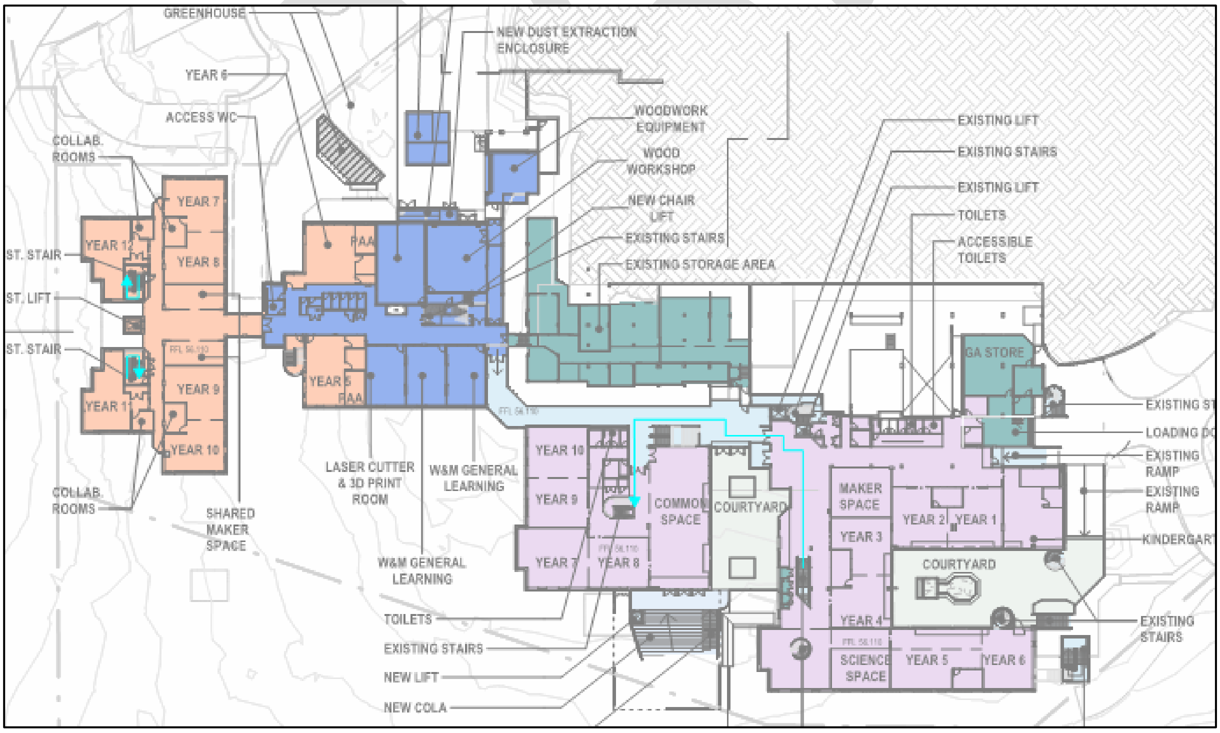

Figure 35 – Path of travel by Occupants on Level 1 from Level 2 to Level 3.

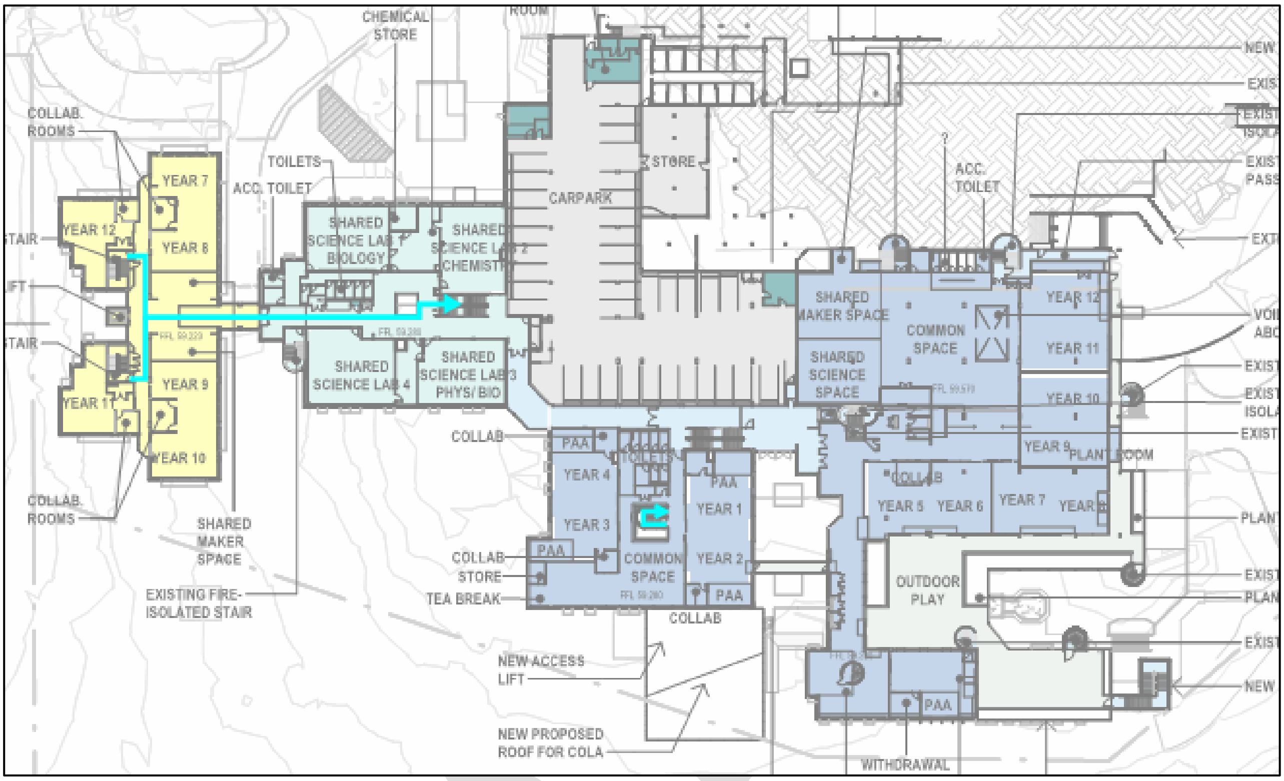

Figure 36 – Path of travel by Occupants on Level 1 from Level 3 to Level 4.

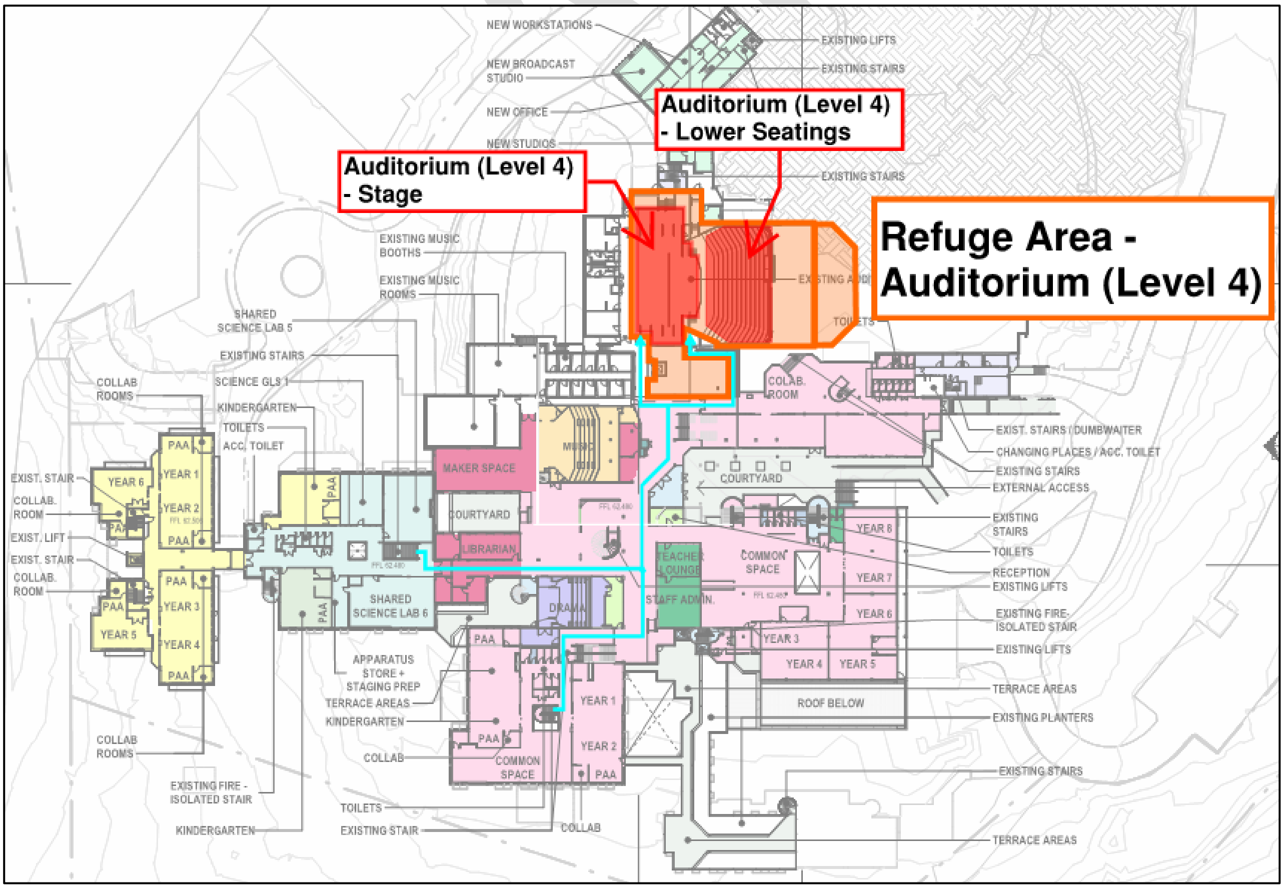

Figure 37 –- Path of travel by Occupants on Level 1 from Level 4 to Auditorium (Refuge Area).

F.2 OCCUPANTS ON LEVEL 2

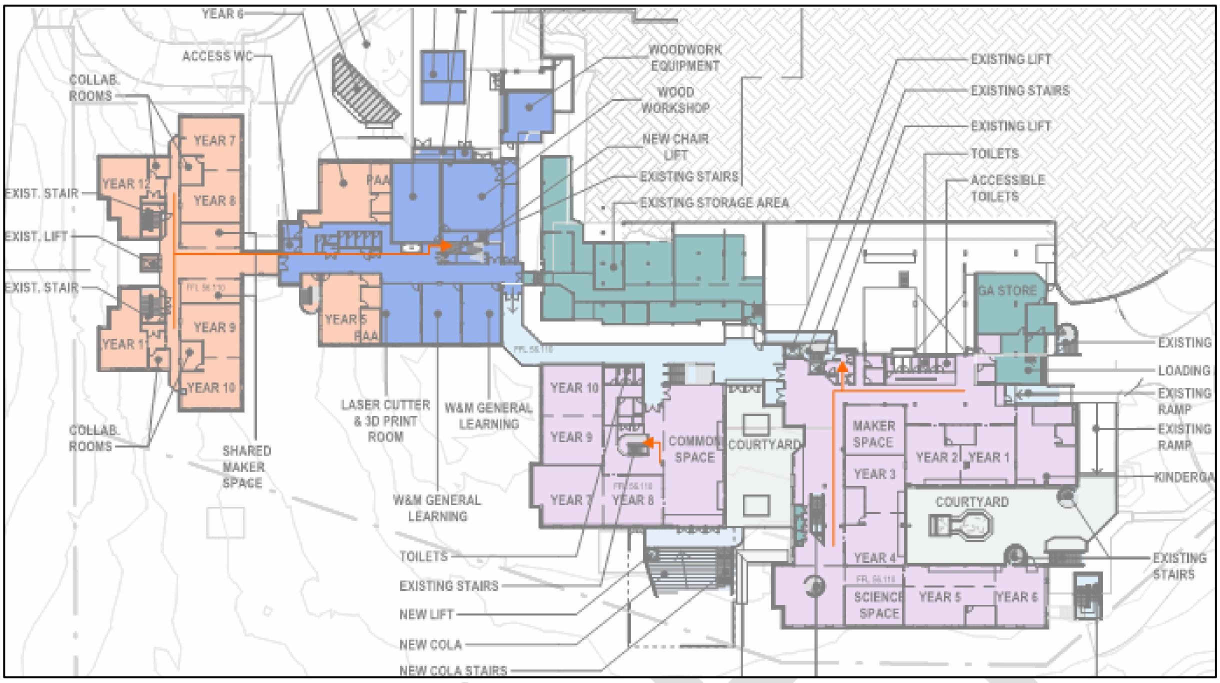

Figure 38 – Path of travel by Occupants on Level 2 from Level 2 to Level 3 (shown in orange colour arrow).

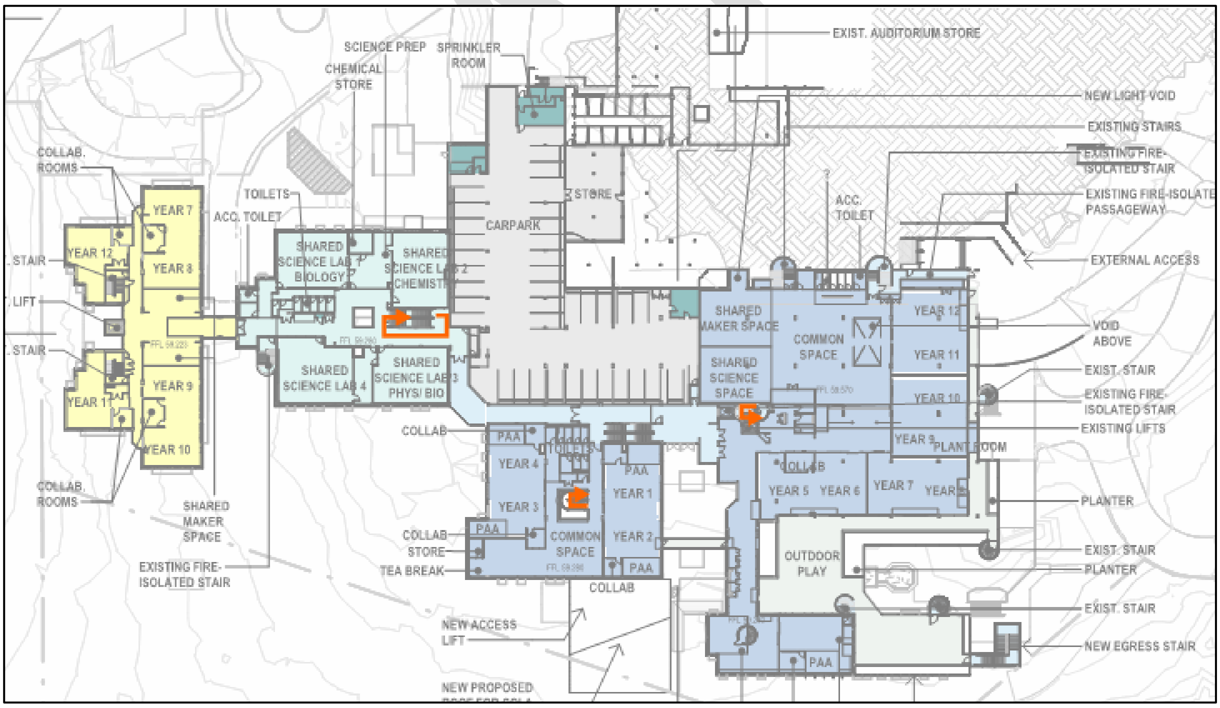

Figure 39 – Path of travel by Occupants on Level 2 from Level 3 to Level 4.

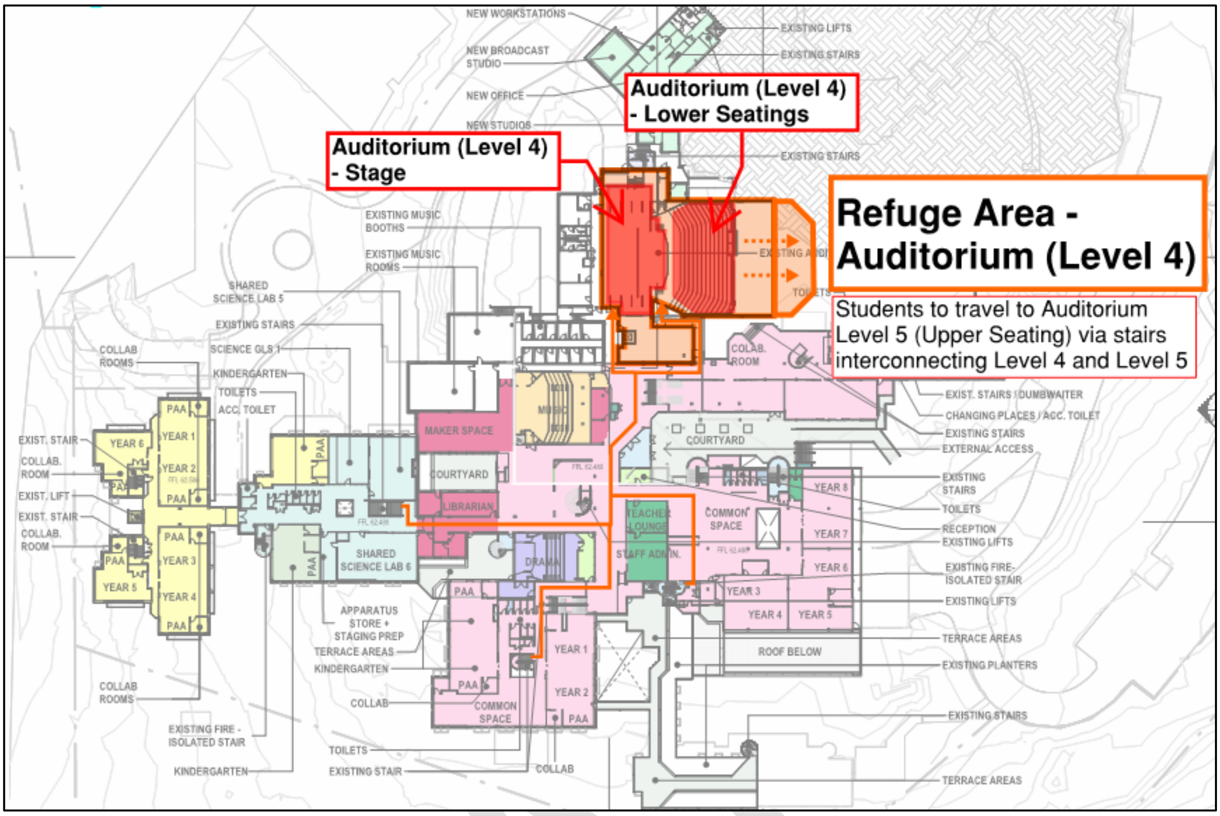

Figure 40 – Path of travel by Occupants on Level 2 from Level 4 to Auditorium (Refuge Area) and to Level 5.

F.3 OCCUPANTS ON LEVEL 3

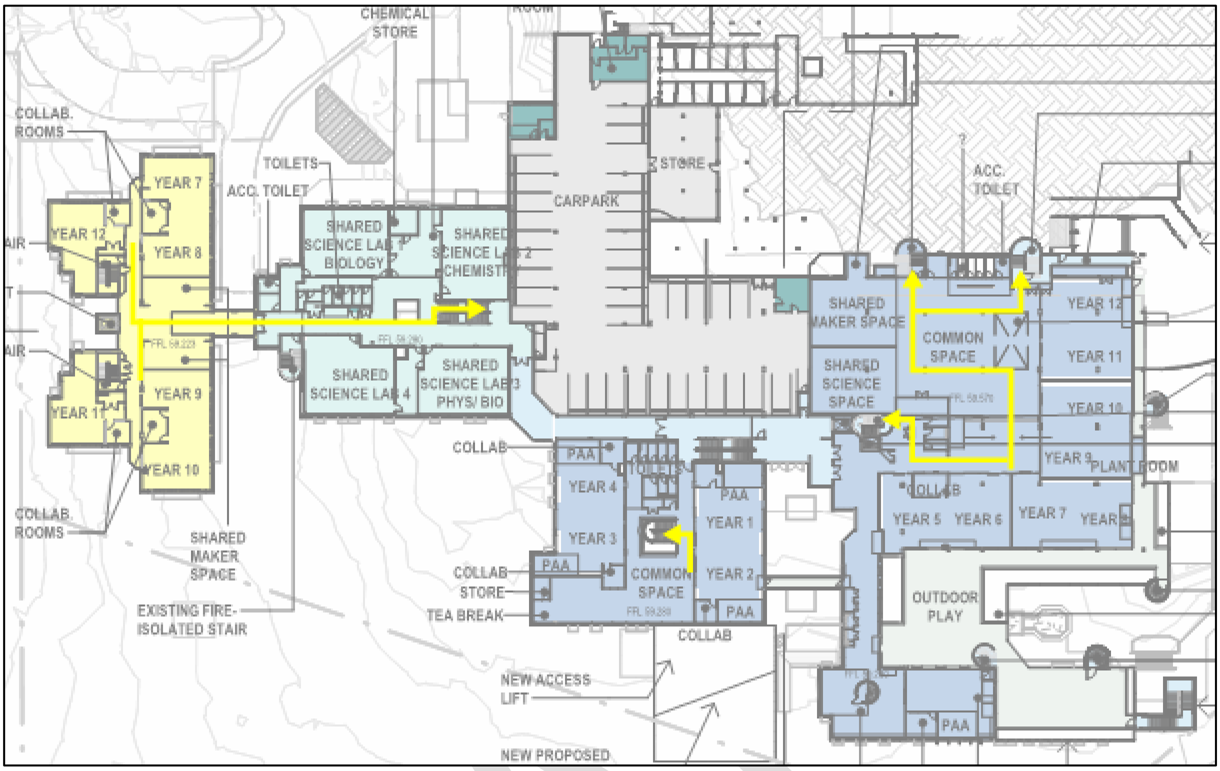

Figure 41 – Path of travel by Occupants on Level 3 from Level 3 to Level 4 (shown in yellow colour arrow).

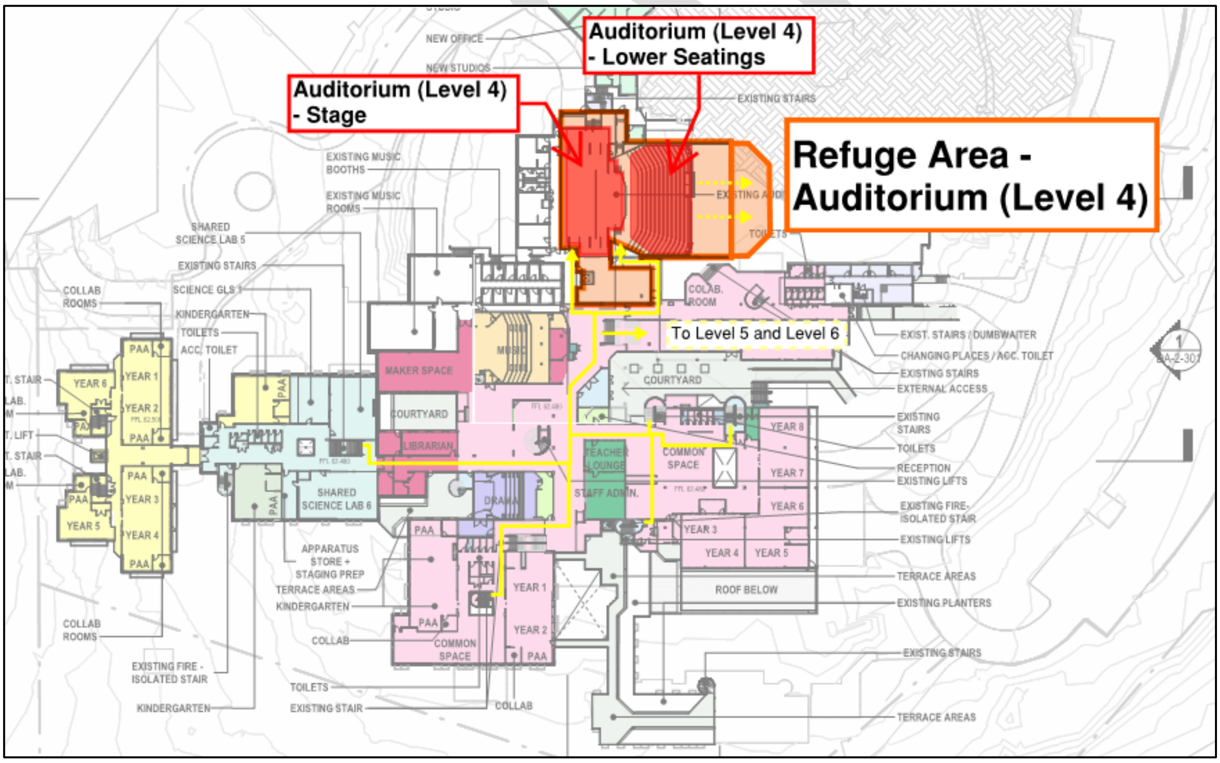

Figure 42 – Path of travel by Occupants on Level 3 from Level 4 to Auditorium (Refuge Area) and to Level 5.

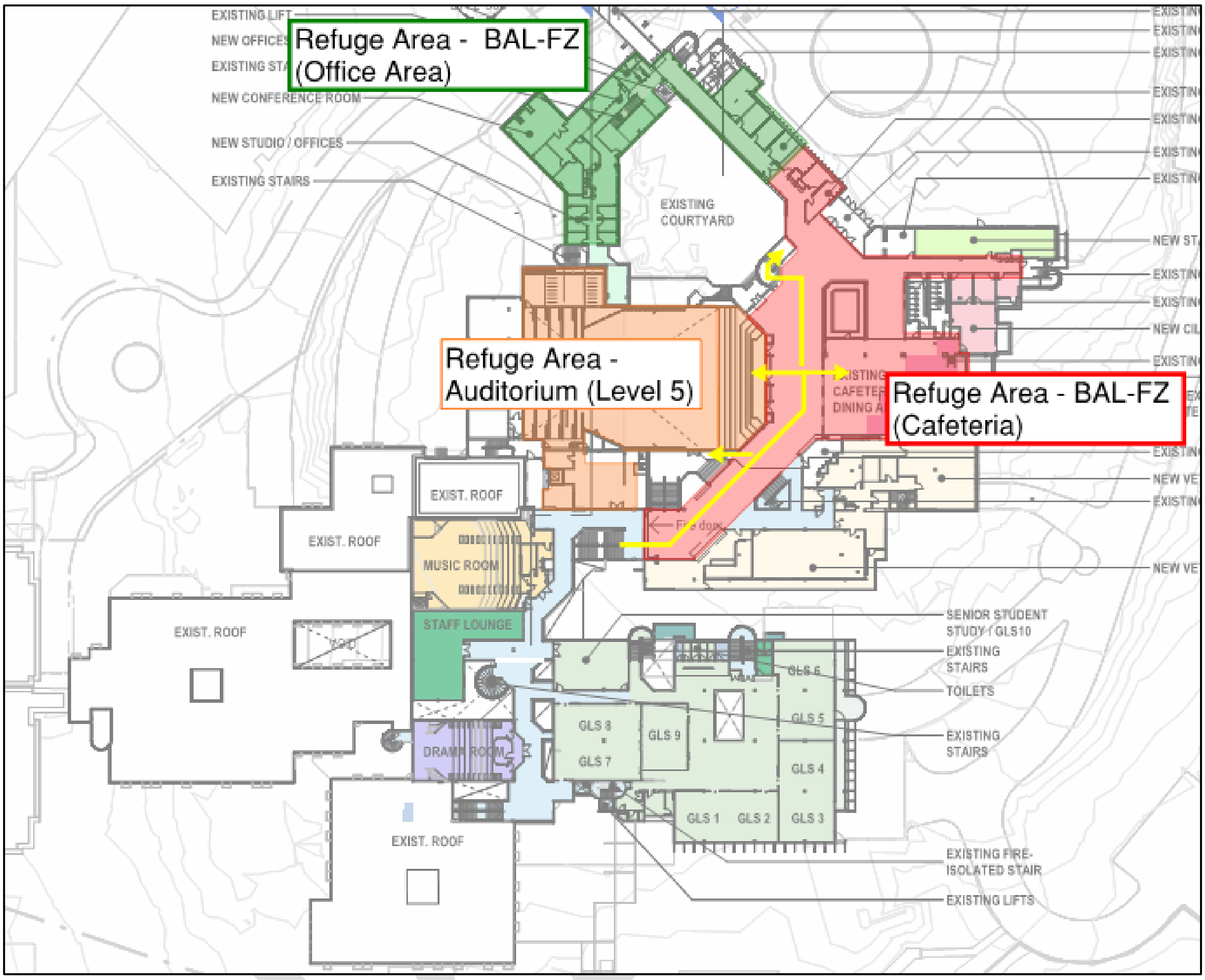

Figure 43 – Path of travel by Occupants on Level 3 from Level 5 to Auditorium (Refuge Area) and to Level 6.

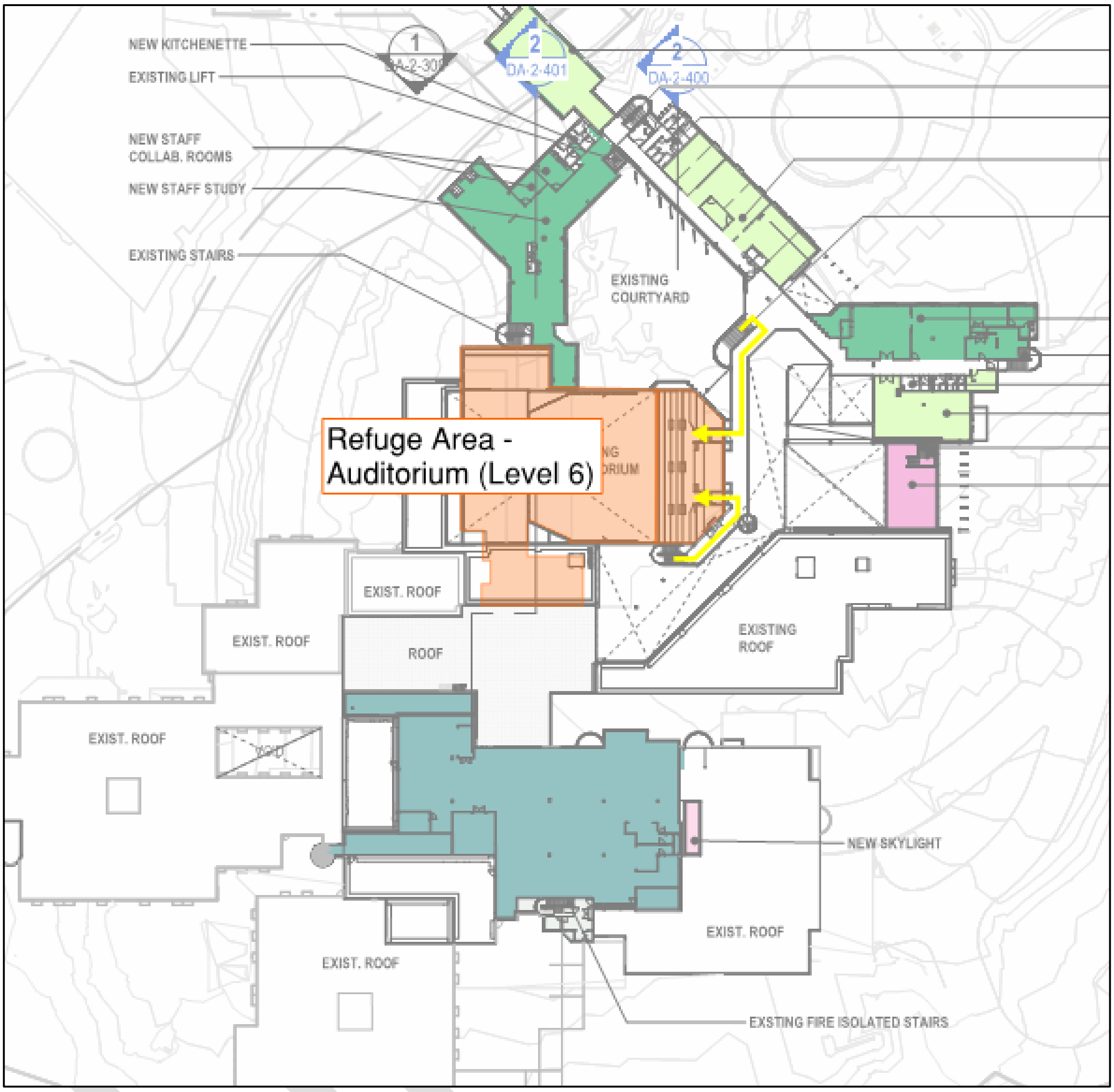

Figure 44 – Path of travel by Occupants on Level 3 from Level 6 to Auditorium (Refuge Area).

F.4 OCCUPANTS ON LEVEL 4

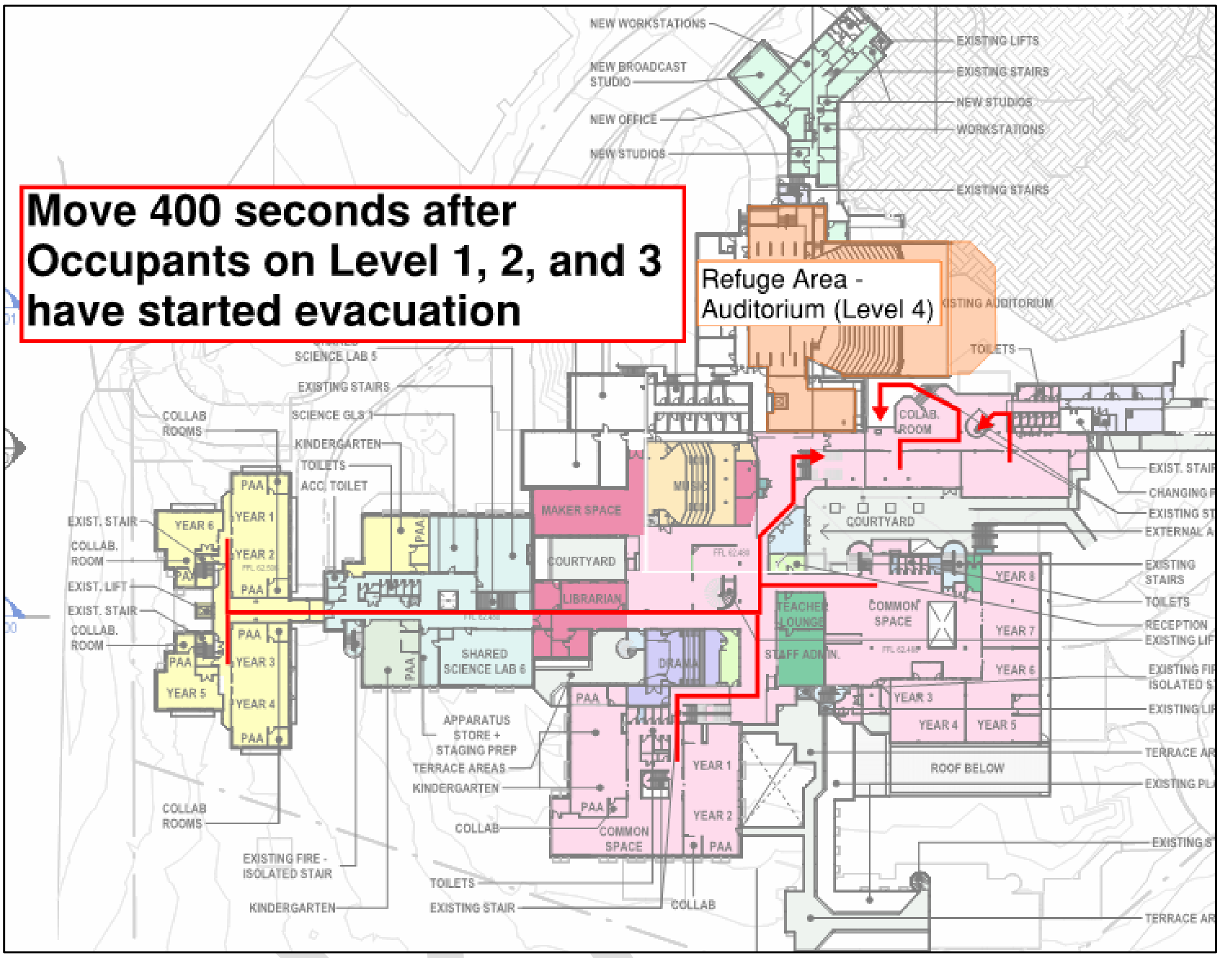

Figure 45 – Path of travel by Occupants on Level 4 from Level 4 to Level 5.

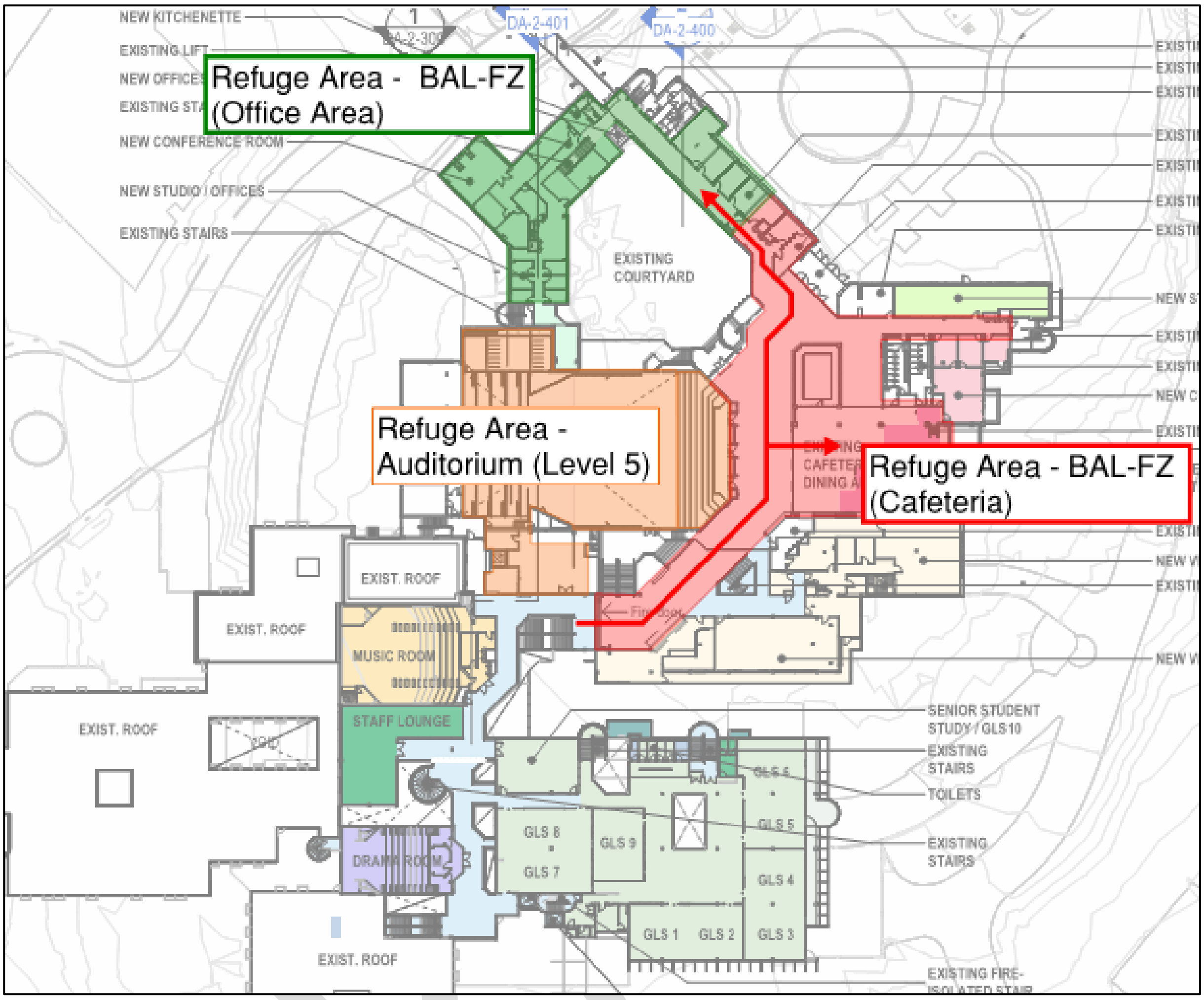

Figure 46 – Path of travel by Occupants on Level 4 from Level 5 to BAL-FZ refuge area (Cafeteria and Office Area).

F.5 OCCUPANTS ON LEVEL 5

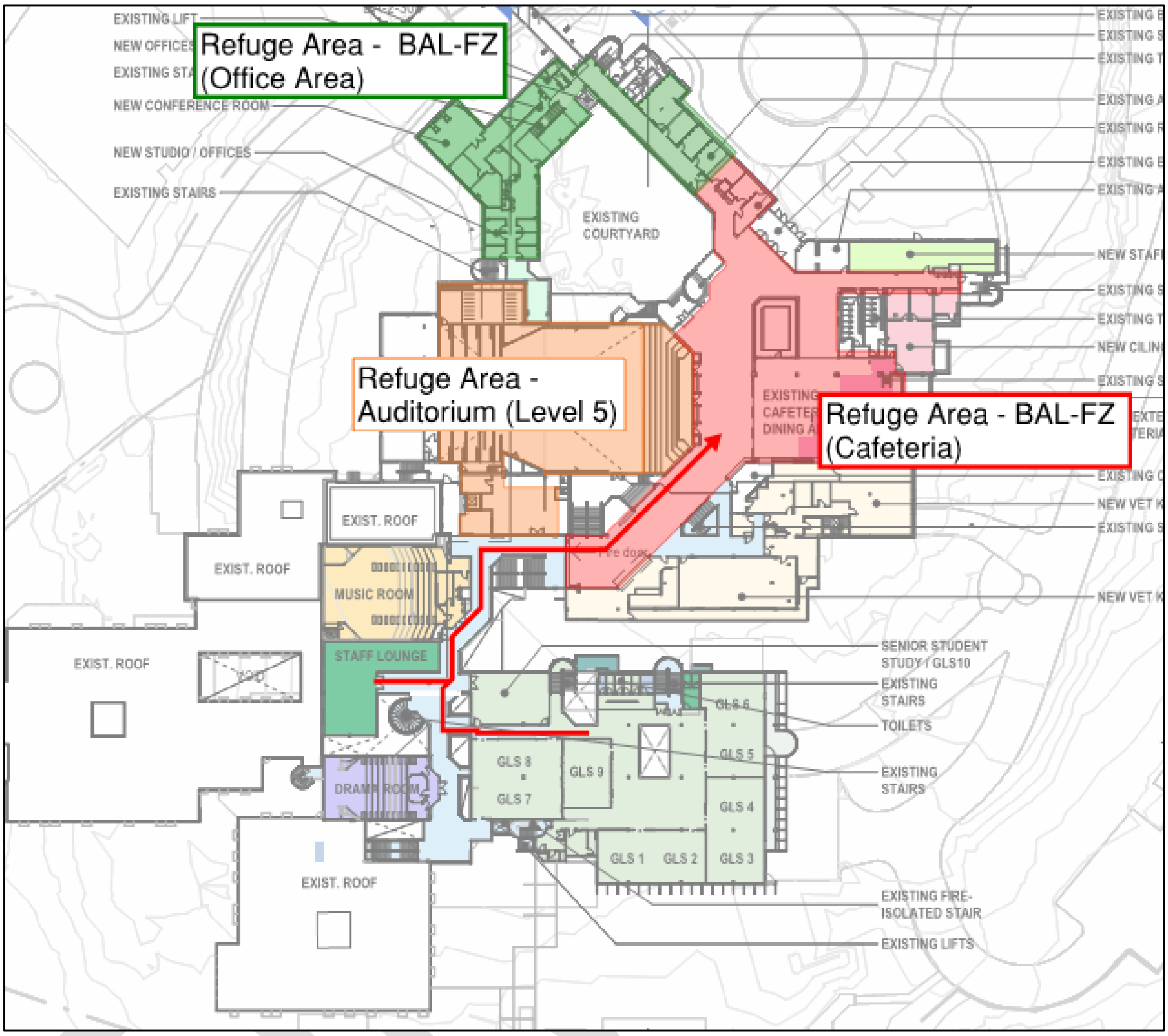

Figure 47 – Path of travel by Occupants on Level 5 from Level 5 to BAL-FZ refuge area (Cafeteria and Office Area).

F.6 OCCUPANTS IN GYMNASIUM

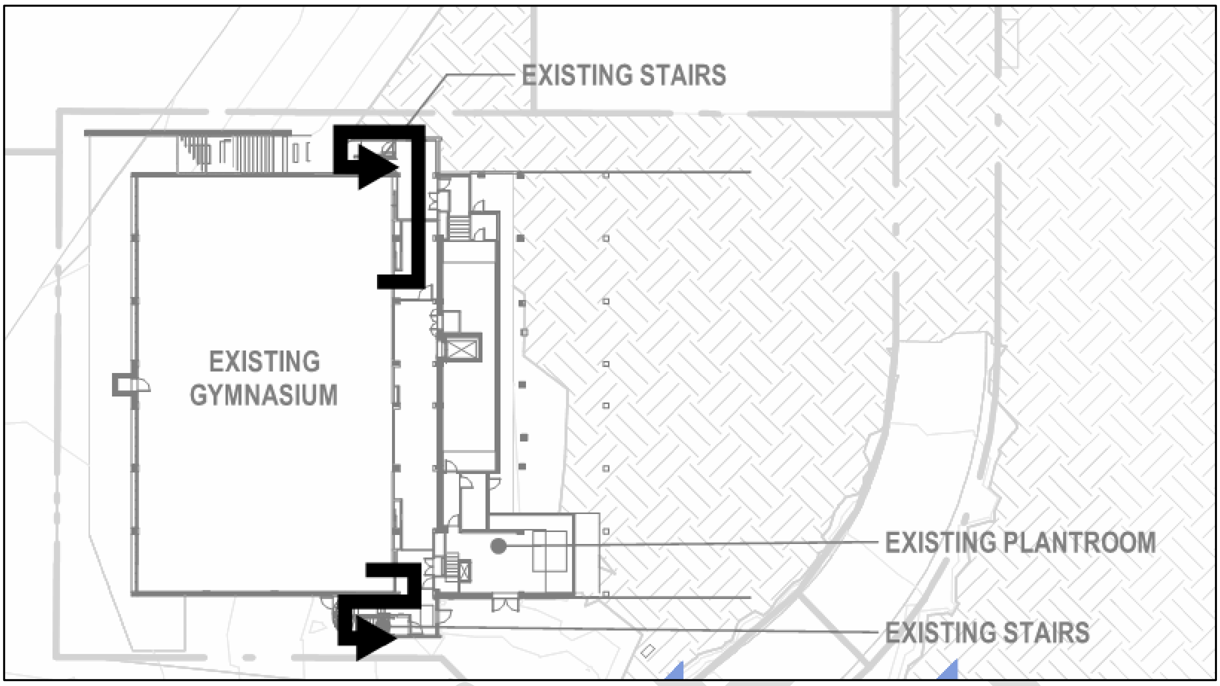

Figure 48 - Path of travel by Occupants in Gymnasium (Level 4) to Gymnasium Corridor to 'External Bridge' on Level 5.

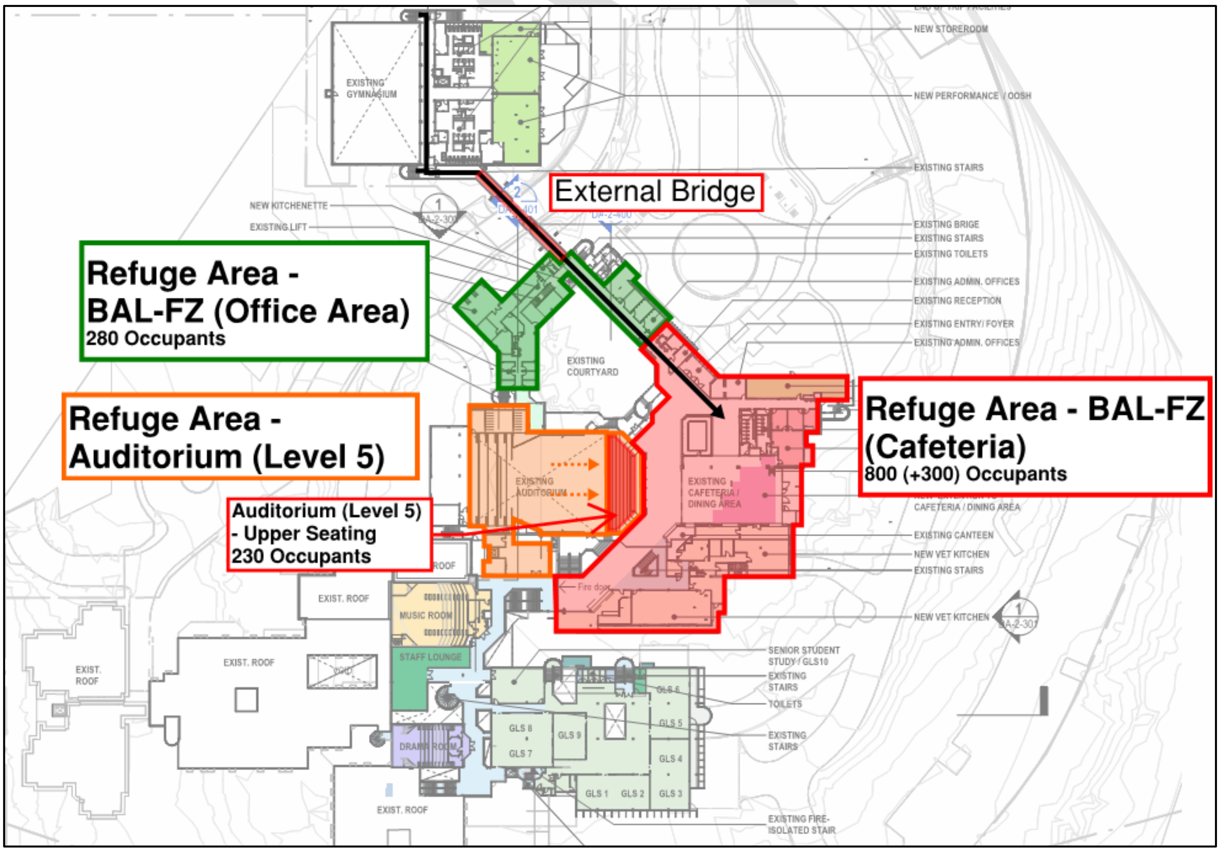

Figure 49 - Path of travel by Occupants from Gymnasium to Refuge Area via external bridge.