WASHINGTON
UNION STATION
STATION EXPANSION

Draft Environmental Impact Statement for Washington Union Station Expansion Project

Appendix A3d – Final Concept Development and Evaluation Report Appendix D: *Supporting Station Infrastructure (Fire, MEP, and Structural) Information for Concept Development*

U.S. Department of Transportation
Federal Railroad Administration

July 13, 2016

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WASHINGTON UNION STATION

STATION EXPANSION

Appendix D

Supporting Station Infrastructure (Fire, MEP, and Structural) Information for Concept Development

Task 2.3D

July 13, 2016

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Contents

Introduction

Scope of work, including coordination with Terminal Infrastructure

This report discusses the initial Concepts for the engineering systems for the Station Expansion Project (SEP) at Washington Union Station (WUS).
The intention of this document is to summarize the significant engineering systems which support the development of the Concepts. The following issues are addressed:

1. Conceptual approaches to egress
2. Above grade structure grid in support of the SEP
3. Accommodation of structure for the adjacent development at Burnham Place and H Street Bridge
4. Structural depth allowances
5. Train Hall ventilation strategy
6. Below grade ventilation strategy
7. Enabling construction of future below ground tracks and platforms
8. Demonstrating passive and active energy conservation measures

Regarding item 7, above, the Additional Below Grade Track (BGT) is no longer being considered as a project element. Please refer to the Executive Summary for a description of the current status of the BGT options. However, although no longer considered to be required on operational grounds, the structural and systems implications of this potential program element were evaluated during concept design and are therefore recorded in this report. The scope of this report is for the engineering systems and infrastructure for the building, in support of the tracks and platforms which are part of the Terminal Infrastructure (TI) Plan, which is being designed by AECOM. TI plans are developing alongside SEP, and therefore are also at a conceptual phase. They are current to this point in time only.

SEP and TI are coordinated, such that the needs of the rail set out in TI, are met by the infrastructure set out by SEP. The demarcation between TI and SEP is addressed within the individual report sections.

Ongoing upgrades to engineering systems within the historic station and Claytor Concourse are ongoing, and do not impact upon the development and comparison of the range of Concepts, and are therefore not included in this report.

Scope of work in relationship to other adjacent development

BURNHAM PLACE

The platforms and tracks are located below the air rights for a future private development, referred to as Burnham Place (BP). SEP is intended to not preclude this development. The project therefore, includes engineering systems to support the Concepts, such as the following:

1. Vertical structures and foundations, coordinated with the platforms and tracks, which also supports the platforms and floors below.
2. Track and platform ventilation, as a consequence of the deck above. Note that the fan associated plants will need to be coordinated with the buildings above.
3. Life safety systems, as a consequence of the deck above.
4. Generators, providing backup power to the systems listed above and below as a consequence of the deck above
5. To support WUS chillers, cooling towers would be accommodated in an external location, currently proposed to be accommodated at deck level.
6. Routes for utility services would be coordinated with the tracks and platforms.

H STREET BRIDGE

H Street Bridge, a six-lane vehicular bridge, spans over the rail yard connecting North Capitol Street with Third Street, NE. It is an independent structure and was constructed in the 1960s and rehabilitated in the 1970s. It is a steel bridge with a concrete deck supported on structural steel beams and columns. For the majority of the bridge length, the steel columns bear on large diameter concrete piers and pile caps. The transition from steel to concrete nominally occurs at the track elevation (the H Street underpass). The large diameter (greater than six feet) concrete piers pass through the H Street underpass level. The pile caps are supported on steel encased concrete piles, approximately 50 feet deep. At East and West ends of the bridge, the bridge girders are supported directly on concrete piers and footings.

The bridge currently serves pedestrian, vehicular traffic including buses and trucks, and the street car route which terminates on the bridge. The bridge was designed to AASHTO Standard Specifications for Highway Bridges, 1969 with Live Load HS 20-44 vehicle plus impact.

The bridge is inspected regularly by the District Department of Transportation (DDOT). DDOT reports the deck and steel structure need to be replaced but the columns/ piers are in good condition. The bridge has been repaired several times, and is anticipated to be replaced by DDOT in the near future independent of but in coordination with the redevelopment of WUS.

The H Street Bridge reconstruction would need to be coordinated with any updated track layouts. Additionally, it is recommended that the design of its new super- and sub-structures be architecturally coordinated with the design team for the SEP as the bridge occupies an important space within the redevelopment –immediately above the new platforms and passenger concourses, with significance for the character and quality of these public areas as well as other above and below grade areas.

Relationship to coordinated documents

TVRA

A threat and vulnerability risk assessment (TVRA) is underway, which has informed the planning and structural design scenarios in particular. Due to the sensitive nature of the methodology and findings, its content is not summarized in this report.

The TVRA would define threat and performance criteria. The following items would be outputs of the TVRA and may affect the structural design of the project.

- Force Protection (Blast)
- Progressive Collapse

Other outcomes of the TVRA will affect other planning aspects of the SEP and will be coordinated in the subsequent phases of design.

DESIGN CRITERIA REVIEW

Design Criteria Review reports are used to memorialize the Basis of Design (BoD) parameters with which the SEP Concepts should comply.

The Draft BoD, which encompasses the Structural Engineering, Mechanical, Electrical and Plumbing (MEP), Fire Engineering, has been submitted as a separate document and contains information on the following:

1. Codes and standards
2. Owner requirements
3. Design parameters
4. Resilience
5. Existing conditions

The BoD establishes the criteria to which all Concepts must comply. This Station Infrastructure report works alongside the BoD to describe and delineate the manner by which the Concepts comply. Therefore, the BoD is an important reference document but its findings are not duplicated in this report.

Structural Engineering Concepts

Column Grid

A number of iterations of column grids were investigated with several factors influencing the results. It is important to note that there are several levels of column grids to consider. At the top is the BP grid which is transferred or otherwise superimposed onto the platform level grid. The concourse level below the track and platforms will have a different grid with the addition of columns to support the track structure. The grid at the concourse level will continue through any below-grade parking down to foundations.

PLATFORM GRIDS

The column spacing in the east-west direction is directly influenced by the track layout. Typically the east-west spacing is approximately 55 FT, centered on the platforms. The column spacing in the north-south direction is more flexible and spacing of 30 FT and 60 FT was investigated. Together two grids were investigated at the platform level, approximately 55 FT x 30 FT and 55 FT x 60 FT. Refer to Figure D-3 for platform level plan.

CONCOURSE GRIDS

Spacing for track supporting columns was considered for 30 FT and 60 FT spans to coincide with the north-south spacing of the BP supporting columns. Together the two grids combine to create an approximately 27.5 FT x 30 FT and 27.5 FT x 60 FT typical grid at the concourse level, which continues down through any below-grade parking down to foundation. The actual grid varies considerably based on location and complexity of the building geometry above. Refer to Figure D-2 for concourse level plan.

BELOW GRADE PARKING GRID

The column grid in any below grade parking levels was set at an approximately 27.5 FT x 30 FT grid in most areas, including areas where a larger approximately 27.5 FT x 60 FT grid exists above at the concourse level. This approach was considered to increase the structural efficiency in these areas where there would be minimal architectural impacts. Additionally, the tighter column spacing would make it easier to conform with TVRA requirements. Refer to Figure D-1 for typical below grade parking level plan.

LOCAL ALTERNATE CONCOURSE GRID

The concourse level will have an approximately 27.5 FT x 30 FT typical grid in non-concourse areas. Refer to Figure D-4 for typical structural section at non-concourse areas.

To enable pedestrian circulation and provide better quality of space within a prominent area of the SEP, it is advantageous to locally create an approximately 55 FT x 60 FT grid in the concourse level at a few key areas including in the vicinity of the H Street concourse as well as along the First-Street concourse.

This would be accomplished by transferring the BP supporting columns at the platform level onto the track supporting columns at the concourse level. Refer to Figure D-5 and Figure D-7 for the inverted gable and alternate modified gable transfer schemes respectively.

The inverted gable scheme would induce unbalanced lateral thrusts at the tops of the track supporting columns. These would be mitigated through a combination of increased column size and stiffness as well as potentially placing shear walls within the First and Second Street entrances. Refer to Figure D-6 for diagram indicating the induced horizontal thrust under gravity loads and how it could be resisted.

A modified gable scheme which flips the gable with a tie member at the bottom was also investigated. This essentially eliminates the issue of unbalanced lateral thrusts into the columns, and should result in a more efficient structural system. While this approach is structurally adequate, it is not preferred due to the visual impact on the passenger concourse, as it lowers the available ceiling height.

It is critical to note that neither the inverted or modified gable transfer schemes can reasonably support any air-rights buildings in the vicinity of the H Street concourse.

The magnitude of the vertical load and the relative flexibility of transfer structure would result in very deep, built-up box girders, which would impact upon the available ceiling height. Additionally, the box-girders would be assembled from heavy plates with complex connections between the members, which would be difficult to construct.

The use of either transfer scheme at the First Street concourse is less complex than at H Street, and would not restrict the footprint of the new air-rights buildings. This is because there would only be one bay of transfers at the First Street concourse, and the BP columns to be transferred would be perimeter columns, which would impose fewer loads onto the transfer structure.

Where either transfer scheme does not support new air-rights building, the magnitude of the loads is significantly reduced. This results in smaller box girders, assembled from thinner plates, with less connection complexity, which would be significantly less difficult to construct.

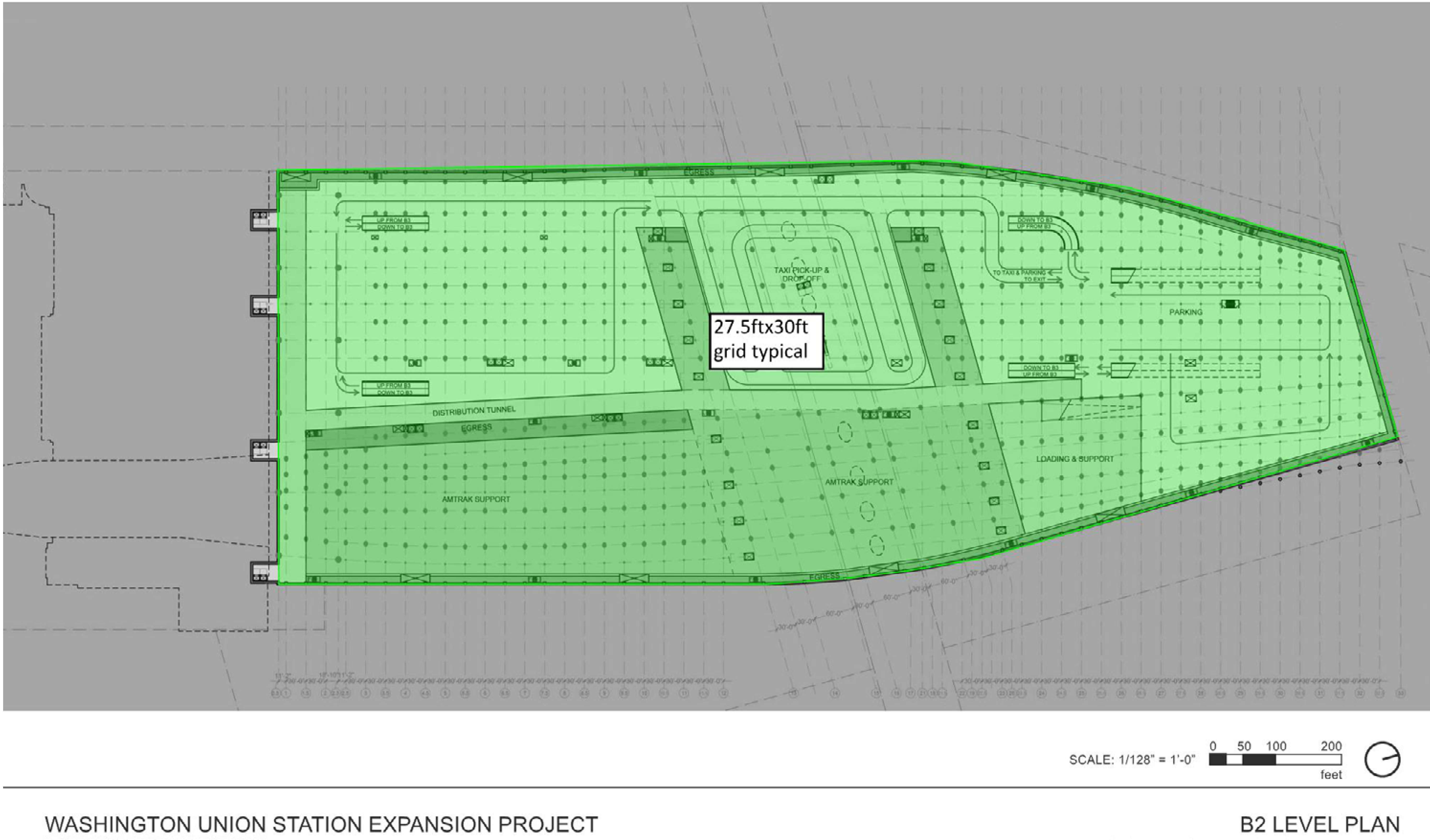
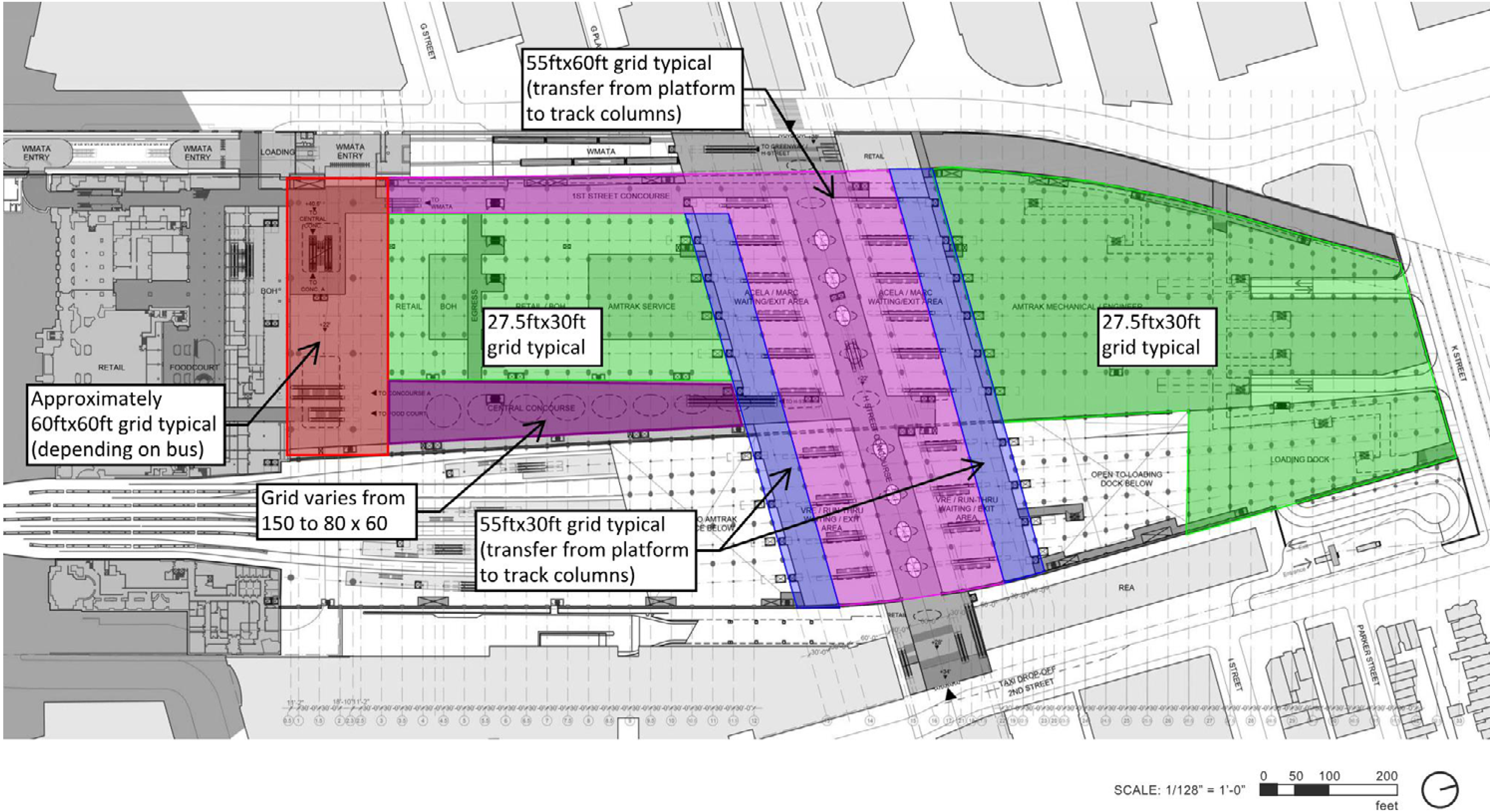


Figure D-1: Parking Grid Plan



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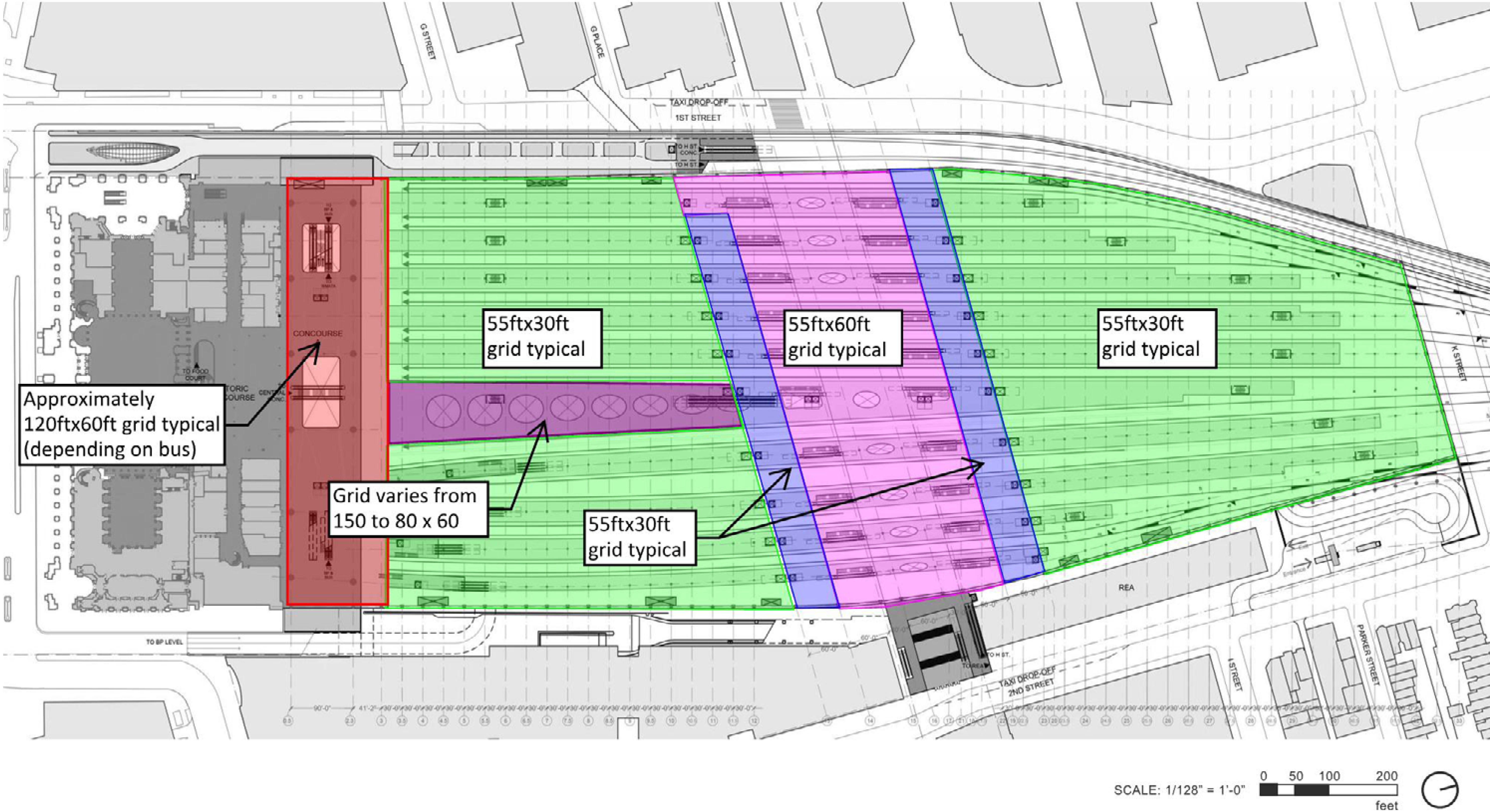
LOWER LEVEL CONCOURSE PLAN

Figure D-2: Concourse Grid Plan



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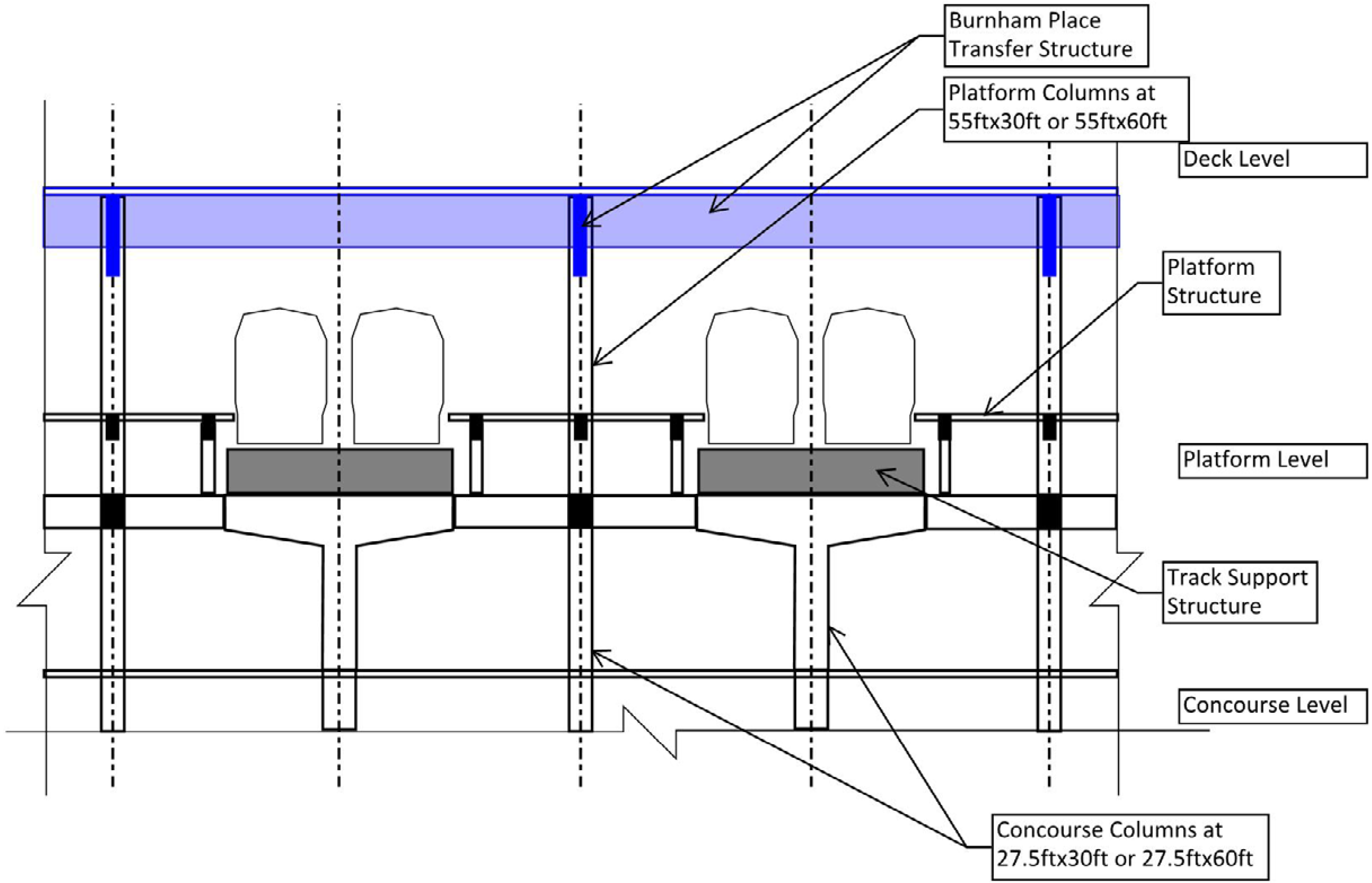
MAIN LEVEL PLAN

Figure D-3: Platform Grid Plan



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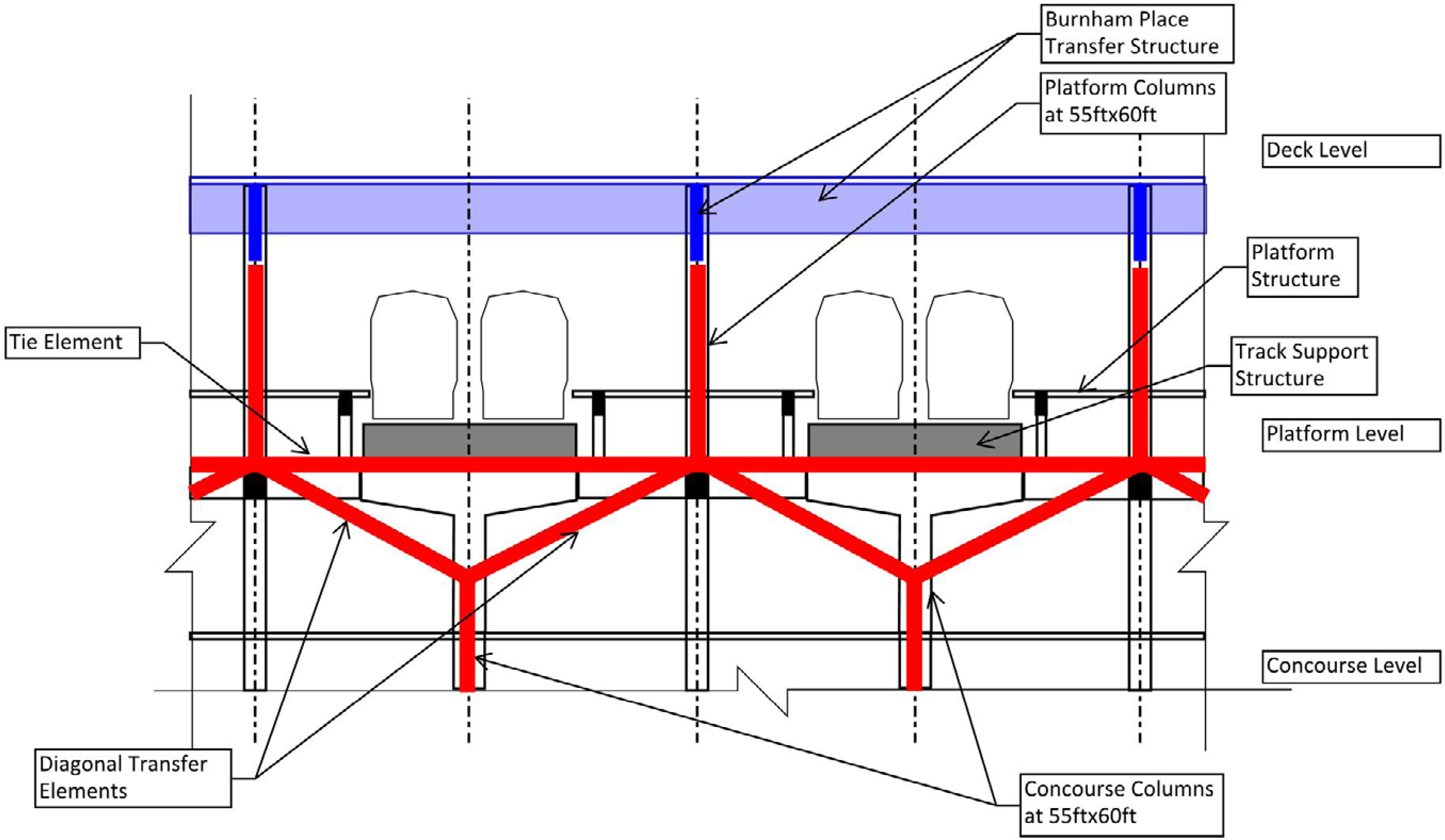
TYPICAL STRUCTURAL SECTION AT NON-CONCOURSE AREAS

Figure D-4: Typical Structural Section at non-concourse areas



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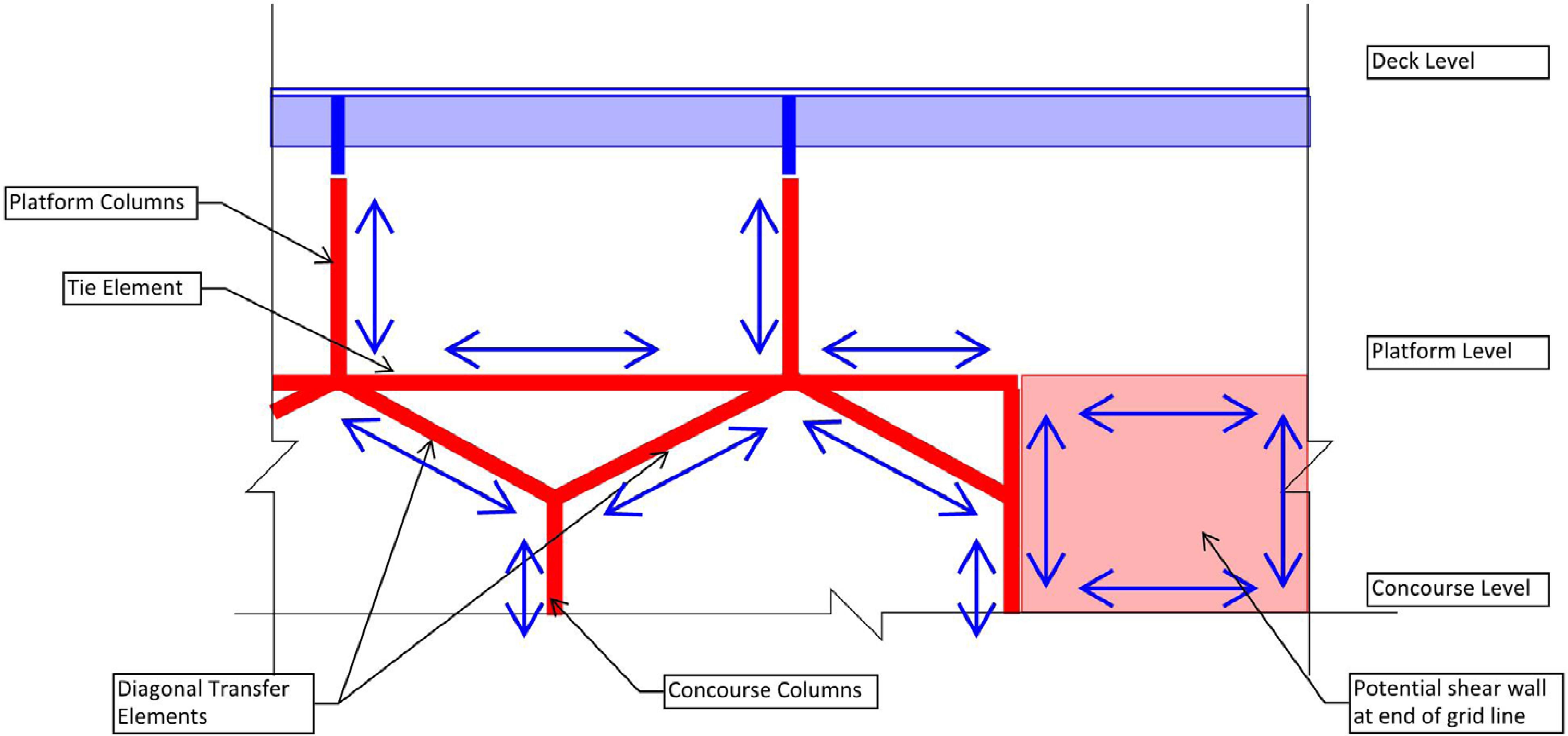
INVERTED GABLE TRANSFER SECTION

Figure D-5: Inverted Gable Transfer



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INVERTED GABLE FORCE DIAGRAM

Figure D-6: Inverted Gable Force Diagram

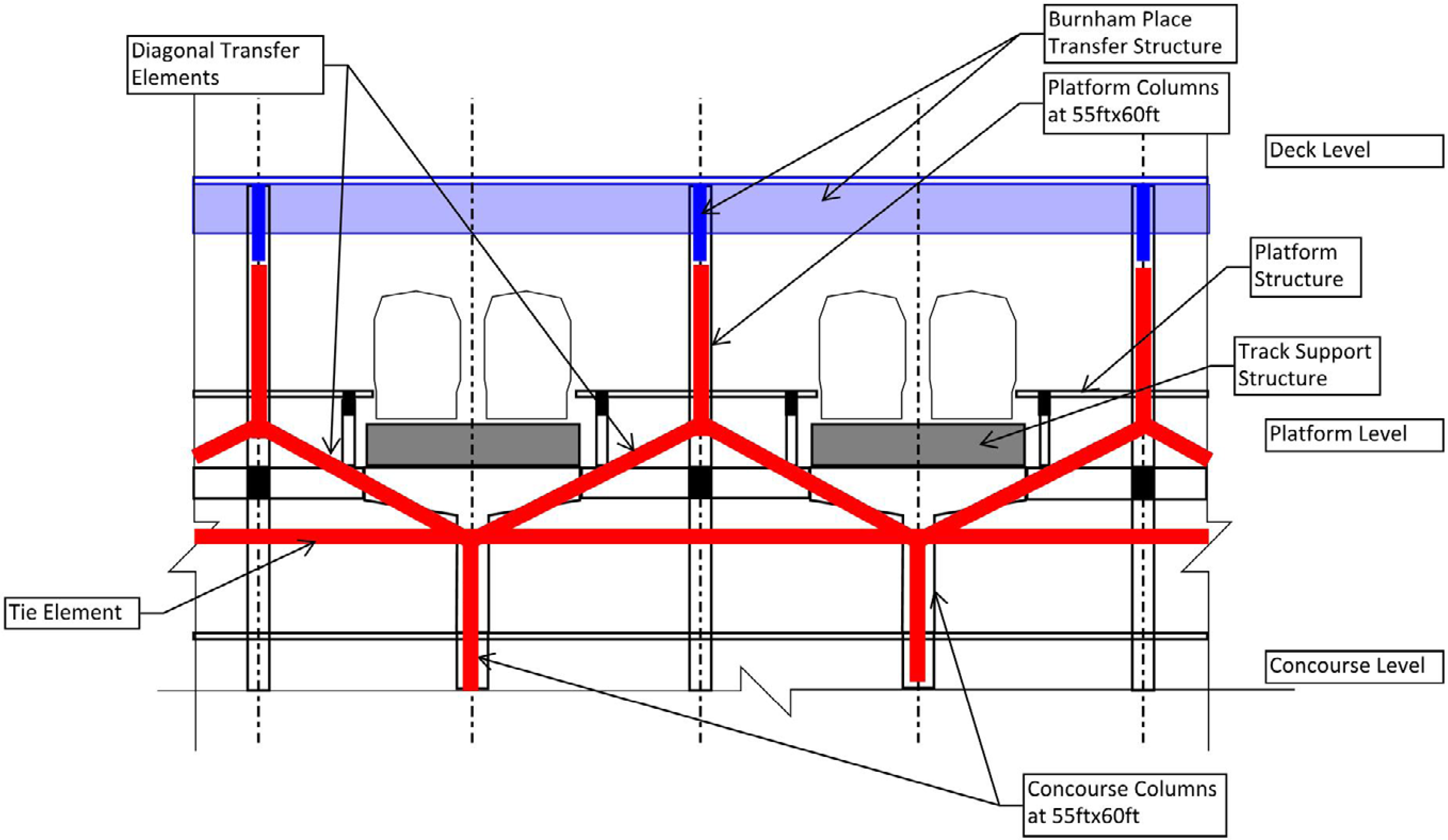


Figure D-7: Modified Gable Transfer Section

Lateral System

The lateral force resisting system (LFRS) for the SEP needs to resist lateral loads applied directly to the station as well as those imposed from any overbuild structures.

A preliminary study of the wind and seismic demands at the site found that seismic demands and requirements would generally be greater than that of wind, and thus drive the design. A final determination would be made once the exact extent of any overbuild is finalized and a geotechnical site specific seismic evaluation is completed.

The seismic force resisting system (SFRS) would consist of moment frames in each direction, which would provide the required clear spaces over the tracks and architectural flexibility in the lower levels. Structural materials would transition over the height of the structure with a primarily steel structure at the top transitioning down to a primarily concrete structure at the bottom.

The lateral system would transition from steel to composite to concrete moment frames from top to bottom of the structure. Simple 2D plane models were used to assess the forces and drifts. Refer to Figure D-8 through Figure D-10 for sample analysis outputs.

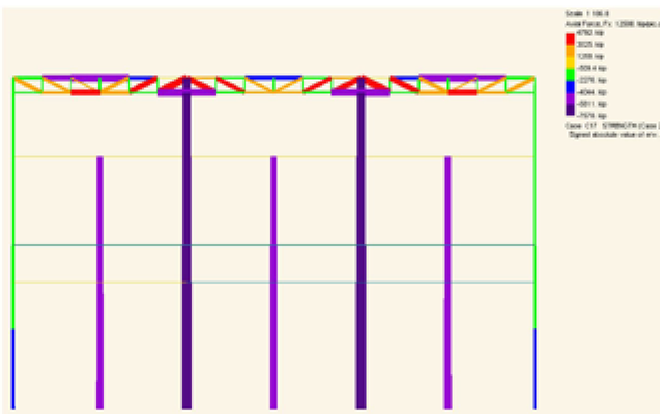


Figure D-8: Envelope Strength including Overbuild and Lateral – Axial Force Diagram

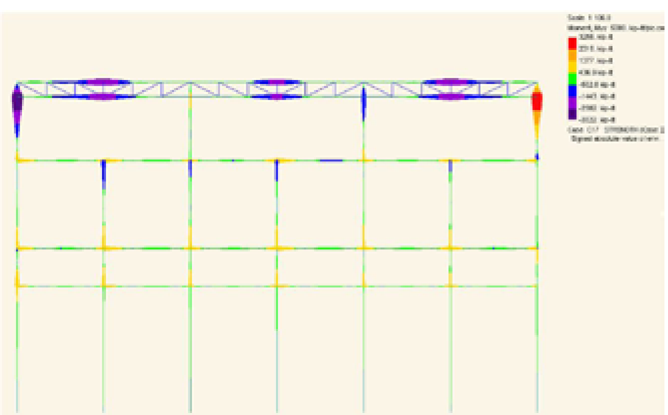


Figure D-9: Envelope Strength including Overbuild and Lateral – Moment

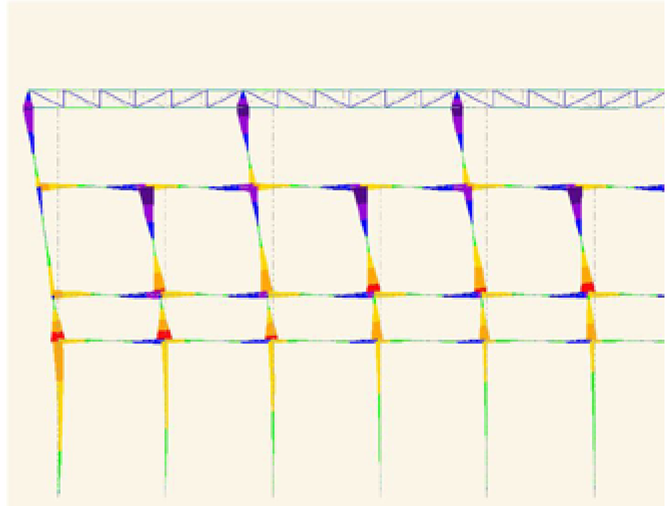


Figure D-10: Seismic Drift – Moment Diagram and Deflected Shape

Platform Column Sizes

The BP supporting columns passing through the platform were identified as a critical element in the overall design, due to their long unbraced length, large gravity loads, large lateral moments and stiffness requirements, and width limitations. The columns are limited to 36in total width including finishes. This dimension allows the columns fit between the vertical circulation elements (VCE). It may be possible to relax the maximum width requirement of the columns in areas away from the VCE in order to increase the structural efficiency. The columns were assumed to be braced at the track supporting pier level as opposed to at the high platform level which lacks the lateral stiffness required to brace the columns.

For the 55 FT x 30 FT grid, the columns could be heavy W14 rolled sections with additional welded plates or built-up box sections. For the 55 FT x 60 FT grid, the columns need to be heavy, built-up box sections with plate thicknesses on the order of 6in or more. Solid steel sections which are built-up from several laminations of welded plates may also be considered where axial loading dominates the column design. The sizes discussed above are for columns that are supporting overbuild. Columns that do not support overbuild will generally be of the same type, but with potentially significant reductions in required plate thicknesses.

In any case, the use of higher strength steel, 65-70ksi, would slightly reduce the overall steel weight of the columns. This slight reduction in material per column may prove significant when extrapolated over the entire site.

Track Supporting Structure

The design of the track layout is in progress. The track supporting structure is designed for Cooper E80 loading and consists of girders spanning between hammerhead piers. The piers would typically be spaced at 30 FT on center with local areas of 60 FT on center spacing. Refer to Figure D-1 through Figure D-3 for typical platform, concourse and below grade parking plans showing extent of each grid spacing at each level.

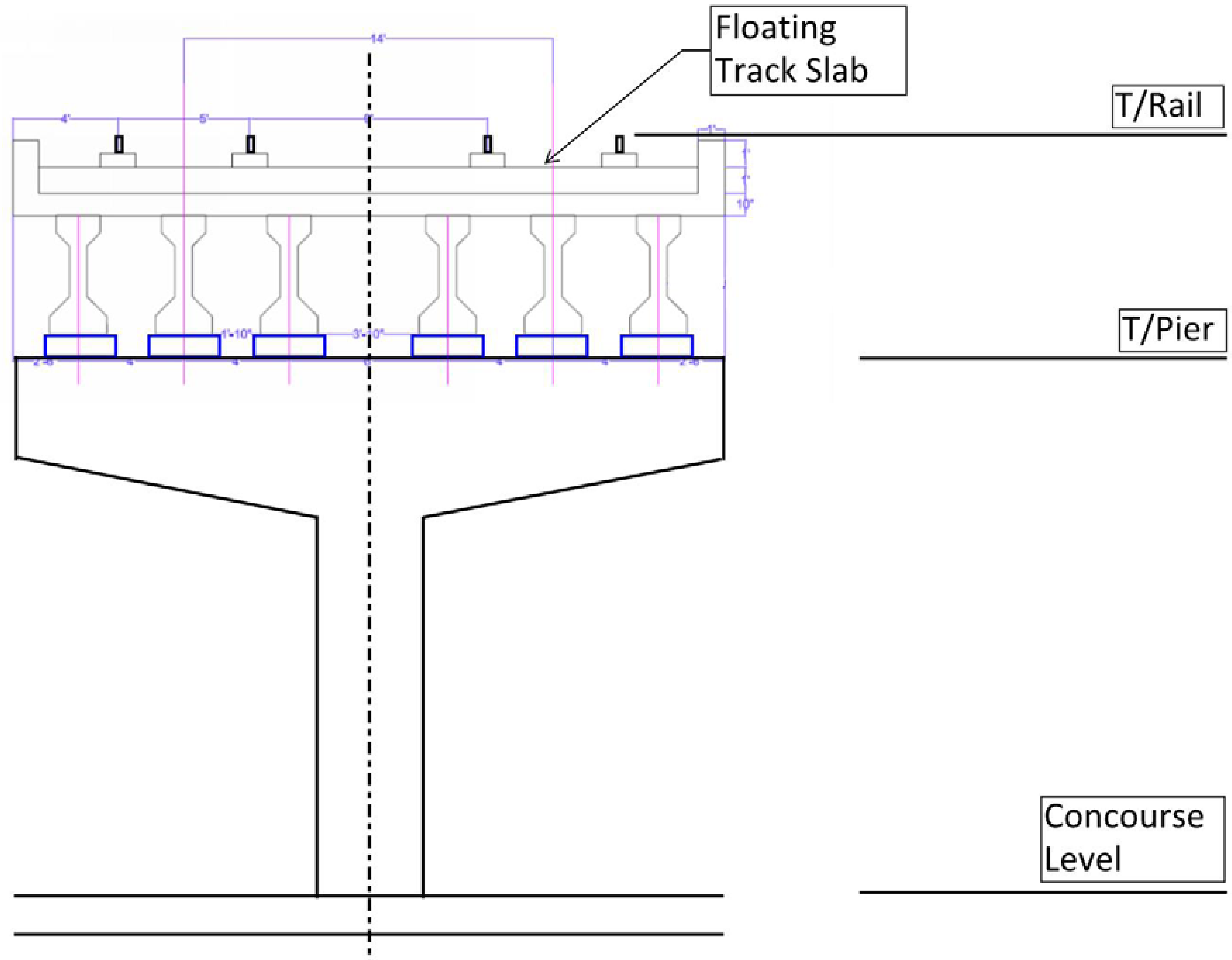
The diameter of the piers is governed by longitudinal train loading and seismic demands. The tops of pier would be braced laterally in the east-west direction to the platform columns, and the bracing beam would act as part of the moment frame in that direction. The piers would consist of large diameter concrete columns approximately 6 FT diameter. Steel sections may be embedded to reduce the required diameter.

It may be desirable to add bracing or moment frame beams between piers in the north-south direction along the tracks as well. This would distribute longitudinal train loads and demands in that direction to multiple piers, and potentially reduce the required diameter. For now they are assumed to work as cantilevers up from the level below.

Girders would span between the piers to support the tracks. For preliminary design we have considered using simple spans, as preferred by Amtrak, with girder depth on the order of span/10 to span/12. It may be possible to reduce the girder depth to span/14 or span/16 for continuous spans. The girders would be either steel or precast/pre-stressed concrete.

Allowance is made for floating track slabs, which may be required to meet vibration and noise criteria.

Refer to Figure D-11 for a section showing typical track support structure in non-concourse areas.



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TYPICAL NON-CONCOURSE AREA TRACK SUPPORT STRUCTURE

Figure D-11: Typical Track Support Structure Section (In non-public / non-concourse areas)

Above Grade Parking

Several of the proposed Concepts require new above grade parking. Typically the new parking is proposed to be located above and as part of a new bus structure. The new structure could have a typical uniform grid potentially at approximately 30 FT x 30 FT which transfers onto a larger bus grid. Alternatively the bus grid could be maintained continuously through the parking levels, in which case a transfer level would not be required.

The new parking would be subject to TVRA requirements which would dictate the design and be resolved in a later phase of design.

The structure could consist of cast-in-place (CIP) concrete beams spanning between CIP concrete columns in both directions, with two-way CIP concrete flat slabs spanning between the beams. Alternatively, the use of pre-cast, pre-stressed or post tensioned elements may be considered to replace the two-way flat slab.

Bus Structure

The new bus structure is proposed to consist of one or two levels above grade. In several Concepts, above grade parking is proposed to be above and supported on the bus structure.

Options for a below grade bus facility were considered but dismissed for several reasons as described in the subsequent “Engineering approaches considered but dismissed” at the end of this Appendix D.

The structure would consist of cast-in-place (CIP) concrete beams spanning between CIP concrete columns in both directions, with one-way CIP concrete beamed slabs spanning between the beams. Alternatively, the use of pre-cast, pre-stressed or post tensioned elements may be considered to replace the beamed slab.

The column grid within the bus varies depending on location considered and layout. A transfer structure would likely be required between the bus structure and the station columns. Alternatively, it may be possible to arrange columns through the bus level in such a way to avoid needing a transfer structure.

Train Hall

All Concepts include a Train Hall proposed to be located south of H Street.

The Train Hall structure would consist of long-span steel roof structure, either trusses, I-beams or complex AESS shapes, spanning to perimeter columns. The lateral system would consist of moment frames in each direction, although there may be opportunity to add diagonal bracing in the perimeter walls. Diagonal bracing may also be added within the roof to stiffen the diaphragm if required.

Existing Parking Structure

The existing parking structure (USPG) is proposed to be removed in all Concepts under consideration. As described in detail below, this proposal is due to its lack of clearance height, impact on track layout, difficulty of in situ modification to fit within a revised track layout, and overall difficulty in complying with TVRA requirements.

- The USPG is a six-level structure consisting of post-tensioned concrete floors supported on several story deep steel transfer trusses.
- The first level of the USPG is immediately over the existing tracks and platforms, and the existing clearances are less than those requested by Amtrak.
- Large diameter columns supporting the USPG pass through track level, limiting opportunities for the Terminal Infrastructure team to revise the track layout. Any new track layout would most likely require modification to the USPG column layout.
- The SEP structural analysis concluded that modification of the existing column locations to fit within the new track layouts would be extremely difficult with significant impacts to scheduling due to the need relocate the majority of the existing foundations, as well as the need to significantly modify the superstructure framing to span to the new support locations.
- The requirements of the TVRA would also be difficult to accommodate within the existing structure as it is non-redundant by nature of the structural system, and is therefore at an increased risk for progressive collapse. Modification to the structural system to either add redundancy or provide force protection at elements would be difficult and would affect the operational performance of the USPG.

Foundations

Criteria for the design of foundations, retaining walls, and other subgrade elements shall be established by a soil investigation performed by a geotechnical engineer licensed in the District of Columbia.

A preliminary site-wide geotechnical investigation is being undertaken by the Amtrak team.

COLUMN FOUNDATIONS

We anticipate that pile foundations socketed into rock would be required at all column locations. Representative foundation reactions for BP and track supporting columns at different spacing are given in Table 1.

COLUMN	GRID/ SPACING	D+L (KIPS)	$D+L_{REDUCED}$ (KIPS)
BP Supporting	30 FT x 60 FT	6950	6475
BP Supporting	60 FT x 60 FT	12520	11590
Track Supporting	30 FT	3640	3610
Track Supporting	60 FT	5320	5290

Table D-1: Representative Column Foundation Reactions

The BP supporting column reactions are calculated for an 11-story overbuild and four (4) stories of below grade public parking. The track supporting column reactions are calculated for two trains over a pier, located for maximum effect, with four (4) stories of below grade public parking.

Live load reduction was considered only at the overbuild levels and below grade parking levels. Live load reduction was not considered at the deck, platform or concourse levels. The use of live load reduction does not appear to result in a significant reduction in foundation demands.

It is understood that the K Street Bridge will not be affected by the SEP and is to remain in place. It appears to have been designed to support E50 loading as opposed to E80 and it is located such that all trains entering the station will cross over it.

Recalculating the foundation reactions listed in Table D-1 above for E50 loading as opposed to E80 reduces the dead + live (D+L) reaction for the 30 FT and 60 FT spaced track supporting columns by 630kips and 1040kips respectively. This represents approximately 17-20% total foundation load reduction at those locations.

Given the magnitude of the load difference this is something that can be revisited in later phases, once the required geotechnical information is available.

SUPPORT OF EXCAVATION (SOE)

Criteria for support of excavation (SOE) shall be established by a soil investigation as noted above, by Amtrak.

Preliminary SEP analysis indicates that secant piles or slurry walls around the perimeter of the exaction with tie-backs as needed will be required to support the proposed SEP. Care will need to be taken adjacent to WMATA and other structures around the site.

Depending on the type of SOE and waterproofing strategy, it is unlikely that the SOE walls would be used to vertically support the edge of the station structure. A line of structural columns would be located along the perimeter, inboard of the SOE to support the edge of the structure.

Note that the SOE along the southern edge of the site, adjacent to the historic concourse, will be offset nominally towards the north to avoid any conflicts with the existing foundations for the historic concourse. A similar offset may be required adjacent to the K Street Bridge and along WMATA.

Interface between Burnham Place and Station Structure

The platform columns would support gravity and overturning loads resulting from BP. BP would need to coordinate exactly how their structure would transfer to the station structure with the SEP team. The private overbuild would also be required to conform to the TVRA requirements. Refer to Figure D-12 for typical scope demarcation.

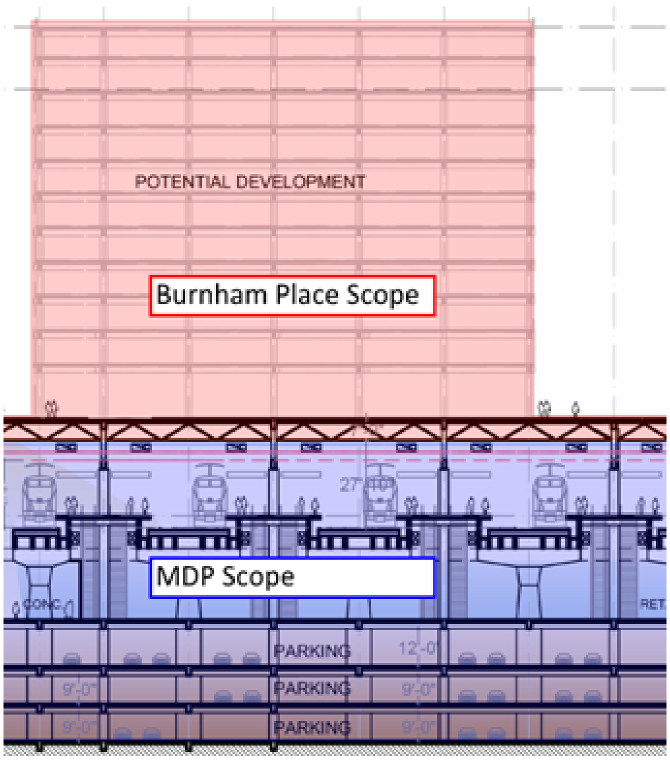


Figure D-12: Section Delineating Burnham Place from SEP Scopes

VERTICAL LOAD TRANSFER

A number of transfer schemes have been explored to transfer the vertical loads of the overbuild onto the station columns. All are feasible and work with the proposed Concepts.

1. Below deck two-way transfer structure
   a. No or minimal restriction on overbuild column grid
   b. Two-way beam and girder transfer system below the deck consisting of trusses in each direction to transfer vertical reactions to station columns
2. Below deck one-way transfer structure
   a. BP columns in the east-west direction land on the north-south running grid lines of the station columns. No restriction on north-south BP column spacing
   b. One-way girder transfer system below the deck consisting of trusses spanning north-south along the length of the platform, where there is less restriction on truss depth than over the tracks
      i. Should result in more efficient truss design
3. Above deck transfer structure / no transfer
   a. Transfer structure located at first overbuild level which lands the BP
   b. Columns directly on the station columns below
   c. Alternately provide no transfer structure and instead match the station column layout below.

Scheme 1 as discussed above is what is reflected in the SEP documentation, as it would provide the most flexibility for the overbuild, and is seen as the most likely choice. The final choice of system would be verified together by the SEP and BP design teams at a later date.

INTEGRATION OF LATERAL SYSTEMS

The station lateral force resisting system (LFRS) would consist of moment frames as discussed previously. The LFRS for any overbuild could consist of either moment frames, braced frames, or core walls.

The choice of LFRS for BP and how to transfer it into the station structure would be verified by the BP design team in coordination with the SEP design team at a later date.

Interface between H Street Bridge and Station Structure

H Street Bridge spans east to west over the rail yard and bisects the site. It is an independent structure with a steel superstructure supported on steel columns which transition to large diameter concrete piers at track elevation (the H Street underpass) and are supported on pile caps. The pile caps are supported on steel encased concrete piles, approximately 50 feet deep. It is anticipated that the existing bridge would be replaced by DDOT in the near future. Any reconstruction would need to be coordinated with the updated track layouts and future below grade spaces as part of the SEP.

All Concepts include one or more stories below the top of existing bridge pile cap. As a result, in all instances the existing bridge foundations will need to be removed and relocated prior to completion of the SEP. Subsequent coordination with DDOT is required to coordinate the interface between SEP and H Street Bridge. However, SEP analysis has considered several ways to sequence the alignment of reconstruction between the two projects, to be discussed with Amtrak and DDOT:

- Defer completion of any bridge reconstruction until after the SEP is underway.
- Replace/rehabilitate the superstructure of the bridge as required now, supported from the existing columns and foundations, then do a complete replacement of the entire bridge during the SEP.
- Replace the superstructure of the bridge now, supported from the existing columns and foundations, but design the superstructure in such a way that during the SEP, the recently replaced superstructure can remain in place and be re-supported off the new SEP structure.

The H Street Bridge falls within the heart of the SEP. In each construction sequence identified above, the final configuration of the H Street Bridge should be integrated with the SEP such that the bridge superstructure is supported from new SEP structure as opposed to its own independent piers and foundations. This approach is critical to the quality of space and functionality of the H Street concourse and results in a bridge that does not require new independent piers or foundations, which should also positively affect the schedule and cost. One approach is to have the new bridge girders supported on beams spanning between station columns. In this case the scope demarcation between H Street Bridge and station infrastructure would occur at the top of the station beam, directly below the bridge girder bearing.

Supporting the H Street Bridge from the SEP structure would eliminate the additional foundation work that would otherwise be required to support the bridge on independent piers and foundations. An integrated approach would also help address potential thermal and waterproofing issues associated with an independent structure above.

Interface between WMATA and Station Structure

The Washington Metropolitan Area Transit Authority (WMATA) Metro Red Line traverses the West side of the property. As the tracks run North, the subgrade station box transitions to two single tubes and then to above grade tracks on ballast.

SEP SOE would need to be coordinated with WMATA. Additionally, temporary shielding or permanent construction over the tracks will likely be required early in the construction process to minimize constraints due to WMATA limits on allowable construction activities over active tracks.

There is an approximately 60 FT long bridge structure which supports the WMATA ballast and tracks as they cross over the H Street underpass. This bridge is supported at the underpass retaining walls, which act as abutments, as well as two interior column bents consisting of several columns each with girders spanning across the tops, which support the bridge beams.

These columns would be removed in order to make way for the First Street entrance. It is likely that the superstructure of the bridge will need to be replaced in order to facilitate removal of these interior supports.This could be done by removing a portion of the bridge to do full reconstruction, one track at a time and would therefore impact upon operation to WMATA. An alternative scheme may include reinforcing the existing bridge structure from below. This latter scheme is more complex, and less efficient resulting in deeper structure however would not significantly impact upon WMATA operation.

The choice of construction method will be reviewed with WMATA and the Constructibility Team in coming phases.

A potentially publically accessible open space could be constructed over WMATA's right of way. Columns to support this feature would be coordinated with WMATA and the structure would be located high enough to meet the required track clearances. This zone would also provide areas for the station's pedestrian access and ventilation. Further coordination would occur in later phases.

Approach to TVRA Requirements

TVRA establishes the guidelines and criteria to which SEP and BP must conform. In subsequent stages of design, SEP and BP must either design for threat-independent progressive collapse (element loss) or alternatively, harden the structure against the design threat where more feasible.

DESIGNING FOR ELEMENT LOSS VS HARDENING

There are certain areas where designing for element loss may not be possible due to the lack of a transfer mechanism. In other instances, it may simply be less intensive to provide hardening. The columns at the platform and level below (either concourse or taxi/parking depending on east/west) do not have an adequate transfer mechanism in place to accommodate potential element loss. At this location, hardening as opposed to creating a transfer mechanism is recommended. In general, the gravity and lateral demands on these columns requires a sufficiently large enough column that the additional effort to harden would be minimized –especially at the platform and concourse levels which would have minimal threat compared to a parking/taxi level.

Similarly, the first parking level below the concourse or taxi/parking is another area where it would be difficult to span over an element loss. An element loss at this level would require all the load from above to be transferred within the ceiling structure of this level. This is distinct from removing an element at the next level down, as there would then be two levels above over which to distribute the transfer loads. As such, hardening is recommended at this level as opposed to creating a transfer mechanism. Here too, the gravity and lateral demands on these columns requires a sufficiently large enough column that the additional effort to harden would be minimized.

It may still prove difficult to create a transfer mechanism at subsequent parking levels below the first, in which case it may be justified to instead provide hardening at all the columns in all the below grade parking levels.

Construction approaches for future additional below grade tracks

This report describes several options to incorporate additional below grade tracks (BGT), which would be located beneath the lower concourse. ***Additional Below Grade Track (BGT) is no longer being considered as a project element. Please refer to the Executive Summary for a description of the current status of the BGT options.***

At the conceptual level, there are several issues to consider related to BGT. Deeper excavation for the BGT would add cost, complexity and schedule for all areas. The issues are as follows:

1. BGT are below the water table, and their implementation would therefore be more challenging than at other conventional stations.
2. Columns for SEP (including BP) would need to be coordinated with BGT. This would likely involve creating transfer structure, above the new tracks.
3. Foundations for SEP would need to be lower than the future tracks and platforms, and would need to accommodate the additional load.
4. Large quantities of earth would need to be removed as part of the excavation process.
5. Utilities for BGT, most significantly ventilation inlets and outlets, would need to connect to external through the on-grade platforms.
6. Access and egress would impact on the planning of the lower concourse area and below grade parking floors. Refer to Fire Section.

There are a number of options to coordinate the possibility of future BGT with the SEP, each with various degrees of costs, schedule and complexity. The SEP may be constructed in such a way to facilitate the addition or completion of BGT at a later date. Alternatively, if specific allowances are not made during the SEP, then the addition of BGT in the future would become infeasible.

OPTION 1: MAKE MINIMUM ALLOWANCES FOR FUTURE BGT DURING SEP

This option seeks to take the minimum action required during the SEP construction so that future BGT may be feasible. It applies to Concepts having above grade parking only.

The SEP foundations would be coordinated with the future BGT box to facilitate its future construction. The following additional effort would be required during the SEP:

- Provide additional SOE to be left in place and used during future BGT construction
- Install deeper foundations in the area of the future BGT box
- Install secondary transfer structure above future BGT box to transfer SEP and BP loads

The following would then be required to complete the future BGT:

- Complete excavation of the BGT box (if required)
- Construct track and platform slabs and waterproofing system
- Complete fit out of BGT
- Refer to Figure D-13.

OPTION 2: CONSTRUCT THE BGT BOX DURING SEP AND LEAVE VACANT

This option seeks to take the opportunity during the SEP construction to complete the structural work required for future BGT, as it would likely be less costly overall to complete this work as part of the SEP as opposed to as part of a separate construction effort. It applies to Concepts having either above or below grade parking. This option would require slightly less additional work for below grade parking Concepts as opposed to those with above grade parking, as the bottom of excavation required for the future BGT is close to that required for the Concepts with below grade parking, and thus less additional SOE would be required.

The structural works, waterproofing, drainage system, and minimum mechanical and electrical systems for of the future BGT would be completed during the SEP to facilitate its future construction. The following additional effort would be required during the SEP:

- Provide additional SOE for construction of the BGT box (less effort required for below grade parking Concepts)
- Install deeper foundations in the area of the BGT box
- Install secondary transfer structure above the BGT box
- Construct track and platform slabs and waterproofing system
- Install drainage system including pumps
- Install mechanical and electrical trenches and duct banks to be utilized in future BGT completion

This would result in minimal effort to complete construction of the BGT at a later date. The BGT box would remain vacant in the meantime. Note that the BGT box would still need regular maintenance prior to completion of the BGT.

Refer to Figure D-14 and Figure D-16.

OPTION 3: CONSTRUCT THE BGT BOX DURING SEP AND USE FOR PARKING PRIOR TO COMPLETION OF BGT

This option completes the infrastructure for future BGT, as it would likely be less costly overall to complete this work as part of the SEP as opposed to as part of a separate construction effort in later years. Furthermore, it seeks to utilize the space as parking until such time that the BGT construction is ready to be completed. It applies to Concepts having below grade parking only.

The structural works, waterproofing, drainage system, and minimum mechanical and electrical systems for of the future BGT would be completed during the SEP to facilitate its future construction. Temporary structural floors would be constructed in the space and integrated with the surrounding parking. The space would be further fit out architecturally and with MEP systems required to accommodate the temporary parking. Later a transfer structure would be constructed above the box, and the temporary parking structure would be removed to allow for the completion of the BGT. The following additional effort would be required during the SEP:

- Provide additional SOE for construction of the BGT box (less effort required for below grade parking Concepts)
- Install deeper foundations in the area of the BGT box
- Construct track and platform slabs and waterproofing system
- Install drainage system including pumps
- Install mechanical and electrical trenches and duct banks to be utilized in future BGT completion
- Install temporary structural framing to support parking
- Provide fit out in the temporary parking area

The following work would be required to complete the BGT:

- Install secondary transfer structure above BGT box
- Remove temporary parking structure
- Complete fit out of BGT

This would result in more effort to complete construction of the BGT at a later date compared to Option 2, however the space would be utilized in the meantime.

Refer to Figure D-17.

OPTION 3A

In this sub option the projected station parking demand would be outside of the BGT box, and any temporary parking located within the box is in excess of that.

OPTION 3B

In this sub option the projected station parking demand would be accommodated both inside and outside of the BGT box. When the BGT is completed and the infill parking removed, the total parking capacity at that time would be less.

OPTION 4: NO SPECIFIC ALLOWANCES FOR BGT BOX DURING SEP

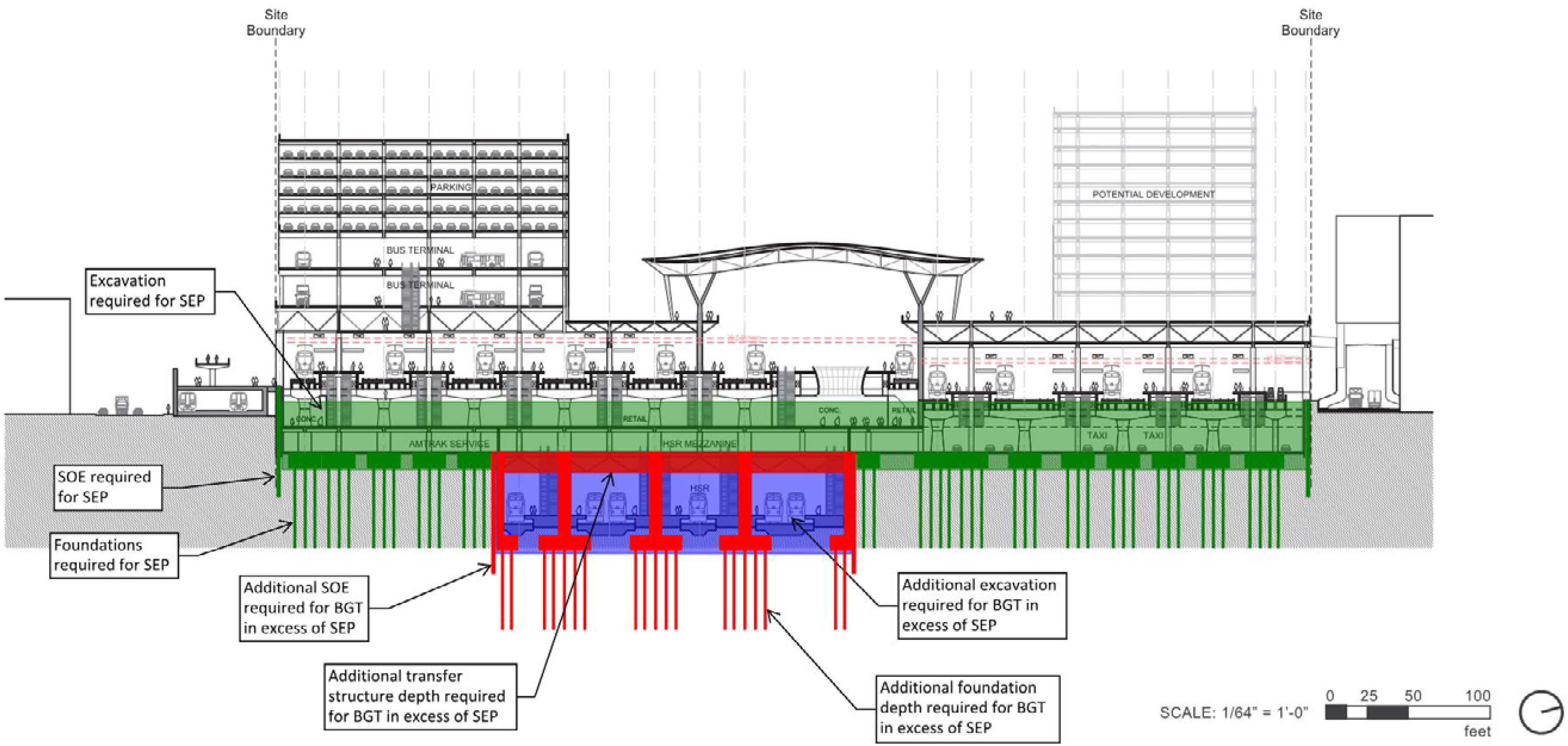
This option seeks to meet the minimum requirement for the SEP, and makes no allowances for future BGT in the SEP construction. As such, we assume that this option essentially makes future BGT infeasible.

This is because any future effort to construct BGT would involve the following:

- Removal of all SEP foundations that interfere with the BGT box
- Removal of any SEP program levels that interfere with the BGT box
- Transfer of loads from removed foundations to entirely new foundations or to different existing locations
- Addition of new large foundations or significant strengthening of existing foundations that are required to support the additional transferred loads.
- Potential construction of additional below grade or above grade program levels to replace what was removed for construction of the BGT box

This effort described above does not appear to be a feasible solution for constructing the future BGT.

This option applies to Concepts having either above grade or below grade parking. Refer to Figure D-15 and Figure D-18.



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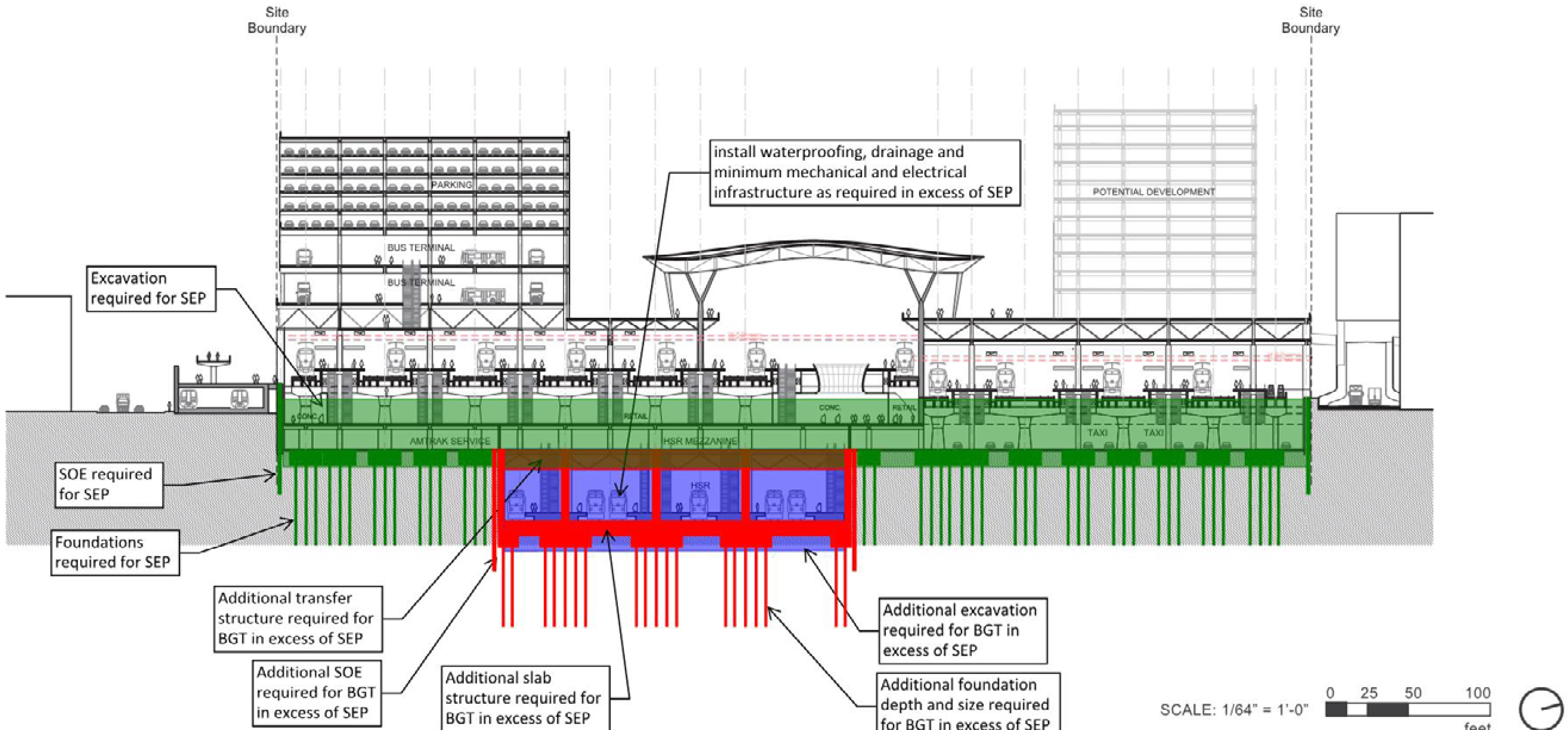
TRANSVERSE SECTION AT SOUTH

Figure D-13: BGT Option 1 - Above Grade Parking



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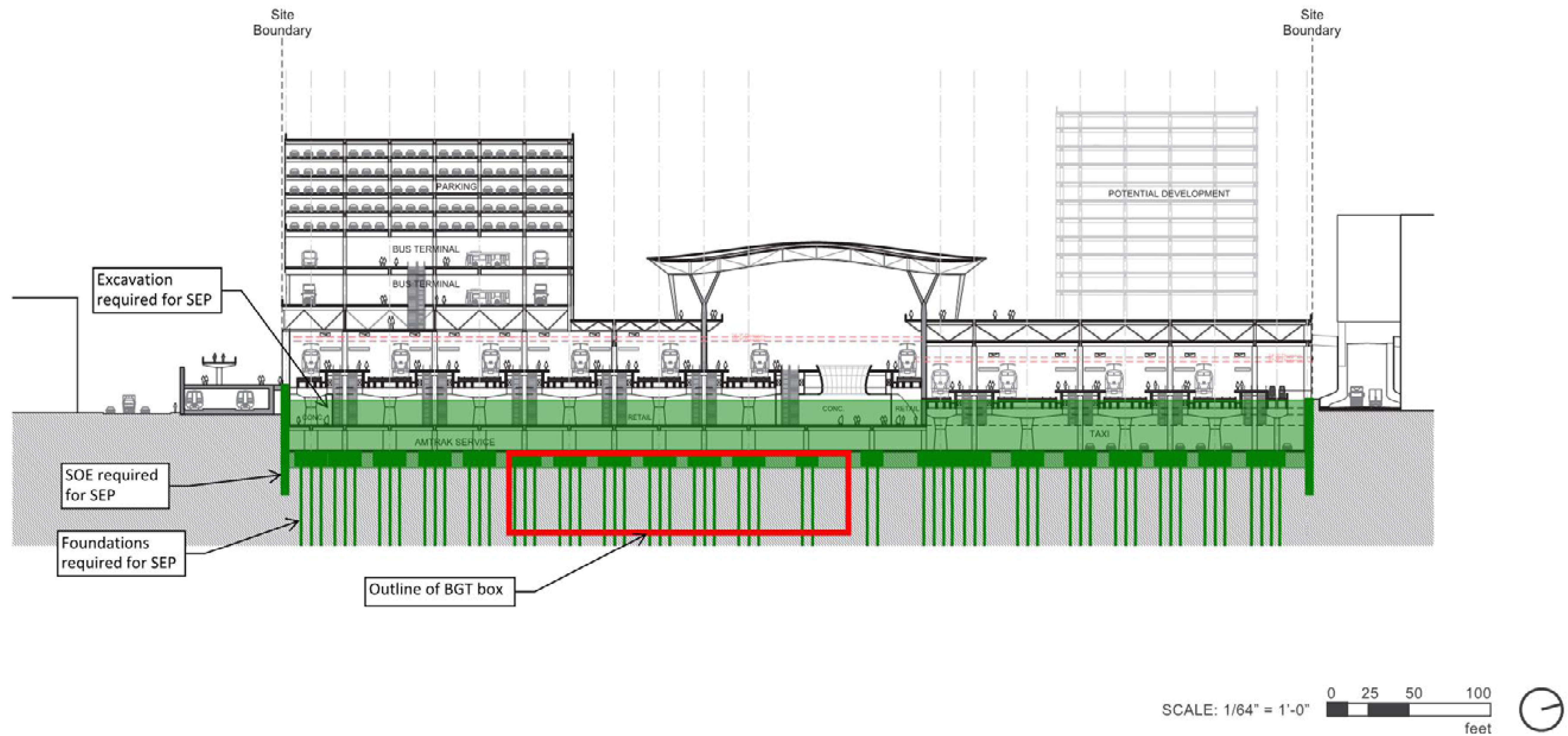
TRANSVERSE SECTION AT SOUTH

Figure D-14: BGT Option 2 - Above Grade Parking



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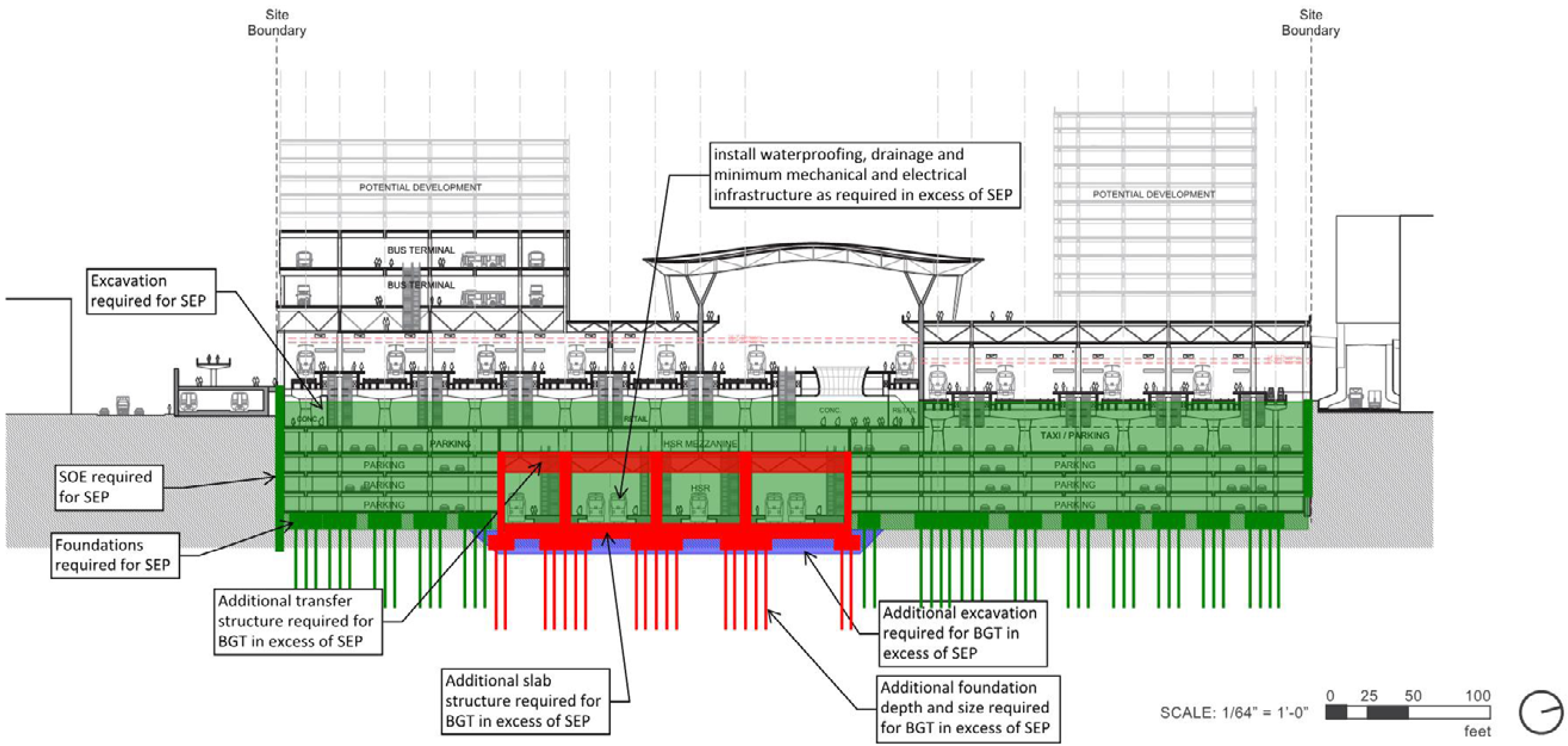
TRANSVERSE SECTION AT SOUTH

Figure D-15: BGT Option 4 - Above Grade Parking



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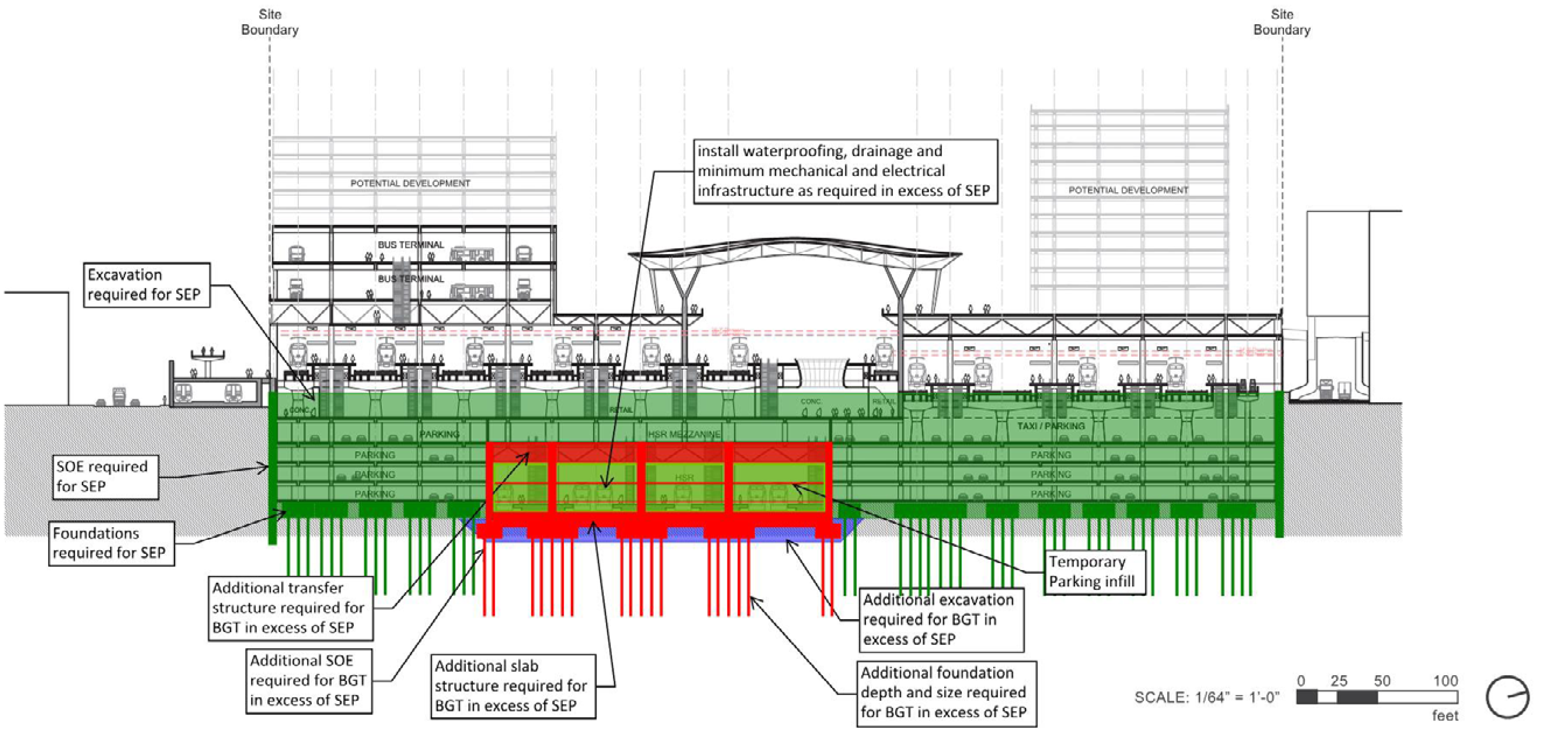
TRANSVERSE SECTION AT SOUTH

Figure D-16: BGT Option 2 - Below Grade Parking



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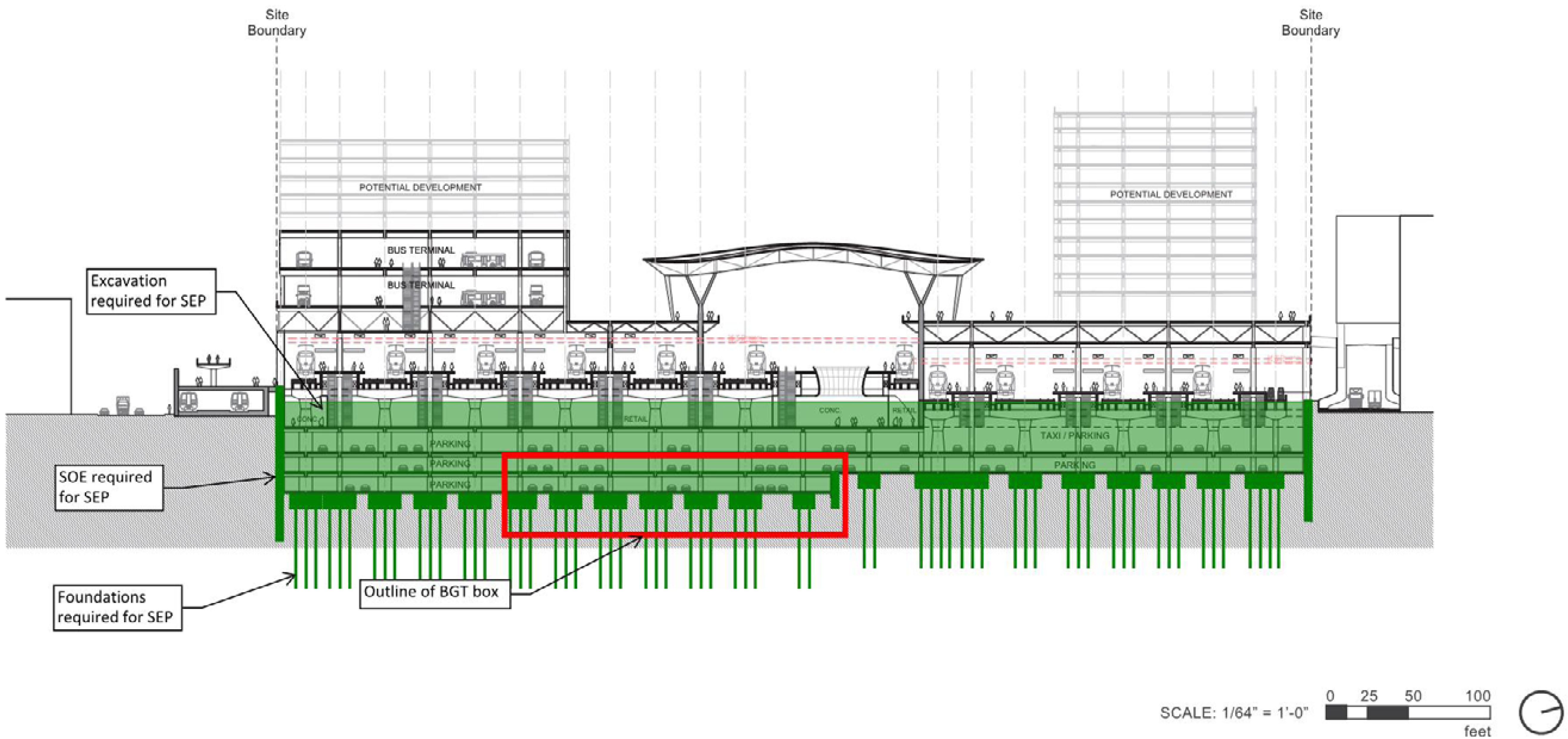
TRANSVERSE SECTION AT SOUTH

Figure D-17: BGT Option 3 - Below Grade Parking



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TRANSVERSE SECTION AT SOUTH

Figure D-18: BGT Option 4 - Below Grade Parking

Specific Overall Concepts

CONCEPTS INVOLVING STATION PARKING ABOVE GRADE WITH AND WITHOUT BGT

In all Concepts with parking above grade, the future BGT would be constructed according to options 1 or 2 as discussed above. Refer to component discussion above for more information about each of the components.

BUS ON SOUTH-WEST

This Concept incorporates above grade parking located on top of the bus structure on the west side, south of H Street.
The version with future BGT would require an additional transfer level above the BGT box. It would be preferable to shift the BGT box one bay towards the center, under the Train Hall, so as to avoid landing any overbuild supporting columns on the additional transfer structure which would be located over the box.

BUS ON SOUTH-EAST

Similar to the above grade parking with bus on South-West Concept discussed above. Only difference is that the combined parking and bus structure is located on the east side.

BUS ON NORTH

Similar to the above grade parking with bus on South-West and South-East Concepts discussed above. Except that the combined parking and bus structure is located on the north end. The north end of the site is narrow and congested with tracks below. It is therefore almost certain that a transfer structure would be required between the combined parking and bus structure and the station structure and that it will most likely be irregular in order to line up with the columns below.
As discussed before, the version with future BGT would require an additional transfer level above the BGT box.

CONCEPTS INVOLVING STATION PARKING BELOW GRADE WITH AND WITHOUT BGT

In all Concepts with parking below grade, the future BGT may be constructed according to options 2 or 3 as discussed above. Refer to component discussion above for more information about each of the components.

BUS ON SOUTH-WEST

Similar to Concept including above grade parking. Integration of the BGT box would be as discussed above.

BUS ON SOUTH-EAST

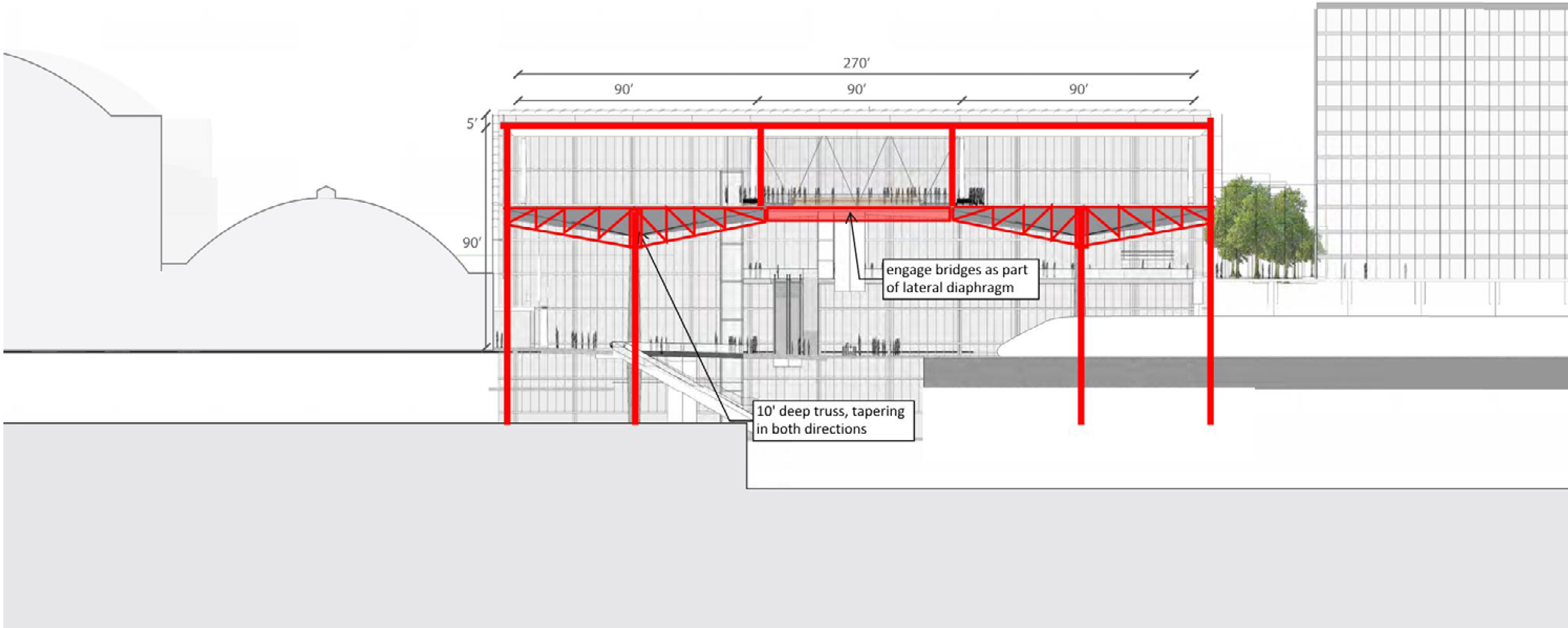
Similar to Concept including above grade parking. Integration of the BGT box would be as discussed above.

BUS ON NORTH

Similar to Concept including above grade parking. Integration of the future BGT box would be as discussed above.

BUS ON SOUTH

This Concept incorporates the bus structure above concourse A and creates a Train Hall over that entire space on the southern end.
The bus loop would be contained in a single level, and the structure supporting the bus could be contained in that single level. Alternatively, an additional mezzanine level could be added below, in which case, the depth of the mezzanine would be used to contain structure supporting the Bus Terminal and Train Hall roof.
The BGT box would not extend under the bus structure in this option, so a second transfer for the bus supporting columns would not be required.
Refer to Figure D-19 and Figure D-20 for structural section and elevation for the bus on south with single level Concept.
Refer to Figure D-21 and Figure D-22 for structural section and elevation for bus on south with mezzanine level Concept.



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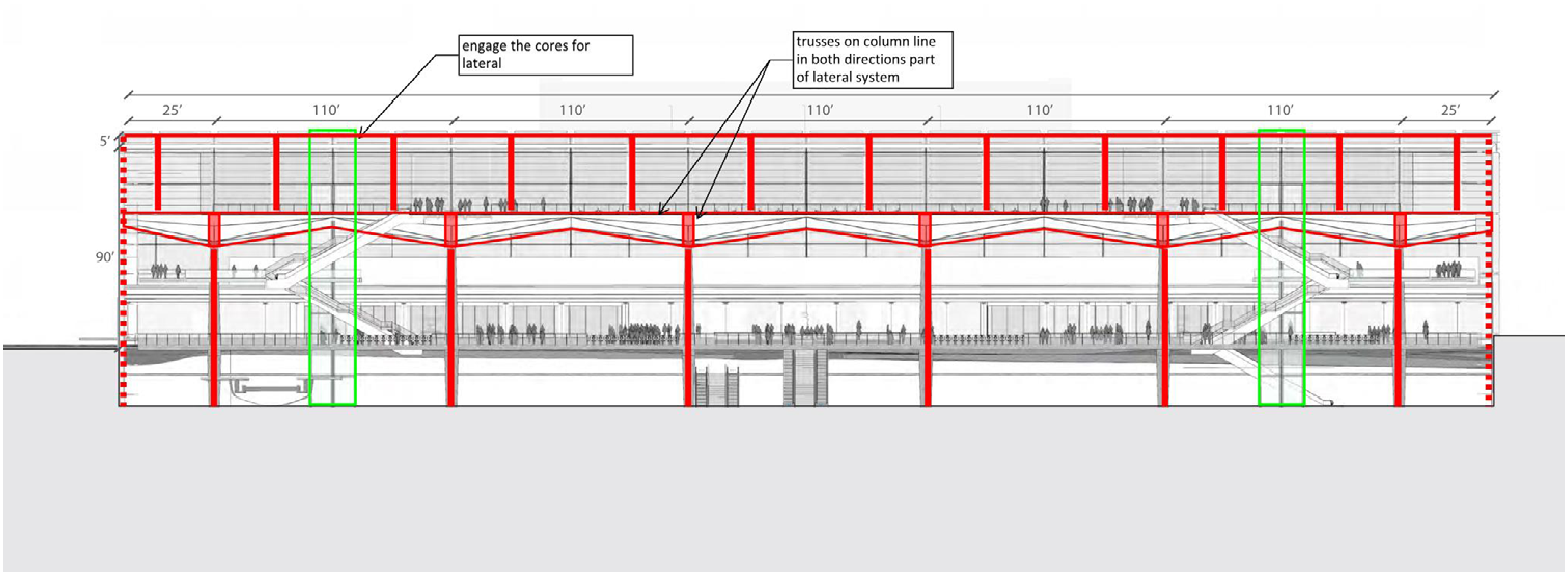
BUS ON SOUTH SINGLE LEVEL SECTION

Figure D-19: Bus on South Single Level Structural Section



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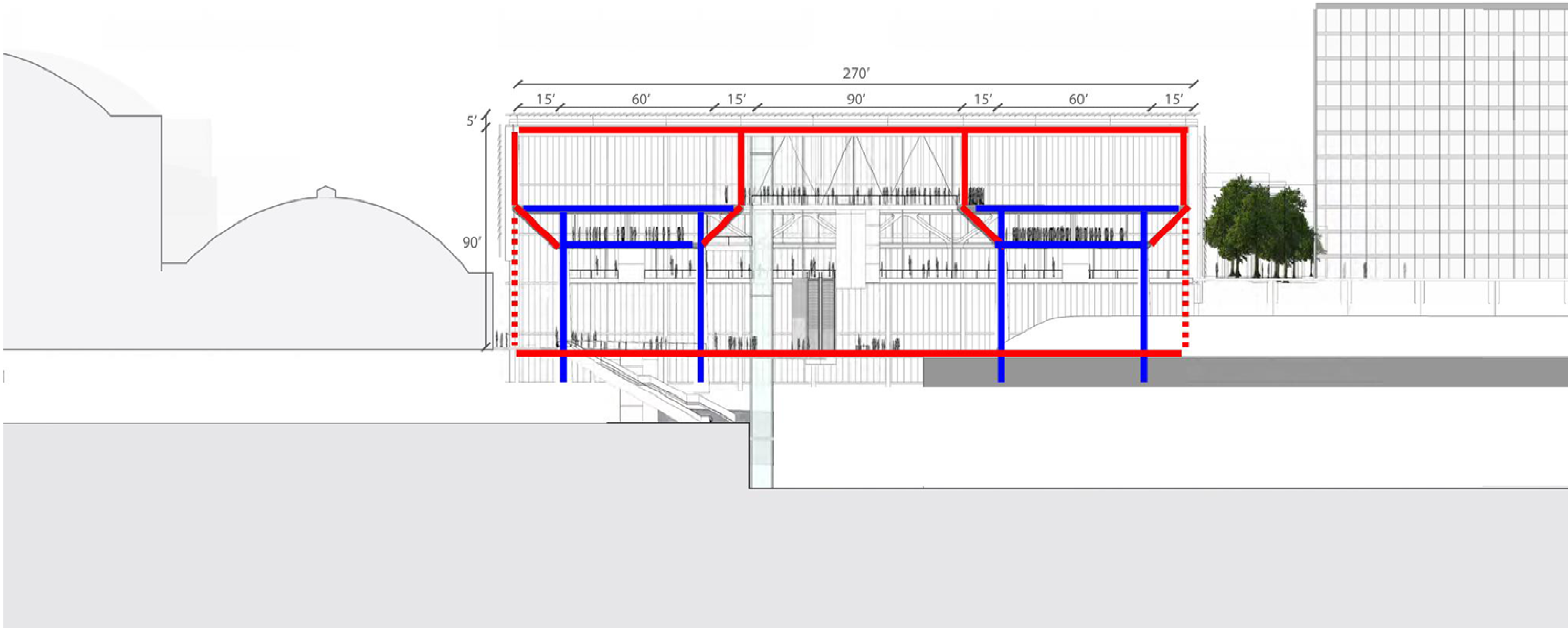
BUS ON SOUTH SINGLE LEVEL ELEVATION

Figure D-20: Bus on South Single Level Structural Elevation



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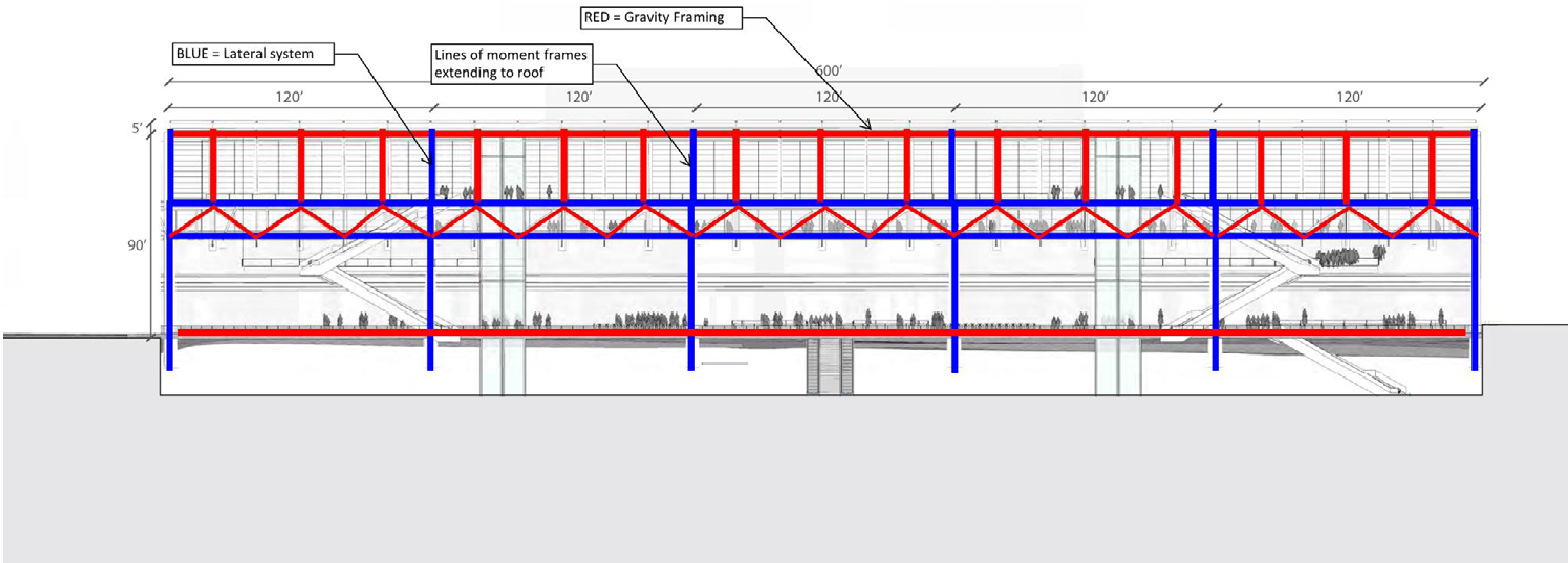
BUS ON SOUTH WITH MEZZANINE LEVEL SECTION

Figure D-21: Bus on South with Mezzanine Level Structural Section



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BUS ON SOUTH WITH MEZZANINE LEVEL ELEVATION

Figure D-22: Bus on South with Mezzanine Level Structural Elevation

Mechanical, Electrical, and Plumbing Concepts

Track and Platform Ventilation

Track and platform ventilation is required as a consequence of the addition of the BP deck, or of any other roof over the tracks. The scope of SEP includes the ventilation of the platform and track areas, terminating at the entrance to the First Street Tunnel, which is operated by Amtrak.

Control of environmental conditions (temperature, air velocity, air pressure, diesel emission containment, smoke removal, noise, etc.) is necessary to meet the diverse needs of normal operations, congestion, and emergencies, including a fire within the track areas. The system also is required to perform for life safety functions.

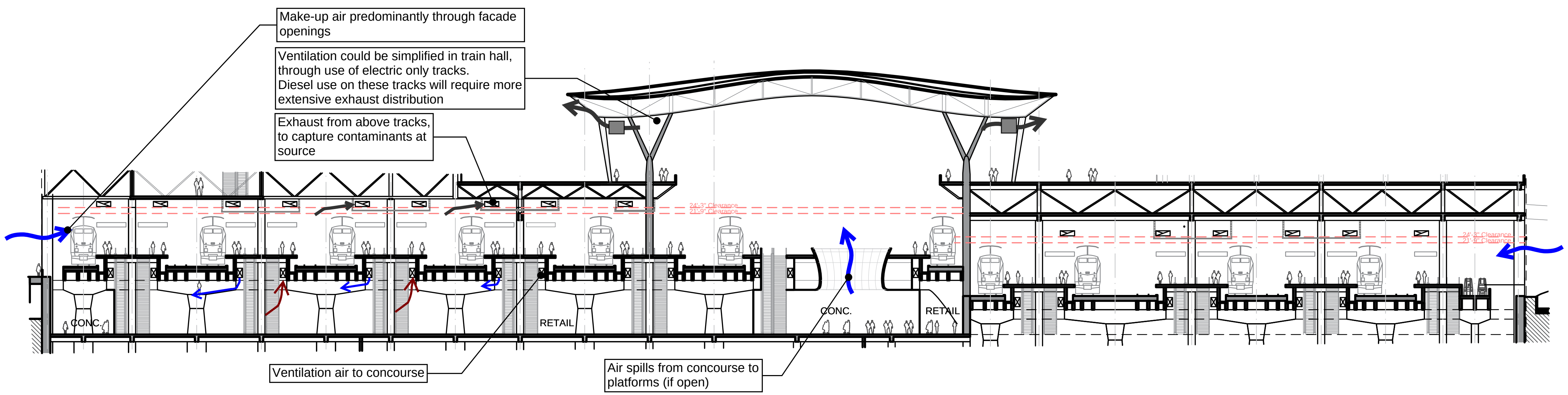
In summary, during a normal operating scenario the ventilation system would be able to achieve the following objectives:

- Emergency operation would need to provide tenable conditions to satisfy NFPA130.
- Dilution of diesel fumes
- Providing ventilation air for passengers and staff
- Temperature Control for passengers
- Temperature control for transit vehicle air conditioners

TRACK & PLATFORM VENTILATION SYSTEMS

Ventilation systems include the following components which is consistent across all Concepts:

- Tracks and platforms would generally be separated from the conditioned concourses, to provide enclosure to conditioned spaces and to limit the spread of fumes. Typically this could be done by glazed screens or barriers, the nature of which would be explored during Concept refinement phase.
- Train Halls would generally be segregated from occupied spaces. Typically this would be done by glazed screens or barriers, the nature and of which would be explored during the next phase of design.
- Adjacent spaces would typically be positively pressurized with respect to this area
- Exhaust fans, rated for high temperature air would generally be located in fan plant rooms above the tracks, coordinated with BP.
- Exhaust would be removed from above the tracks, capturing the contaminants or smoke to minimize migration around the train hall
- Openings for natural air makeup, to the tracks and platforms would be provided. Some additional supply air may be provided, which would be reviewed during subsequent.
- Ceiling baffles would be provided at the platform edges, to limit the spread of smoke and capture smoke and improve system effectiveness.
- The strategy is as shown in Figure D-23
- The scope and systems will be similar whether TI track Option 14 or 16 will be used. Refer to Figure D-24 and Figure D-25 for more information.
- Refer to Figure D-26 and Figure D-27 for examples of how fan plant could be integrated at BP level.



SCALE: 1/64" = 1'-0"

0 25 50 100
feet

Figure D-23 - Track and Platform Ventilation Strategy

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TRANSVERSE SECTION AT SOUTH

BUS ON SOUTH-WEST NEW STRUCTURE - PARKING ABOVE (WITH ADDITIONAL BELOW-GRADE TRACKS)

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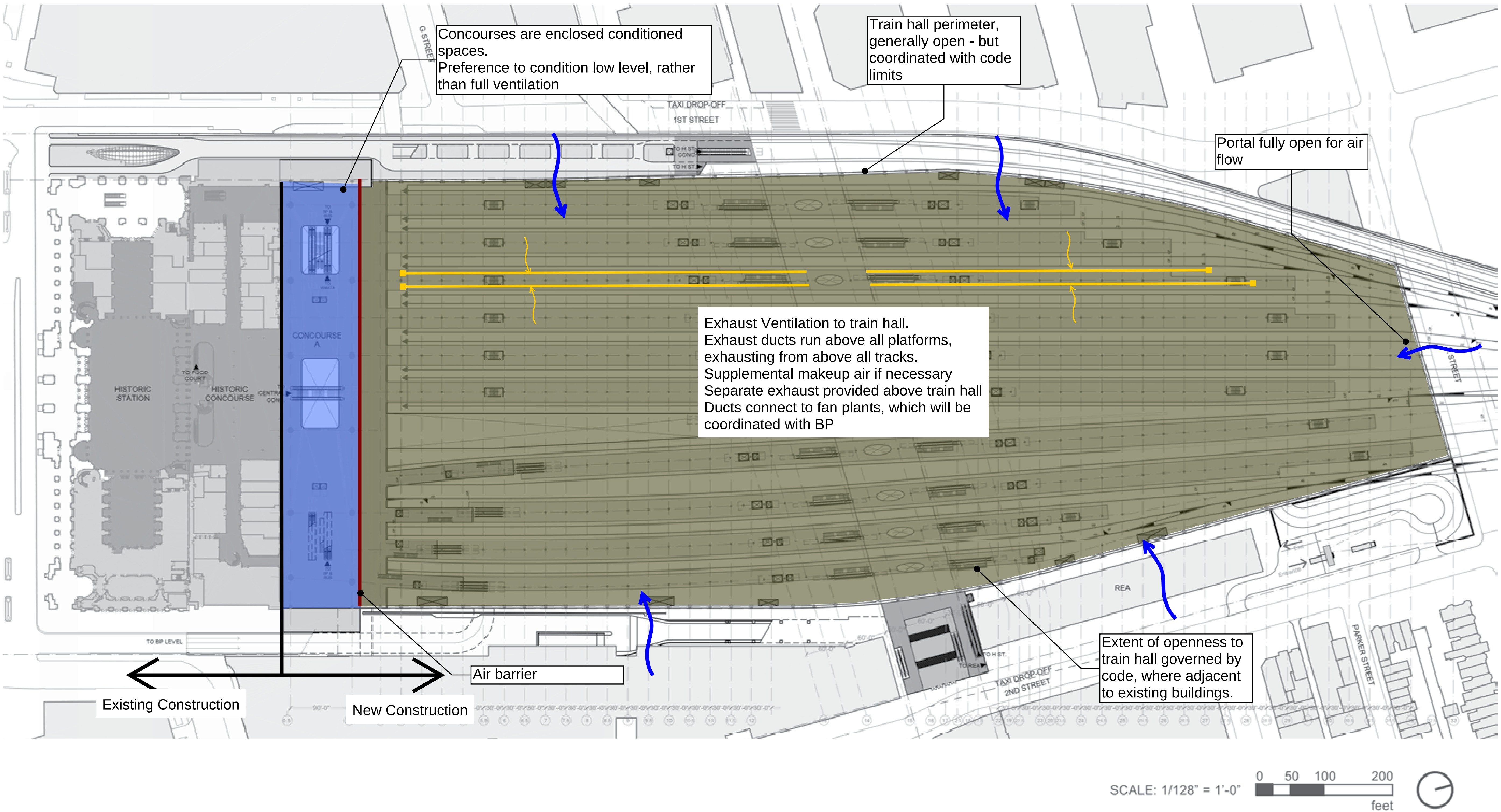

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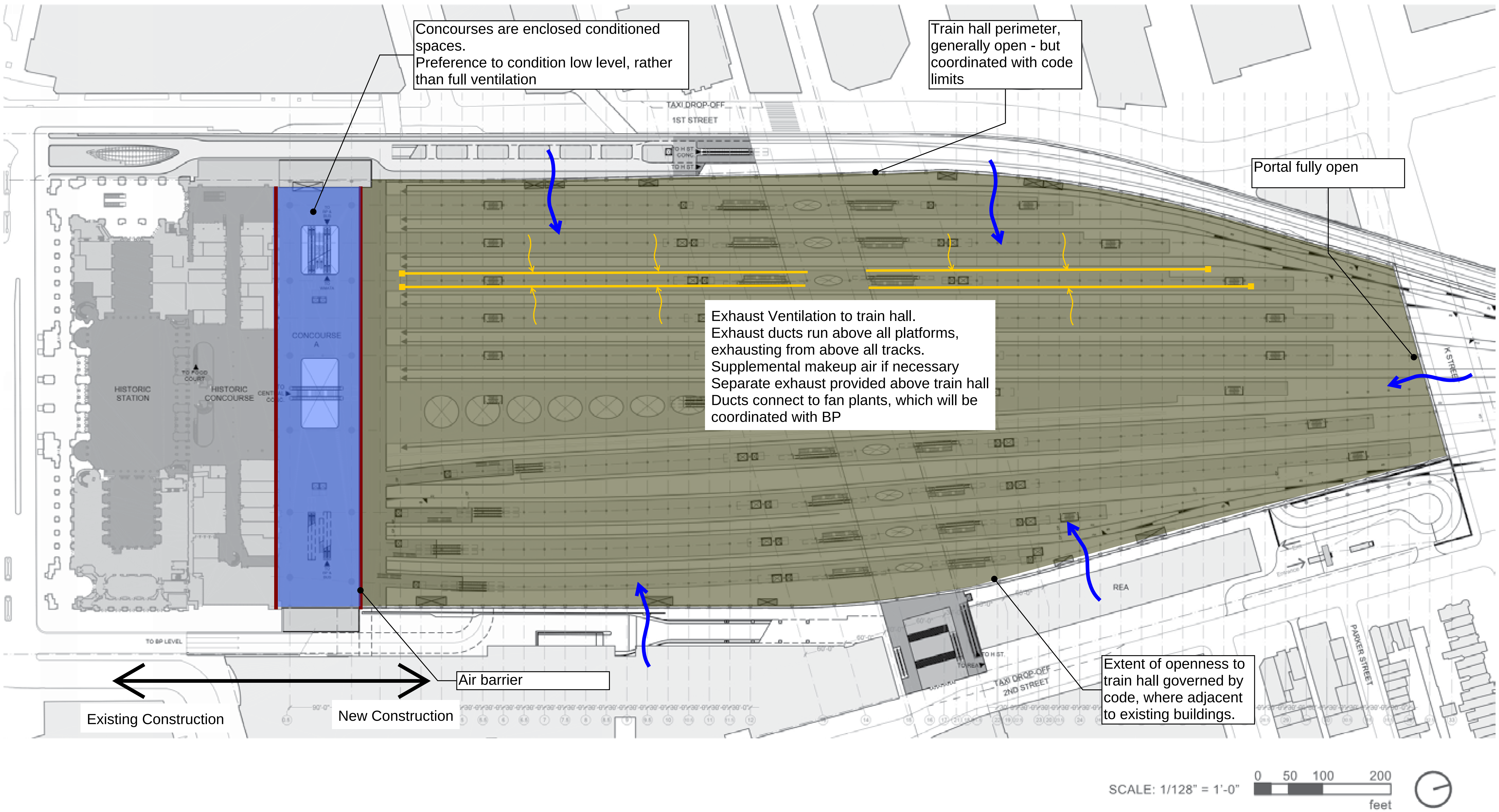
MAIN LEVEL PLAN

TI OPTION 14

Figure D-24 - Ventilation strategy of Tracks and Platforms TI Option 14



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MAIN LEVEL PLAN

TI OPTION 16

Figure D-25 - Ventilation of Train Hall. TI Option 16

FAN PLANTS

6X HORIZONTAL FANS ON BURNHAM PLACE

Each fan room is approx. 54' wide.
Louver has 650 S.F. free area and
1,300 S.F. total area
(i.e. 54'x24' louver min. 10' above deck)

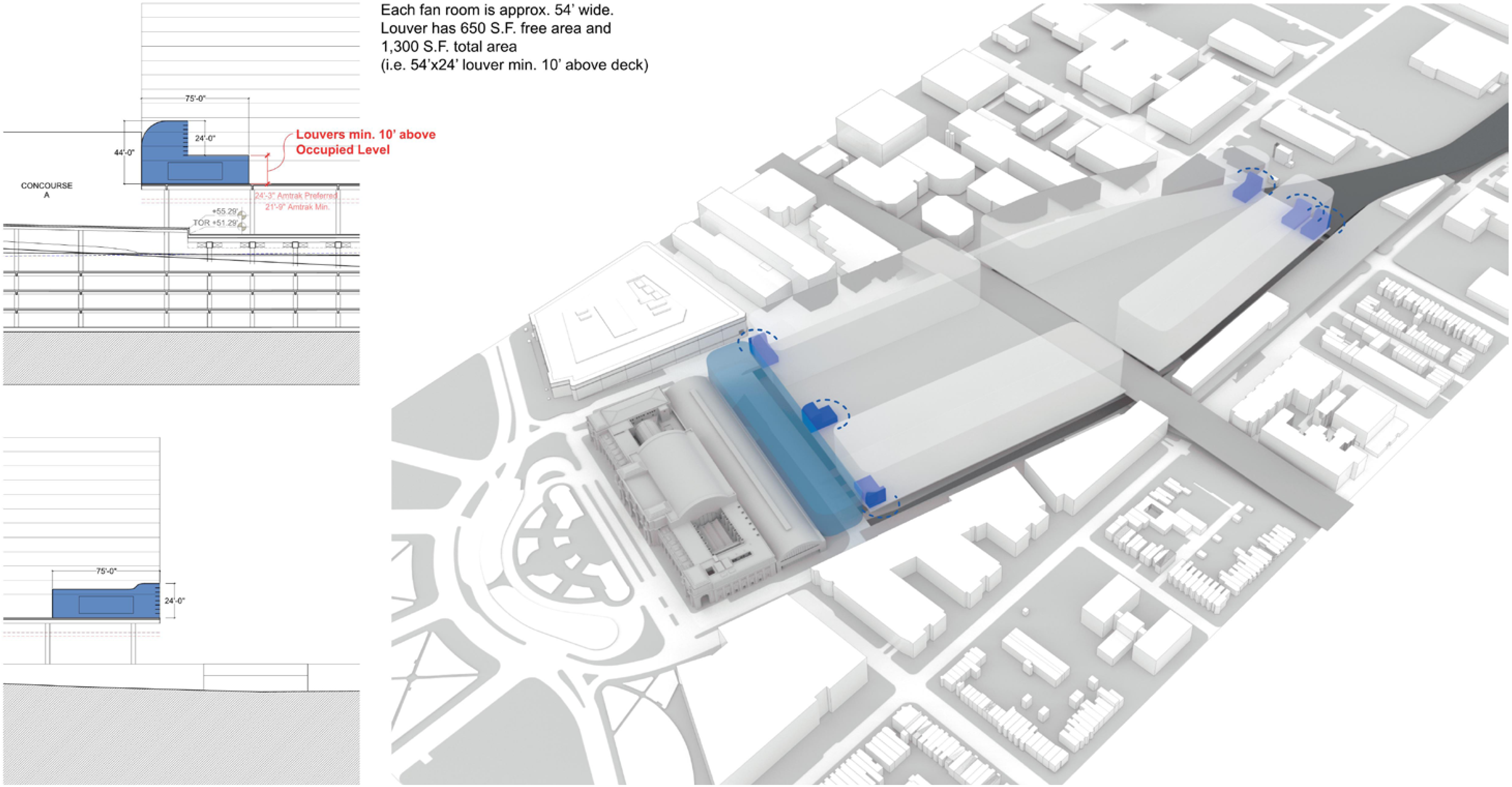
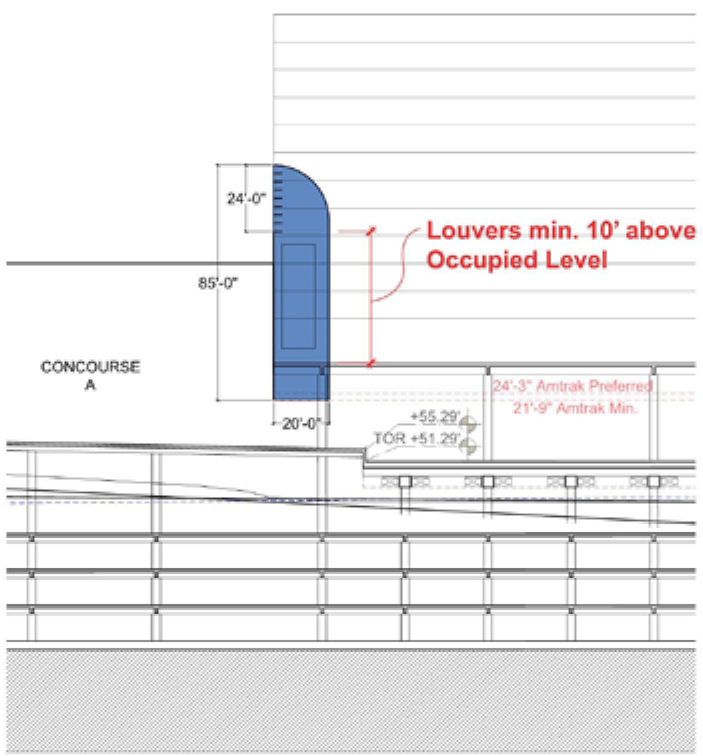


Figure D-26 - Horizontal Fan Plant Integration

FAN PLANTS

6X VERTICAL FANS (21'-9" ABOVE TOP OF RAIL)



Each fan room is approx. 54' wide.
Louver has 650 S.F. free area and
1,300 S.F. total area
(i.e. 54'x24' louver min. 10' above deck)

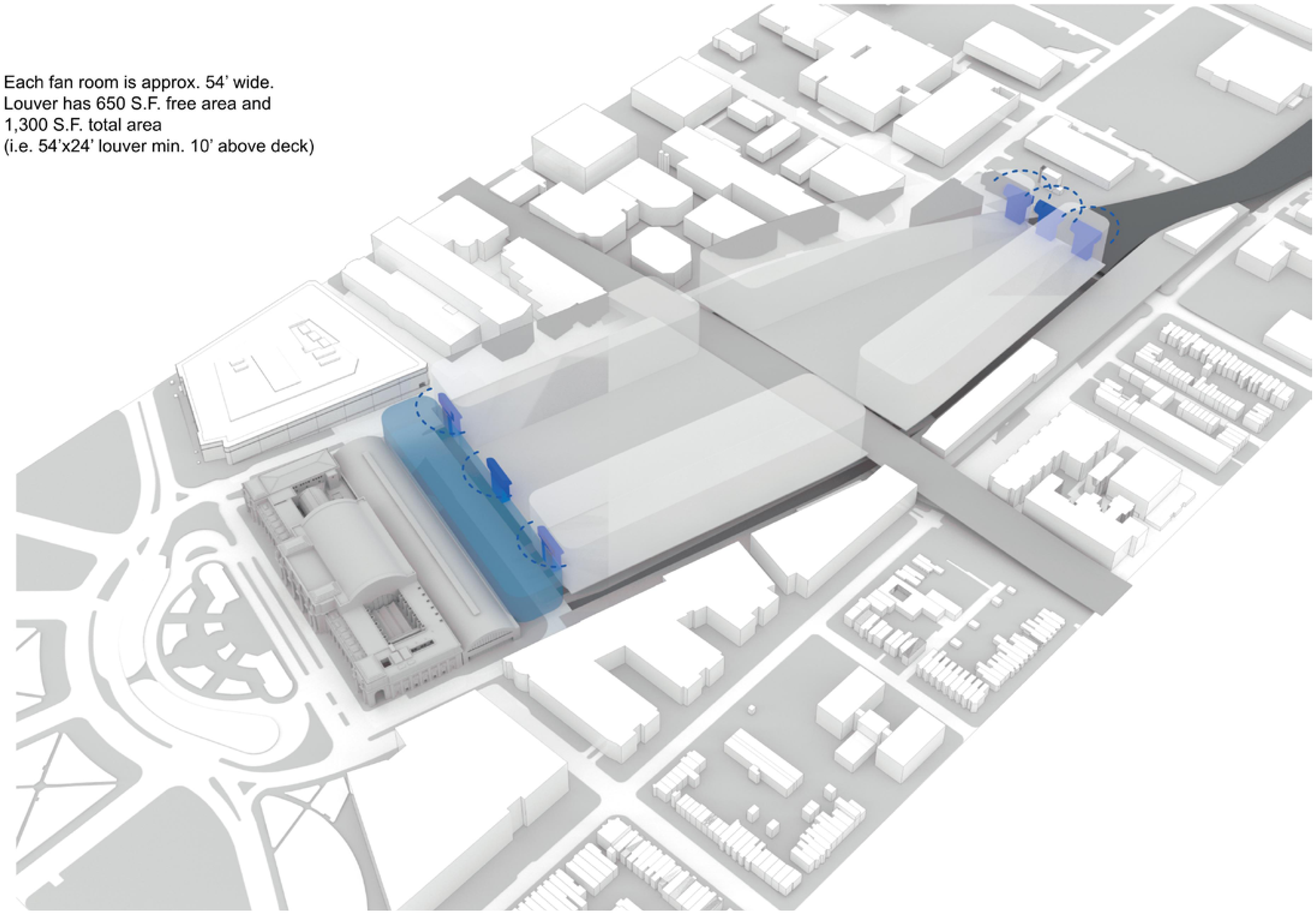


Figure D-27 - Vertical Fan Plant Integration

FAN PLANTS

6X HORIZONTAL FANS ON ROOF OF OVERBUILD

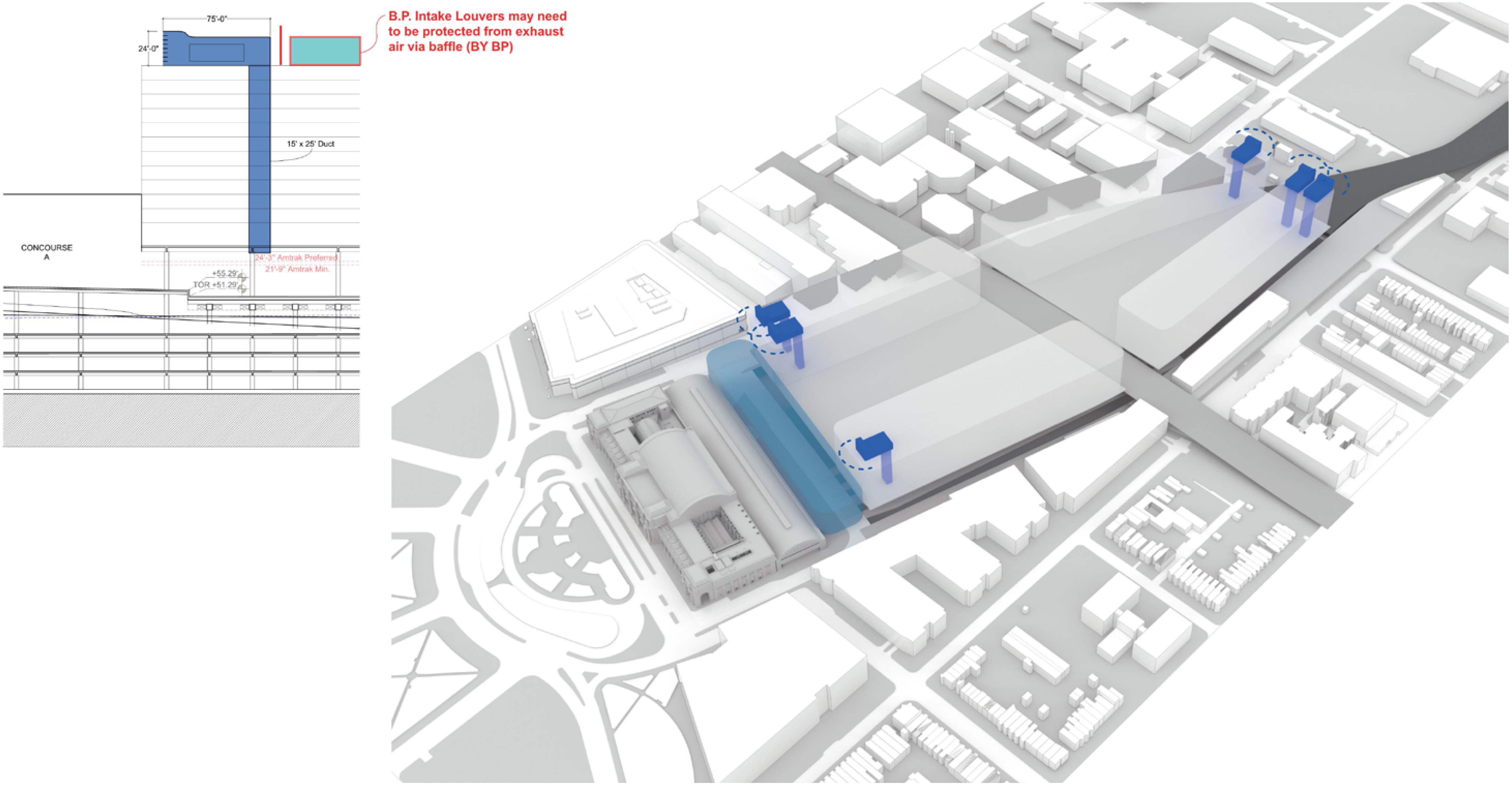


Figure D-28 - Horizontal Fans on Roof of Overbuild

HVAC STRATEGY TO OTHER SPACES

All areas require ventilation.

Structural shafts would be provided linking the mechanical equipment, to louvers on the outside walls. The majority of the new program is proposed to be below the tracks, and disconnected from sources of fresh air, therefore the inlet and exhaust to these spaces needs to be coordinated with the tracks and platforms so as to avoid conflicts.

The overall approach to ventilation and ventilation systems are consistent across all Concepts and are as follows:

EXISTING CONCOURSES

It is recommended that the historic concourses be fed from new equipment, installed by USRC prior to SEP construction work. Therefore a detailed approach is not addressed in this report.

CONDITIONED NEW CONCOURSES

There are a number of options for the heating, ventilation and air conditioning of the proposed new concourses spaces, which will advanced in later phases. However, comment to each Concept is the following conceptual approach:

- For efficiency, tall spaces would ideally be fed from a lower level, conditioning the occupied zone only and allowing air to stratify. Return air would typically be removed from high level.
- Ventilation equipment would be housed in mechanical rooms.
- Systems would accommodate varying occupancy, reducing outside air quantities to save energy.

SEMI HEATED CONCOURSES

Background heat would be provided to circulation concourses, which are generally not occupied and are often open to unconditioned spaces. As most passengers would travel through these directly to non-conditioned spaces or to outside, they are not treated to the same standards. The systems serving these spaces may be as follows:

- Ventilation air would be provided
- Radiant heating would be considered for efficiency and comfort reasons.
- Adiabatic cooling is an option to provide some reduction in internal temperature.

Refer to Figure D-29 and Figure D-30 for the extent of conditioned and semi conditioned concourses.

PARKING STRUCTURE VENTILATION

Concepts include public parking either below or above grade.

ABOVE GRADE PARKING

Open, above grade car parks could be ventilated by natural means if the space meets the definition provided in the IBC contained in Section 406.5.2.

Wall openings shall be provided on two walls of each tier with each opening equaling or exceeding 20 percent of the total perimeter and the aggregate length no less than 40 percent of the total perimeter.

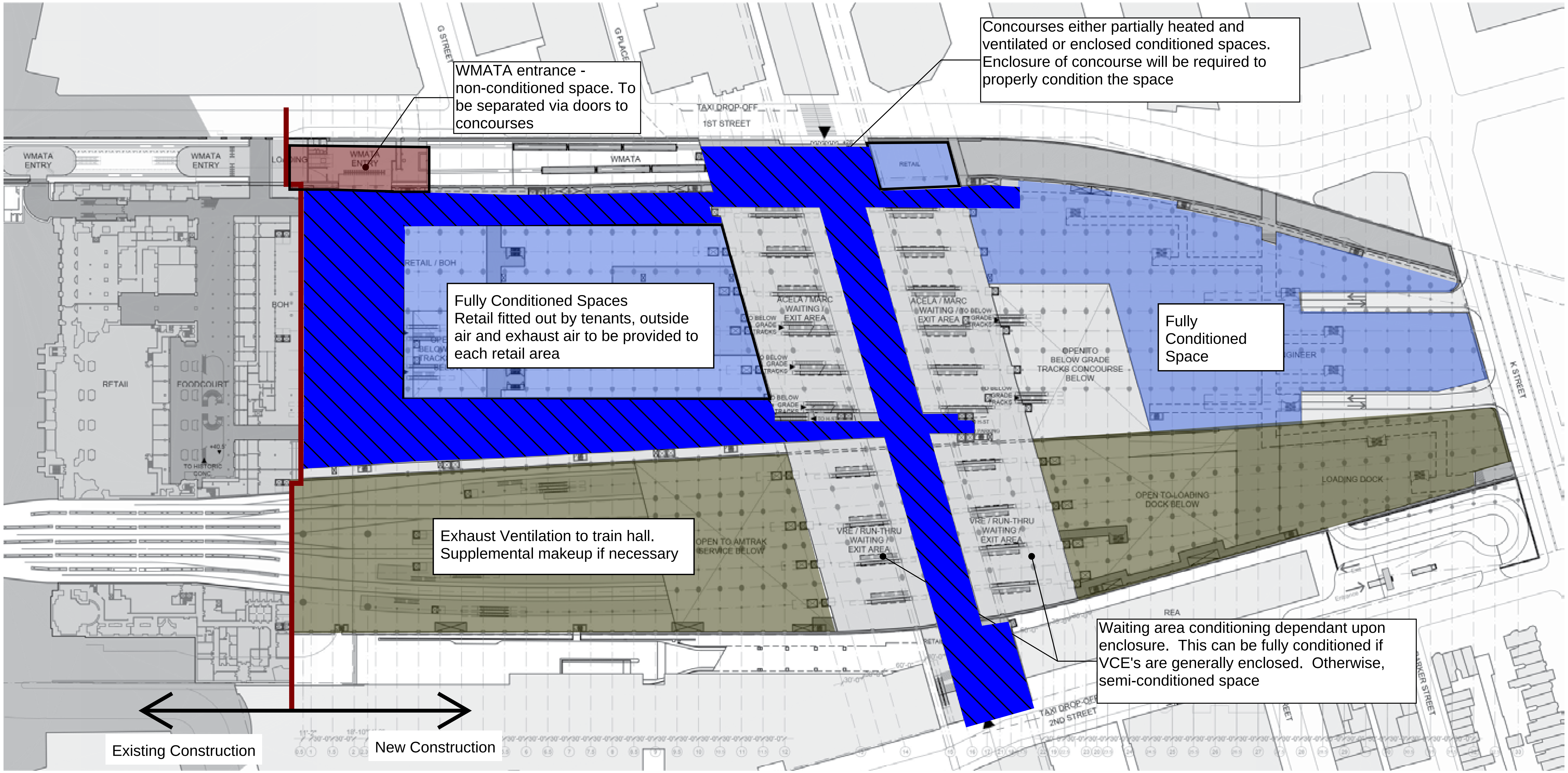
Below grade parking mechanical ventilation would be provided to maintain required air quality in below grade areas.

The system would include:

- Exhaust fans and make-up fans, which would be connected via ductwork or structural plenums to the ventilated areas.
- Supply and exhaust registers, which would be distributed to provide evenly distributed ventilation
- Whilst this is not code mandated, the same equipment is recommended to be used for smoke control ventilation in an emergency situation.
- Air quality monitoring controls, to adjust ventilation rates and save energy when not required.

If the public parking is not located adjacent to outside air, then supply fans and ducts / plenums should be provided.

Refer to D-36 which indicates the strategy being employed.



SCALE: 1/128" = 1'-0"   0 50 100 200 feet

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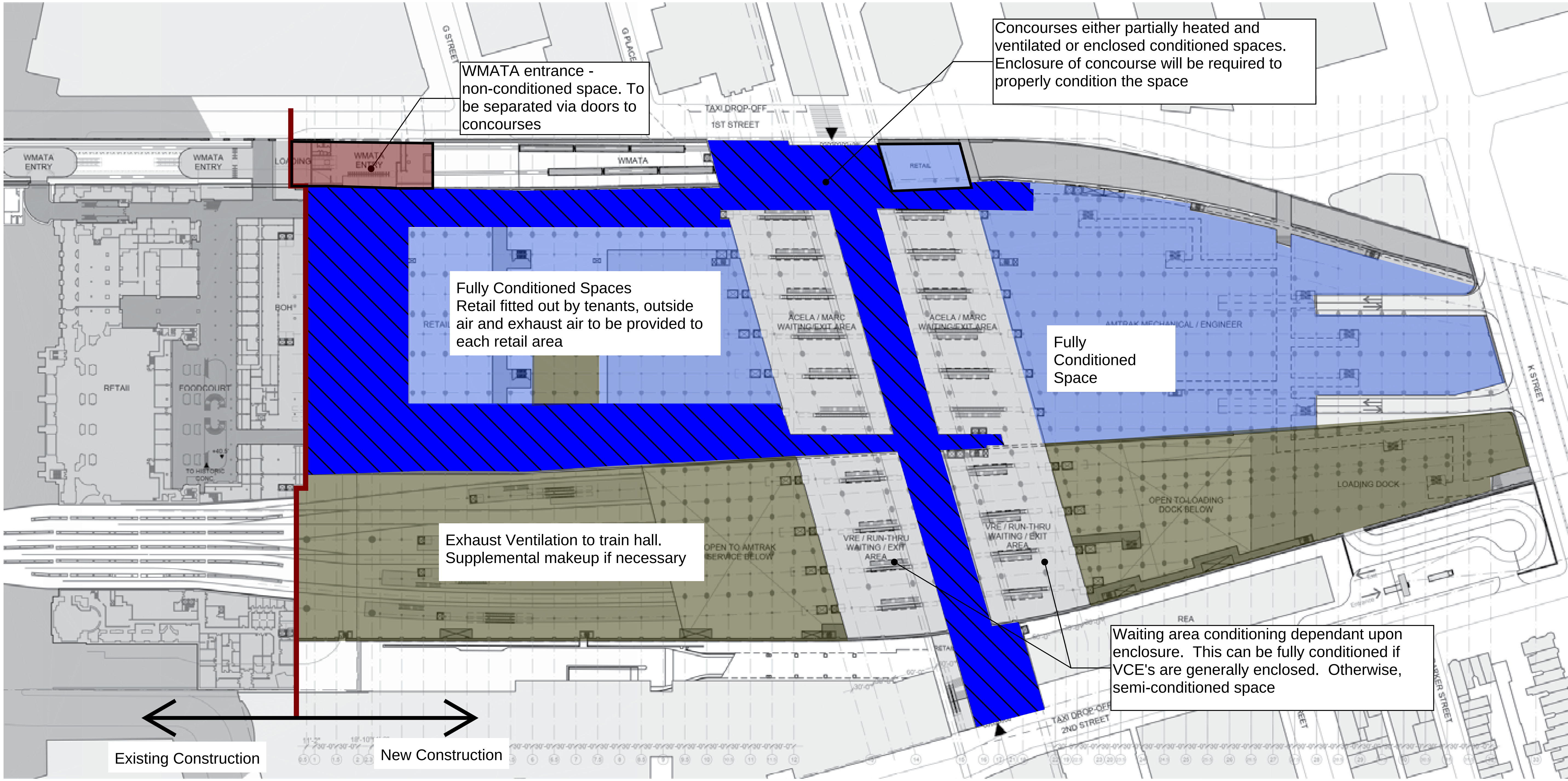
LOWER LEVEL CONCOURSE PLAN

Figure D-29 Concourse Level HVAC Approach With Below Grade Tracks



SCALE: 1/128" = 1'-0"

0 50 100 200 feet

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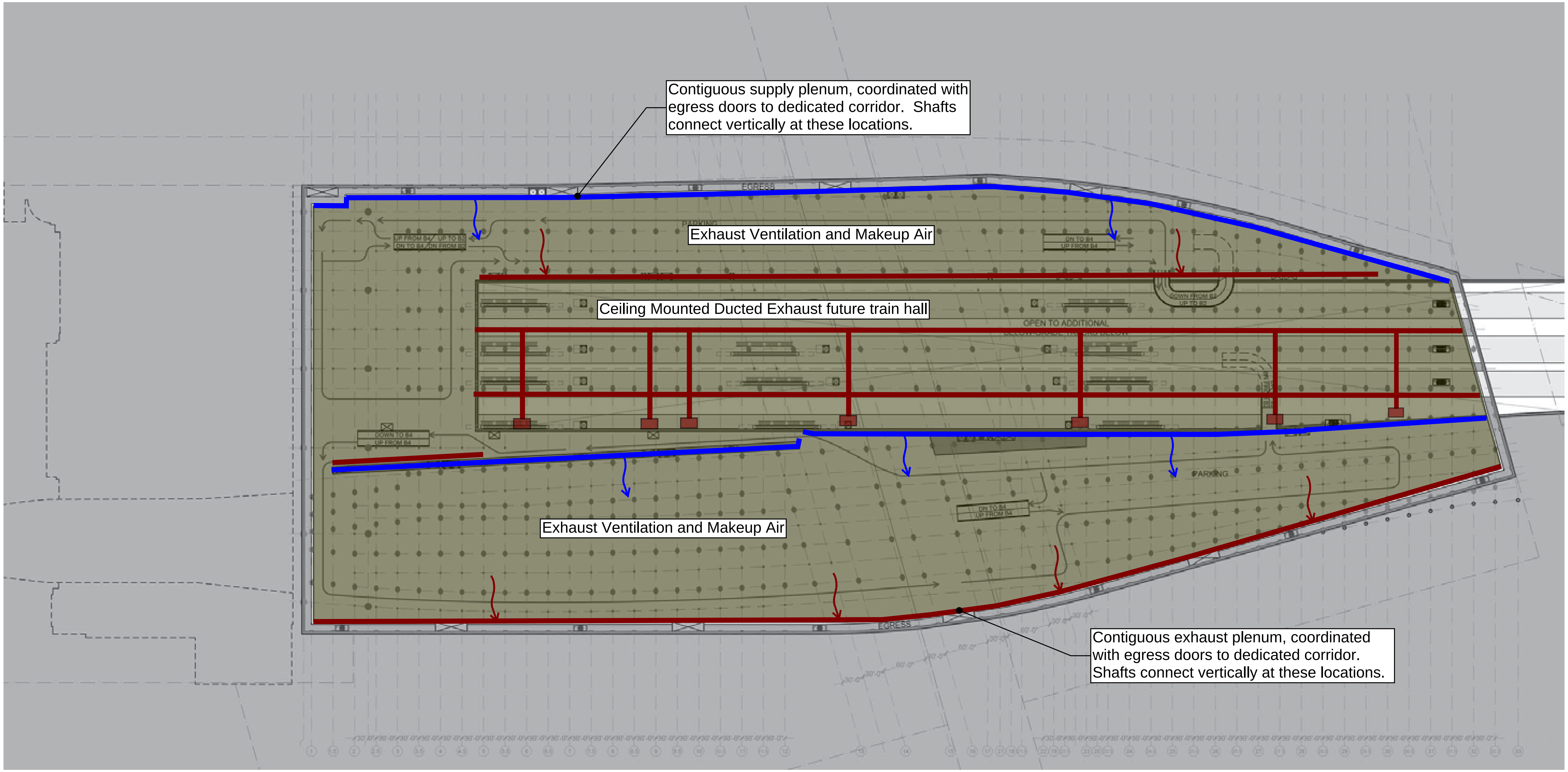
LOWER LEVEL CONCOURSE PLAN

Figure D-30 - Lower Concourse - no below grade tracks



SCALE: 1/128" = 1'-0"

0 50 100 200

feet

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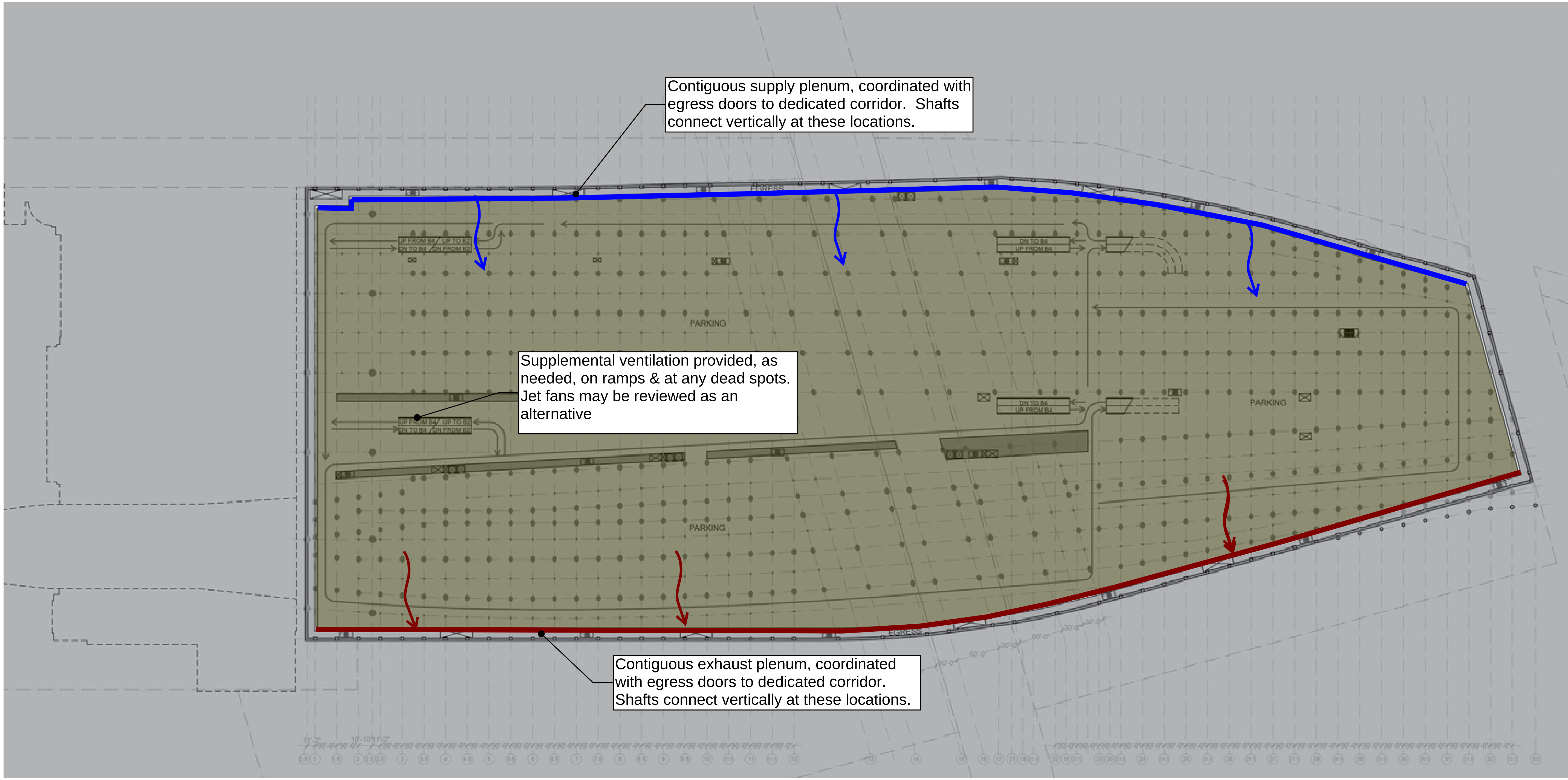
Figure D-31 - B3 Level with below grade tracks

DRAFT

B3 LEVEL PLAN

(WITH ADDITIONAL BELOW GRADE TRACKS)

July, 14, 2016



SCALE: 1/128" = 1'-0"

0 50 100 200
feet

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Figure D-32 - B3 Level without below grade tracks

B3 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS)

July, 14, 2016

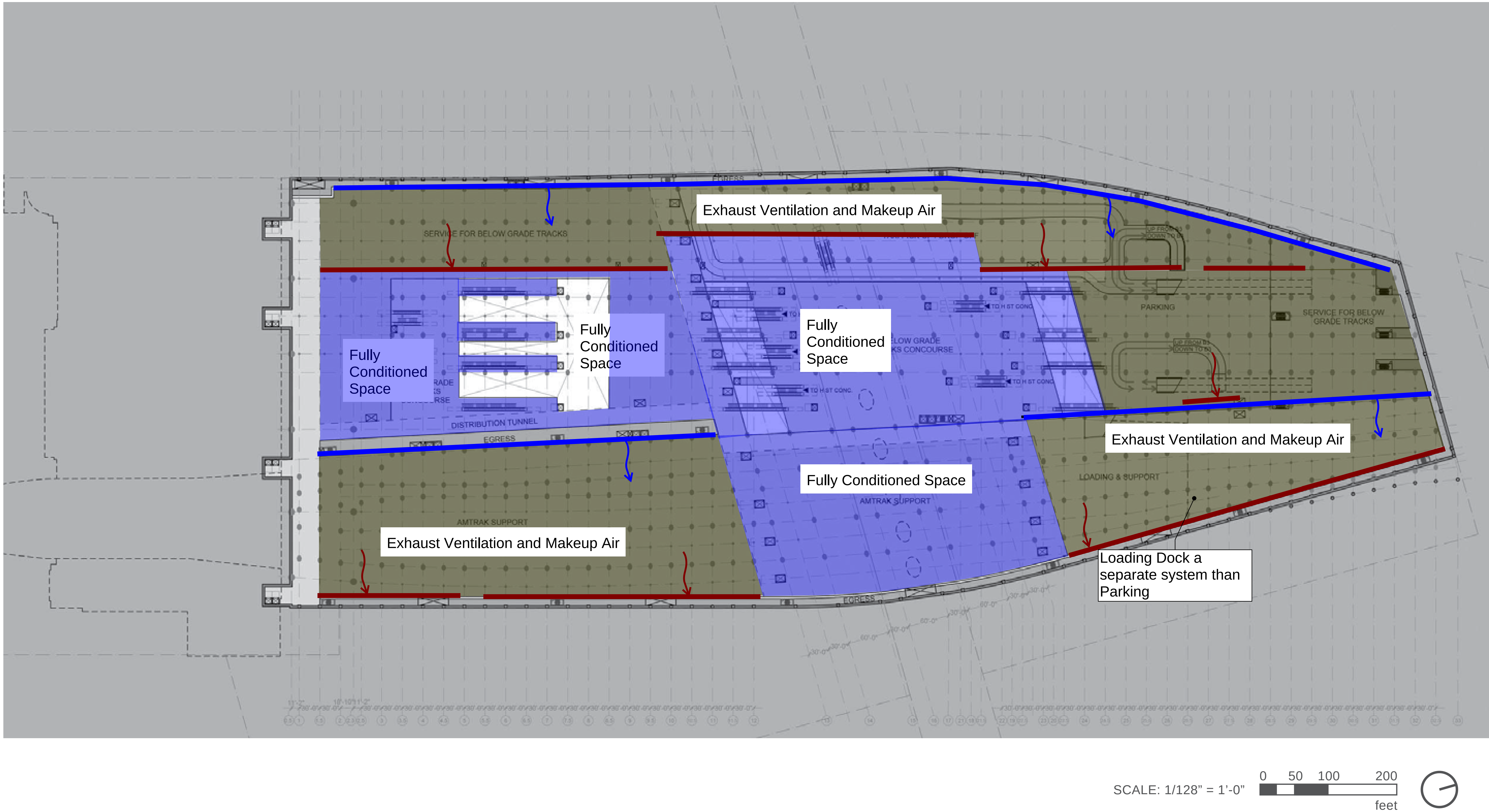

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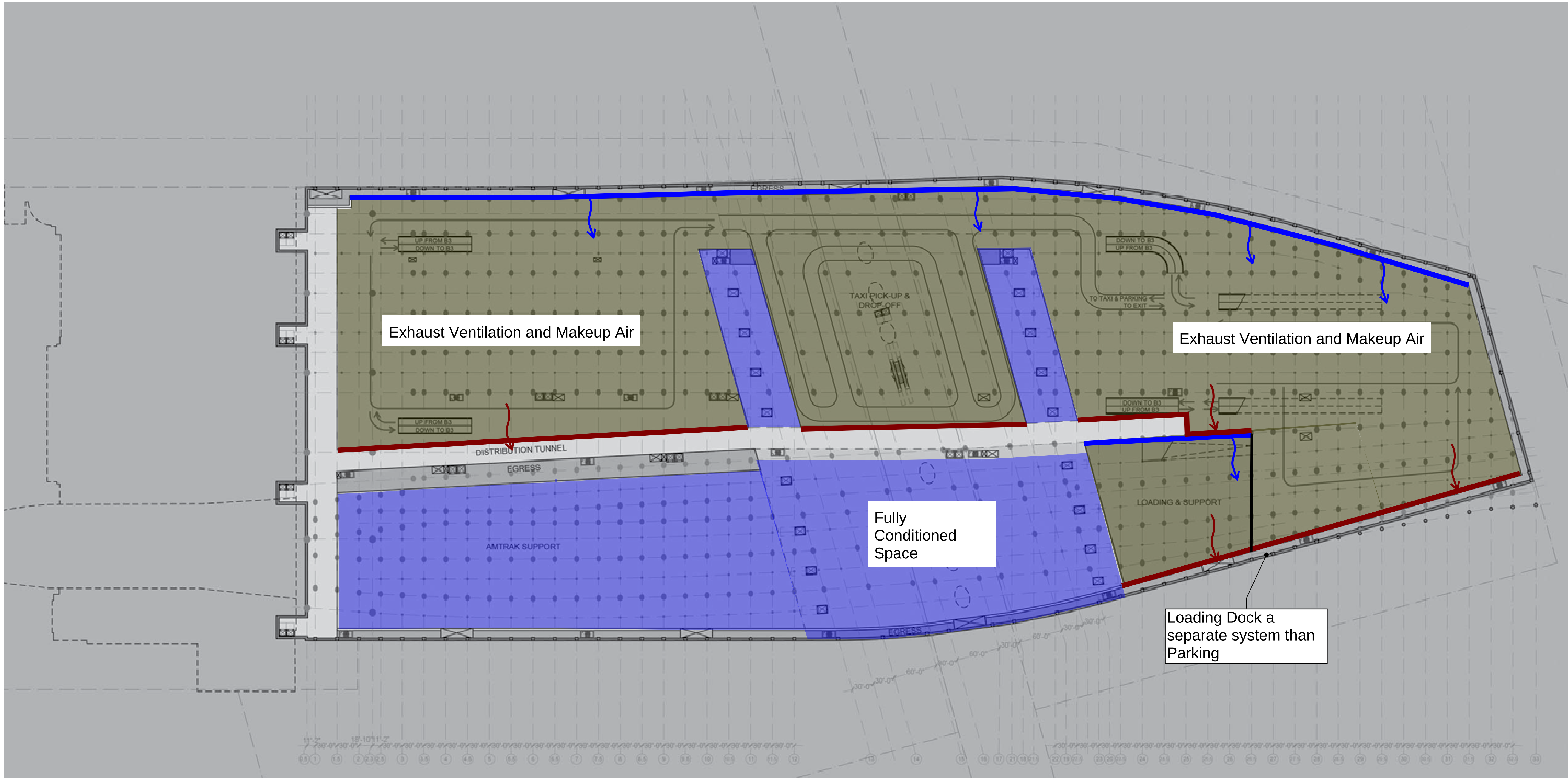
Figure D-33 - B2 Level Plan with Below Grade parking and tracks

DRAFT

B2 LEVEL PLAN

(WITH ADDITIONAL BELOW GRADE TRACKS)

July, 14, 2016



SCALE: 1/128" = 1'-0" 0 50 100 200 feet

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Figure D-34 B2 Level plan taxi, loading, parking, no BGT

B2 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS)

July, 14, 2016

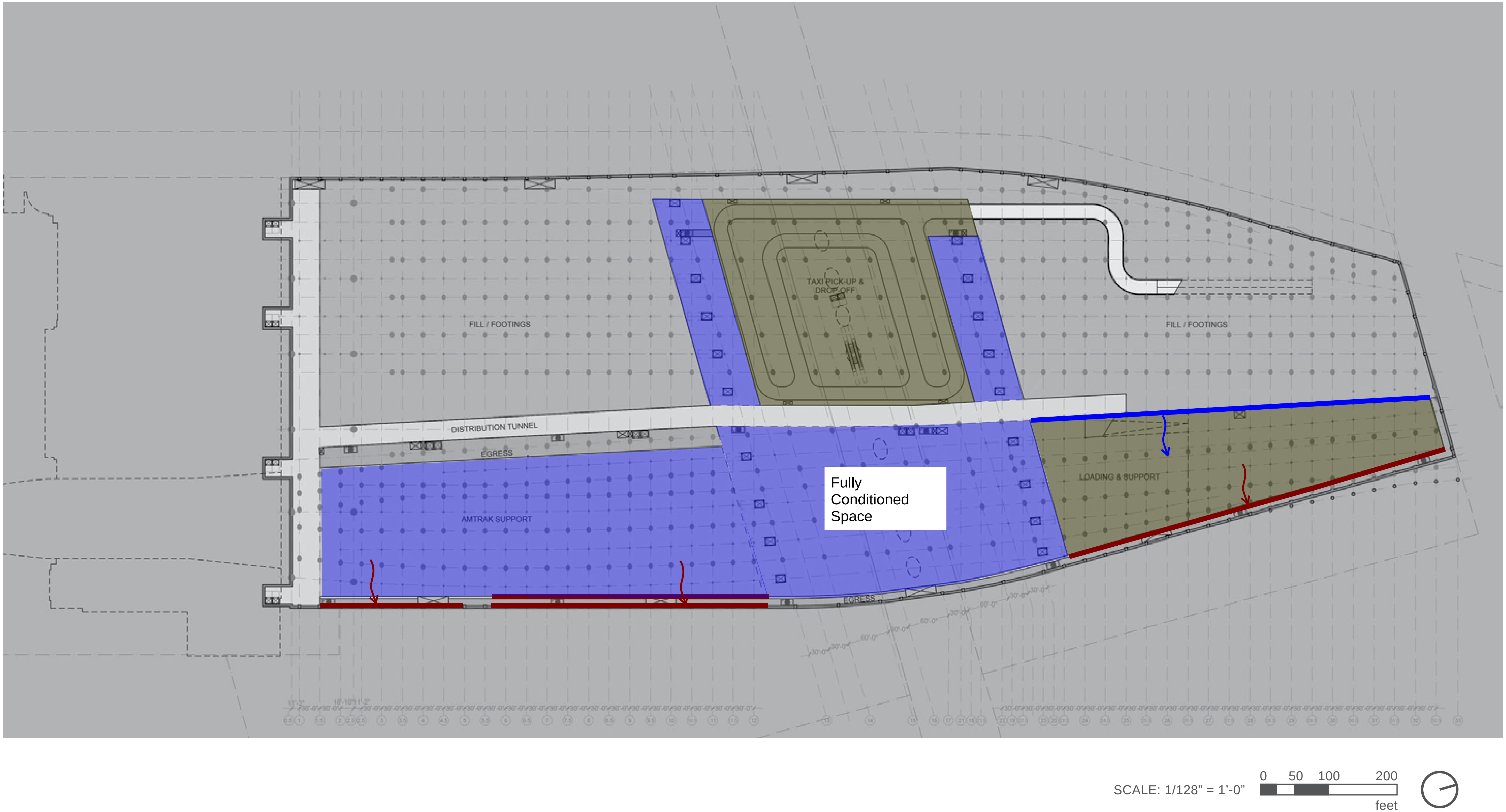

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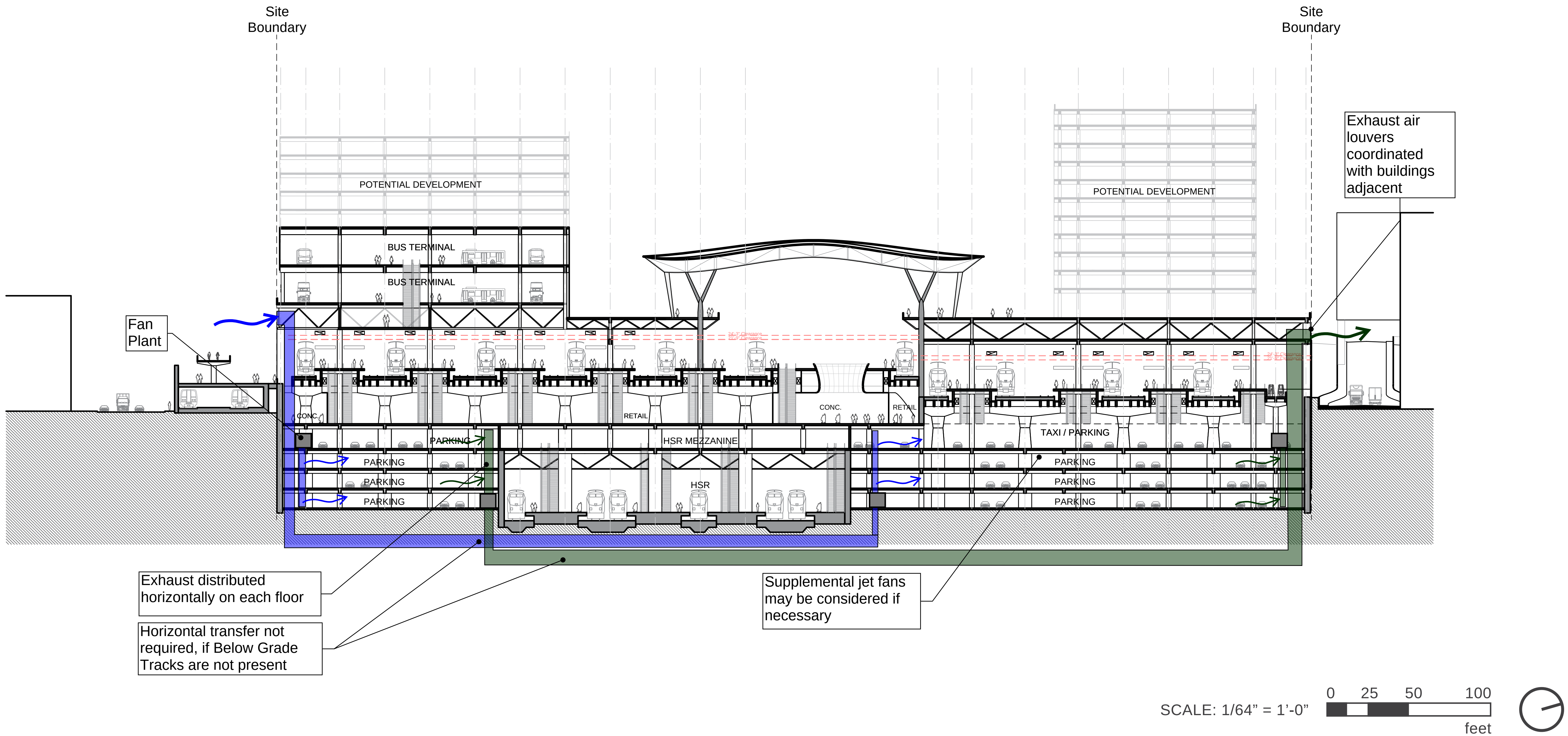
Figure D-35 - B2 Level Plan Taxi, Loading, no BGT and no Parking

DRAFT

B2 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS AND PARKING)

July, 14, 2016



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PUBLIC PARKING VENTILATION STRATEGY

DRAFT

BUS ON SOUTH-WEST NEW STRUCTURE - PARKING BELOW (WITH ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-36 - Parking Ventilation Strategy

FUTURE BELOW GRADE TRACKS

Additional Below Grade Tracks (BGT) is no longer being considered as a project element. Please refer to the Executive Summary for a description of the current status of the BGT options.

Future tracks would require ventilation for the comfort and safety of the passengers. The system would have the following features:

- The system would be rated for high temperature smoke control removal.
- Provision for future systems would be accommodated, providing adequate infrastructure including rated shafts and louvers.
- Fan plants could be constructed in the future, either by converting program space or by excavating new space
- Smoke exhaust would be required from ceiling level of the future tracks and platforms, as well as the future passenger concourse.
- Make up air would be required.
- All equipment would need to be connected to emergency power. Rather than constructing this capacity during initial construction, an area to accommodate external generators could be allocated to enable these to be installed at a future date

Accommodating the BGT would require deeper ventilation tunnels, larger shafts and more standing power. It is therefore more onerous to coordination with TI and BP teams.

COORDINATED MEP APPROACH

There are four main Concepts which are significantly different in how the HVAC systems will be impacted.

These are as follows:

1. Below grade public parking, future BGT accommodated (Figure D-38)
2. Above grade public parking, future BGT accommodated (Figure D-39)
3. Above grade public parking, future BGT accommodated (Figure D-40)
4. Below grade public parking, future BGT accommodated (Figure D-41)

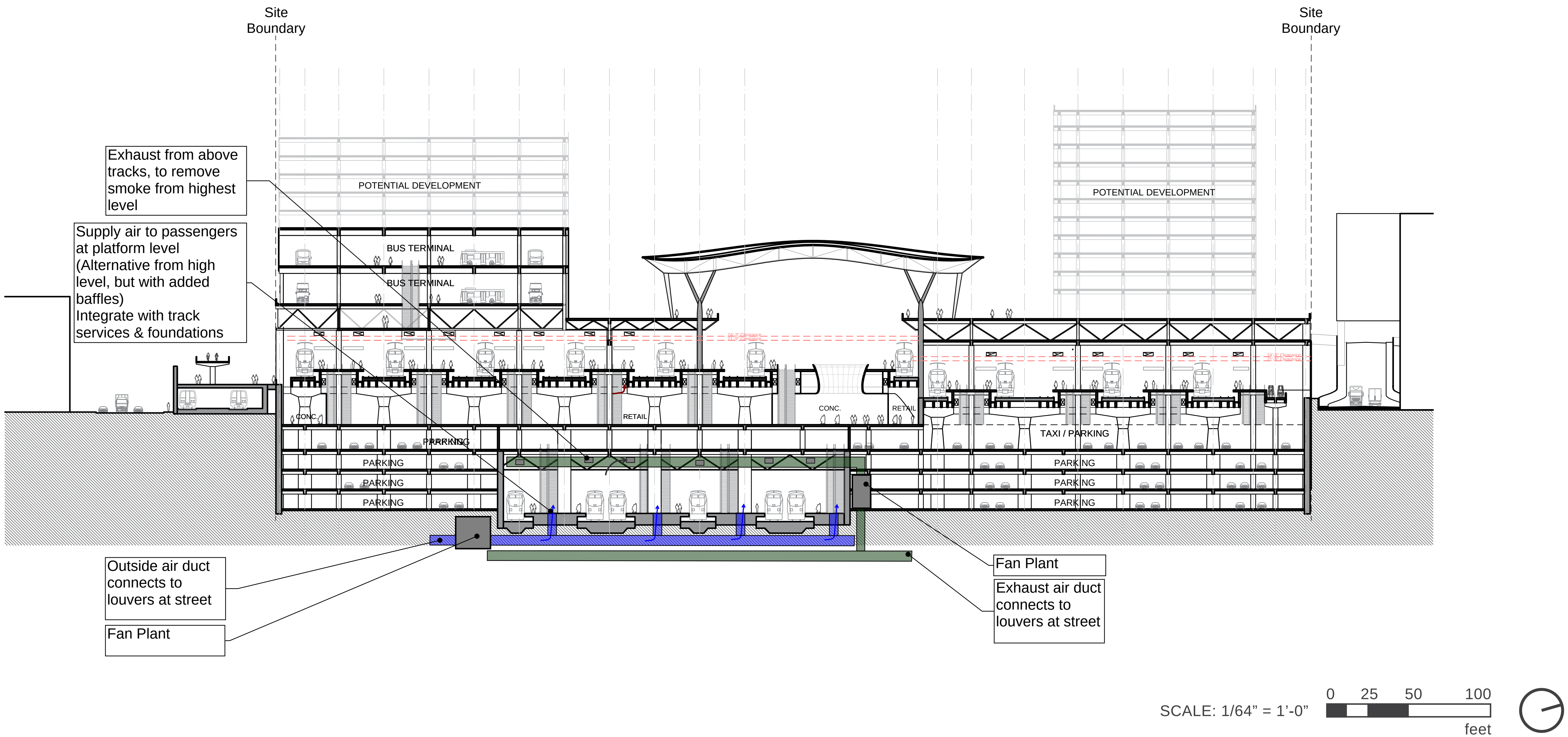
To prevent mixing of air streams, outside air and exhaust air would be on opposite elevations, connecting via vertical shafts to mechanical rooms / fan plant located around the lower floors.

Ventilation tunnels, running underneath the lowest slab, would supplement.

Where possible, fan plant would be adjacent to these shafts, however, Ventilation tunnels would be provided to connect to shafts which are distributed around the floor plate. Of significance, the options that include BGT necessarily require tunnels connecting underneath the BGT, which could have a significant impact upon construction schedule.

Shaft areas are represented in Table D-2, indicating the shaft areas for various permutations of below grade program.

The following figures Figure D-38 to Figure D-41 summarize the zoning of HVAC services, with and without Below Grade Tracks.



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BELOW GRADE TRACKS VENTILATION STRATEGY

TRANSVERSE SECTION AT SOUTH

DRAFT

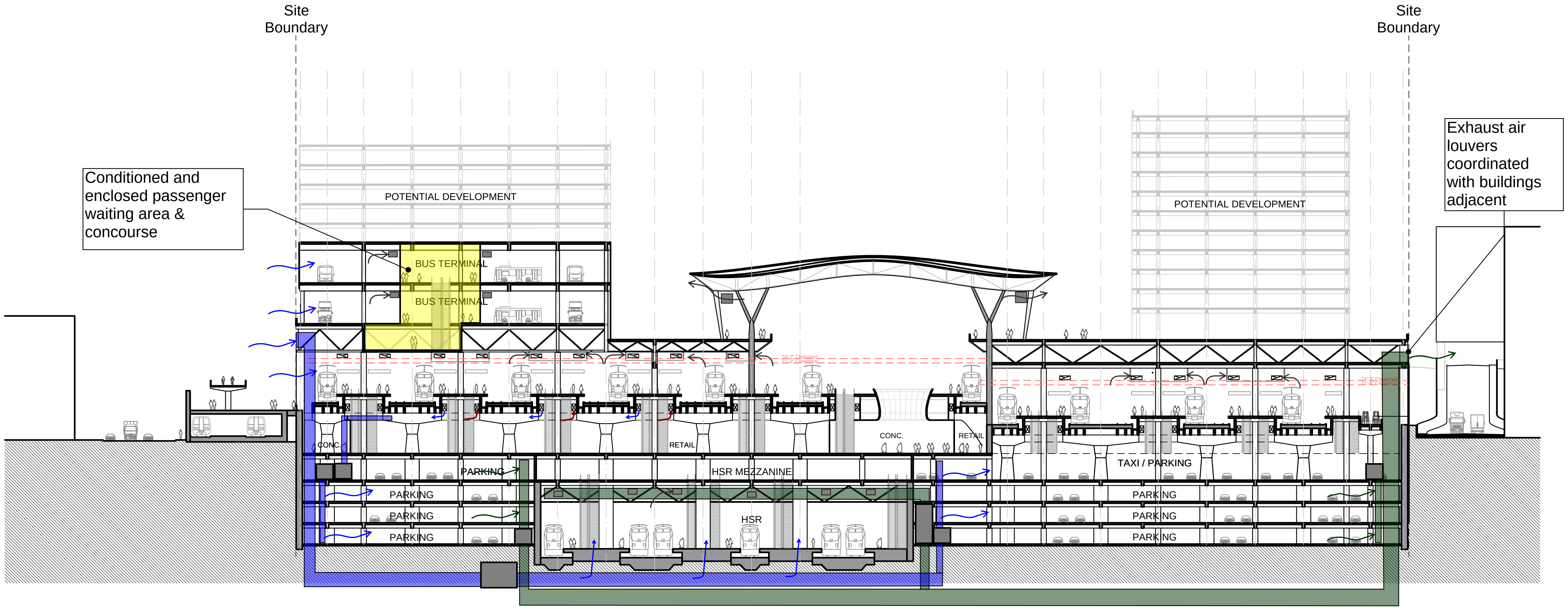
BUS ON SOUTH-WEST NEW STRUCTURE - PARKING BELOW (WITH ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-37 - Below Grade Tracks Ventilation Strategy

Table D-2 - Shaft Areas

	QUANTITY OF SHAFTS											
	4	6	8	4	6	8	4	6	8	4	6	8
	INTERNAL SIZE OF SHAFT (SQ.FT)			**EXTERNAL SIZE OF SHAFT (SQ.FT)**			**INTERNAL SIZE OF SHAFT (SQ.FT)**			**EXTERNAL SIZE OF SHAFT (SQ.FT)**		
SHAFT SIZES WITH BELOW GRADE TRACKS AND BELOW GRADE PARKING												
Combined Shaft	433	289	216	433	289	216	563	375	281	563	375	281
Parking	124	83	62	124	83	62	161	108	81	161	108	81
Concourse	47	31	23	42	28	21	61	40	30	55	36	27
Below Grade Tracks	110	73	55	110	73	55	142	95	71	142	95	71
SHAFT SIZES WITHOUT BELOW GRADE TRACKS & WITH BELOW GRADE PARKING												
Combined Shaft	323	215	162	323	215	162	323	215	162	323	215	162
Parking	124	83	62	124	83	62	161	108	81	161	108	81
Concourse	47	31	23	42	28	21	61	40	30	55	36	27
Below Grade Tracks	0	0	0	0	0	0	0	0	0	0	0	0
SHAFT SIZES WITHOUT BELOW GRADE TRACKS & WITHOUT BELOW GRADE PARKING												
Combined Shaft	75	50	37	75	50	37	75	50	37	75	50	37
Parking	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concourse	47	31	23	42	28	21	61	40	30	55	36	27
Below Grade Tracks	0	0	0	0	0	0	0	0	0	0	0	0
SHAFT SIZES WITH BELOW GRADE TRACKS & WITHOUT BELOW GRADE PARKING												
Combined Shaft	184	123	92	184	123	92	184	123	92	184	123	92
Parking	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concourse	47	31	23	42	28	21	61	40	30	55	36	27
Below Grade Tracks	110	73	55	110	73	55	142	95	71	142	95	71



SCALE: 1/64" = 1'-0"

0 25 50 100
feet

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VENTILATION STRATEGY

TRANSVERSE SE

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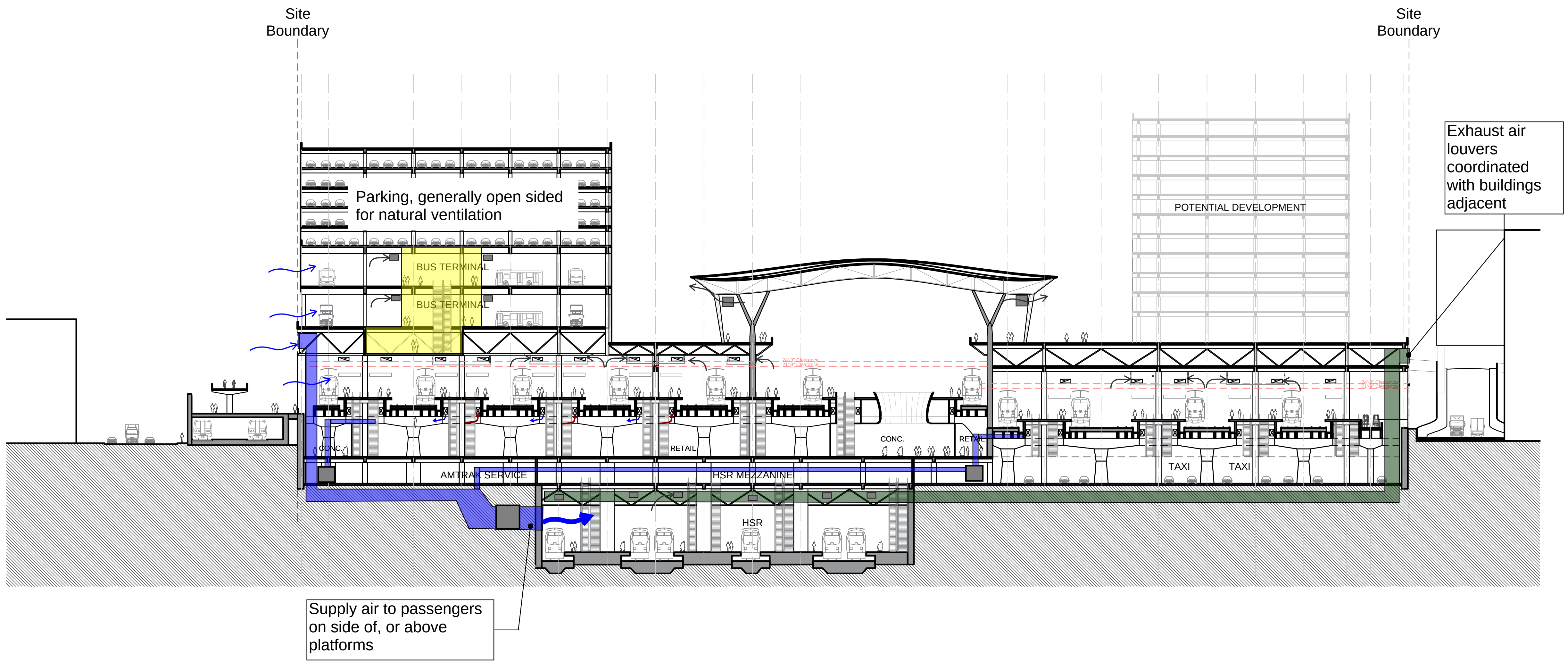
BUS ON SOUTH-WEST NEW STRUCTURE - PARKING BELOW (WITH ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-38 - Coordinated HVAC approach BGT & Below Grade Parking



SCALE: 1/64" = 1'-0"

0 25 50 100
feet

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VENTILATION STRATEGY

TRANSVERE SECTION AT SOUTH

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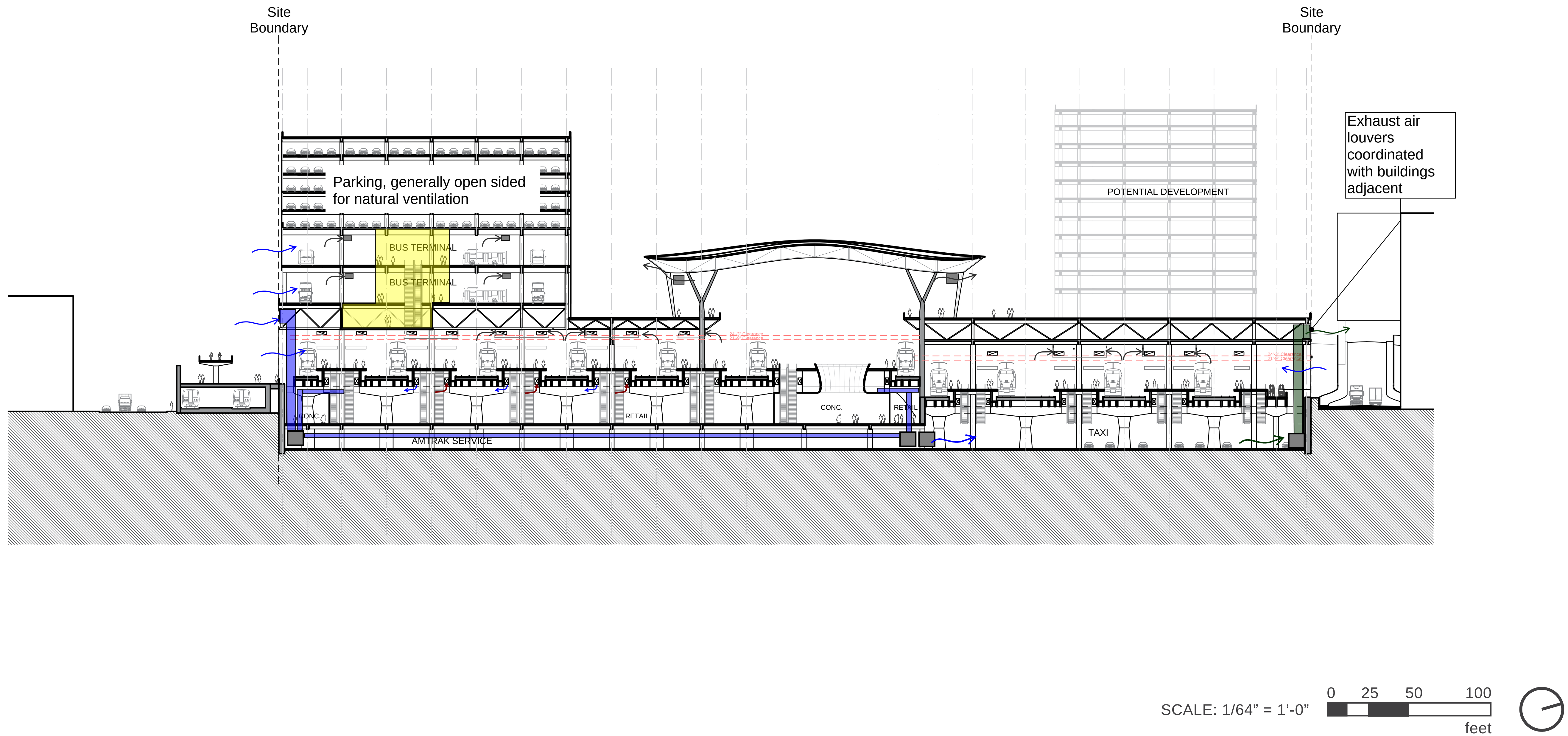
BUS ON SOUTH-WEST NEW STRUCTURE - PARKING ABOVE (WITH ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-39 - Coordinated HVAC approach BGT & Above Grade Parking



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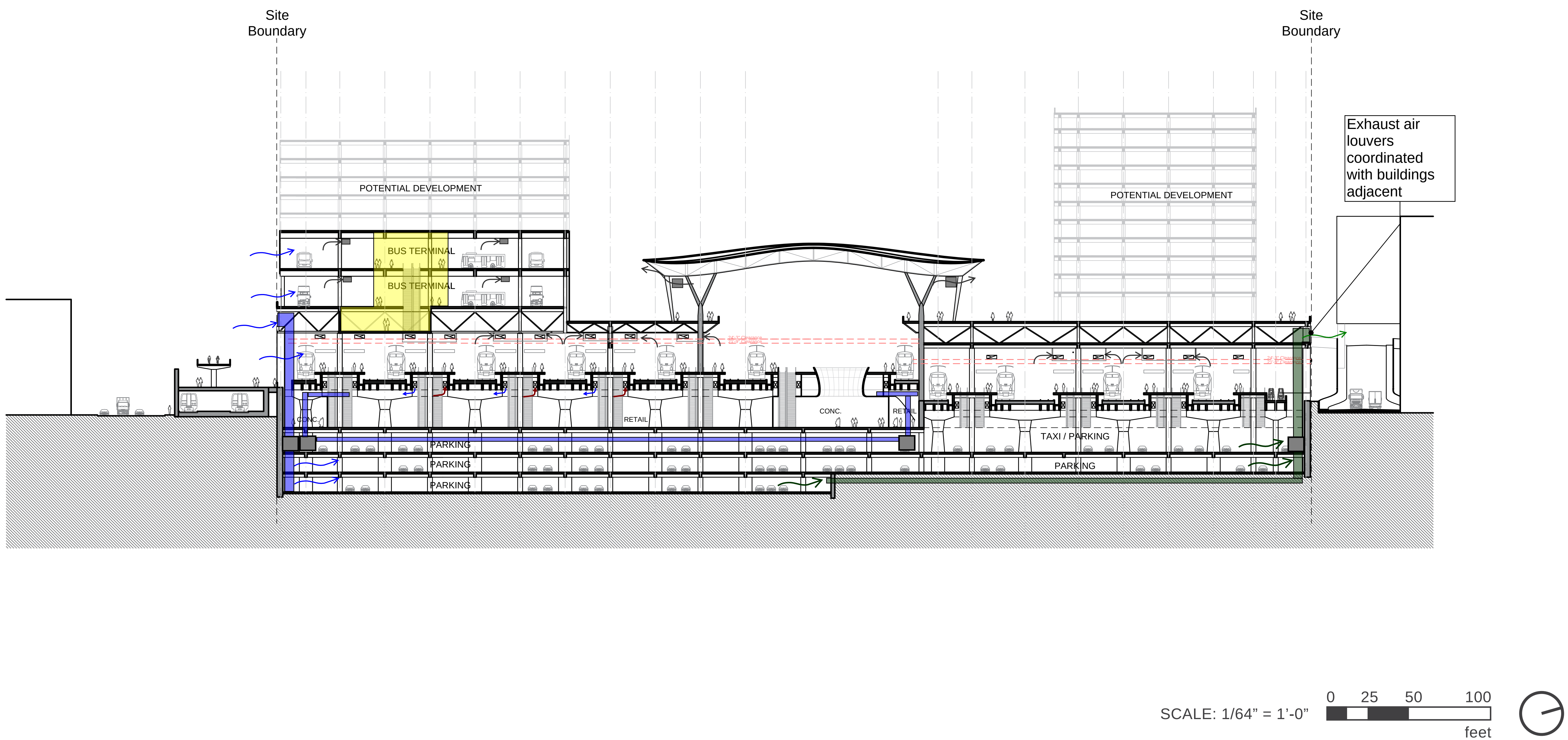
BUS ON SOUTH-WEST NEW STRUCTURE - PARKING ABOVE (NO ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-40 - Coordinated HVAC approach No BGT & above Grade Parking



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BUS ON SOUTH-WEST NEW STRUCTURE - PARKING BELOW (NO ADDITIONAL BELOW-GRADE TRACKS)

July, 14, 2016

Figure D-41 - Coordinated HVAC approach No BGT & Below Grade Parking

Bus Terminal South (Concept 1)

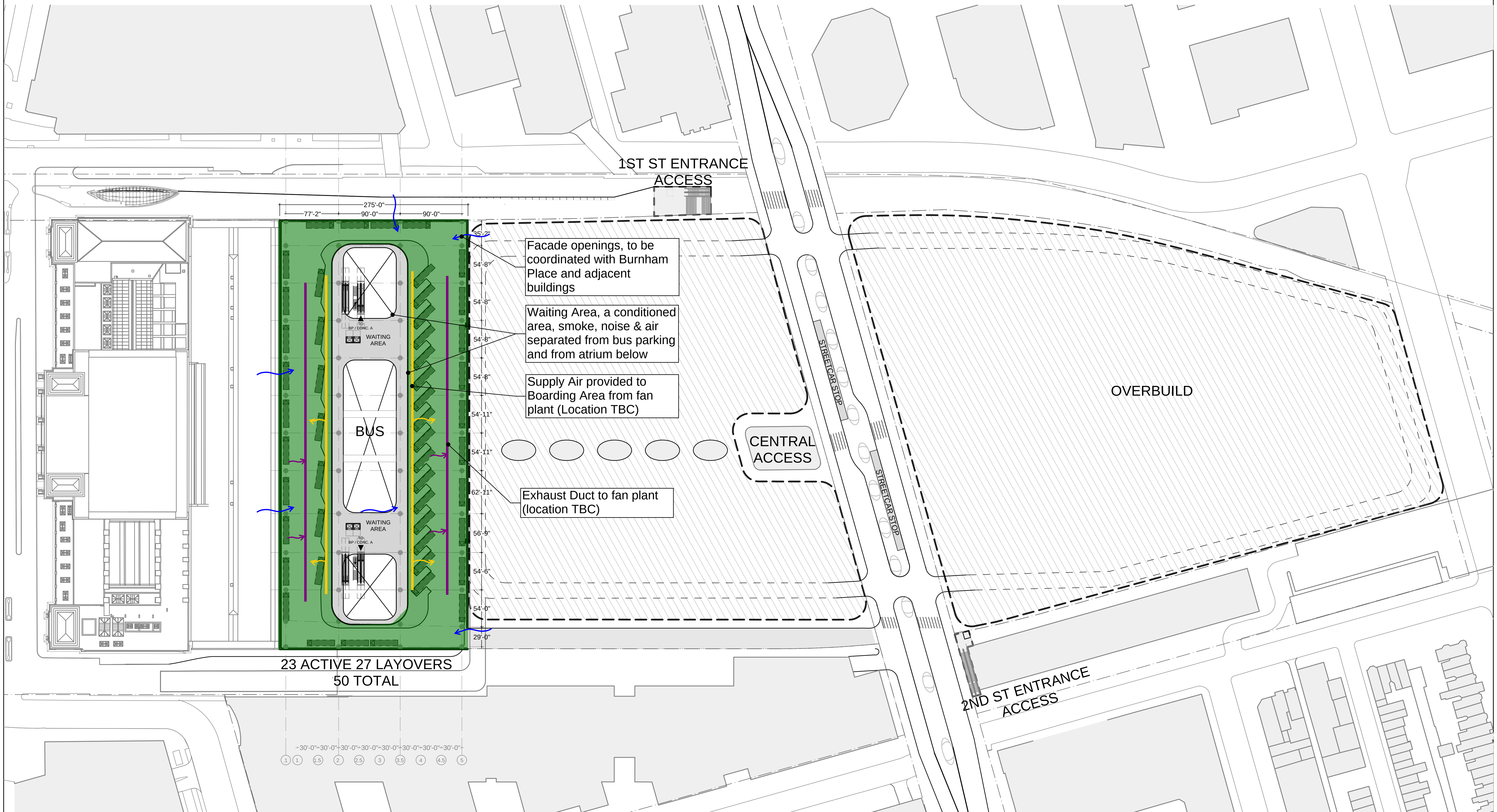


Figure D-42 - Bus Station Ventilation (options above Concourse A)

N 0' 50' 100' 200'

EL = 102.50'

Bus Terminal (Concept 2)

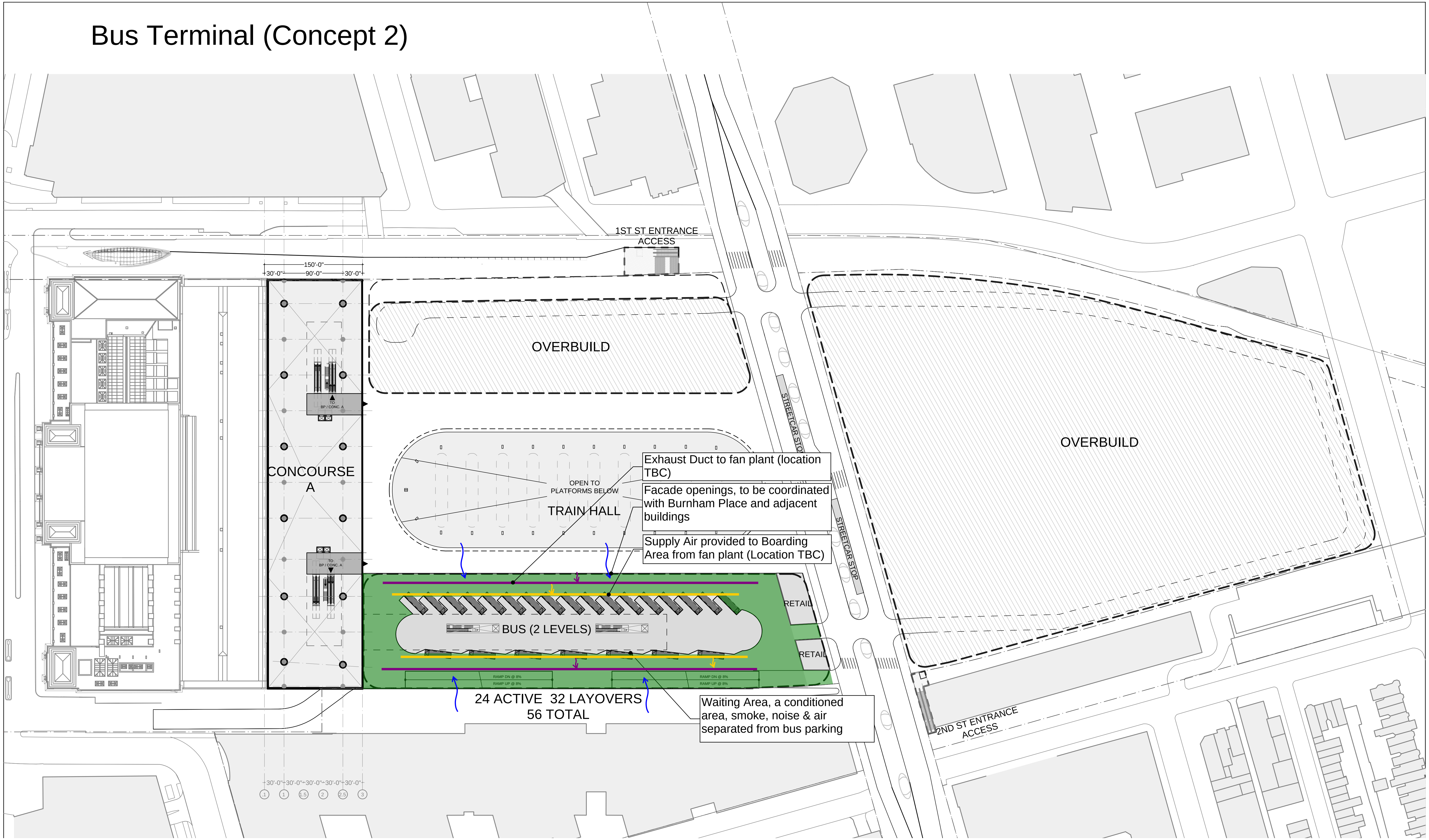


Figure D-43 - Bus Station Ventilation (for Bus Station on North, South East and South West

N 0' 50' 100' 200'

EL = 102.50'

Fire Engineering

The planning of the Concepts is informed by egress circulation and access for firefighting, the principles of which are contained within this report. Other notable aspects of the fire strategy are contained within the Draft BoD, as they do not significantly impact upon the assessment of these Concept options.

The approach being developed is to generally comply with prescriptive methods prescribed in code where possible.

Exits

The required number of exits from any room, space or floor is required to be based on the following. (NFPA 101, 7.4.1.2)

- 1-500 occupants – two (2) exits
- 501-1,000 occupants – three (3) exits
- More than 1,000 occupants - four (4) exits

EXIT SEPARATION

Where two or more exits or exit access doorways are required, they are required to be placed a distance apart equal to not less than one-third the length of the maximum overall diagonal dimension of the area to be served. (NFPA 101, 7.5.1.3.3)

TRAVEL DISTANCE

The common path of travel and the exit access travel distance is required to be measured at right angles. Required distances are listed in the Table below.

DESCRIPTION OF AREA USE	DEAD END (FT)	COMMON PATH OF TRAVEL (FT)	TRAVEL DISTANCE (FT)
STATION EXPANSION			
Assembly (Waiting Areas, Restaurant) (NFPA 101, Table A.7.6)	20	75	250
Mercantile (Retail Shops) (NFPA 101, Table A.7.6)	50	75	250
Business (NFPA 101, Table A.7.6)	50	100	300
Enclosed Parking Garage (NFPA 101, 42.8.2.5, .6)	50	50	200
Ordinary Hazard Storage (Misc. Storage) (NFPA 101, 42.2.5)	100	100	400
Low Hazard Storage (NFPA 101, 42.2.5)	NA	NA	NA
RAIL YARD			
Platform (NFPA 130, 5.3.3.6)	NA	82	325
BOH / Maintenance (NFPA 101, Table A.7.6)	100	100	400

Fire Department Access

Over the course of several meetings, DC Fire Emergency Medical Services (FEMS) stated that they would require several means of access to the WUS complex.

With this in mind, access should be provided to the complex at the following locations:

- Columbus Circle (note this would be proximate to the existing fire command center)

- First Street / H Street

- Second Street / H Street

Potentially access could also be provided from BP deck, which would require coordination.

Fire department trucks would not gain access to the platform and track areas, Fire Fighters would access via the routes highlighted above, fighting fires from standpipes at platform level designed as part of this scope of work.

Engineered Fire Strategy Approach

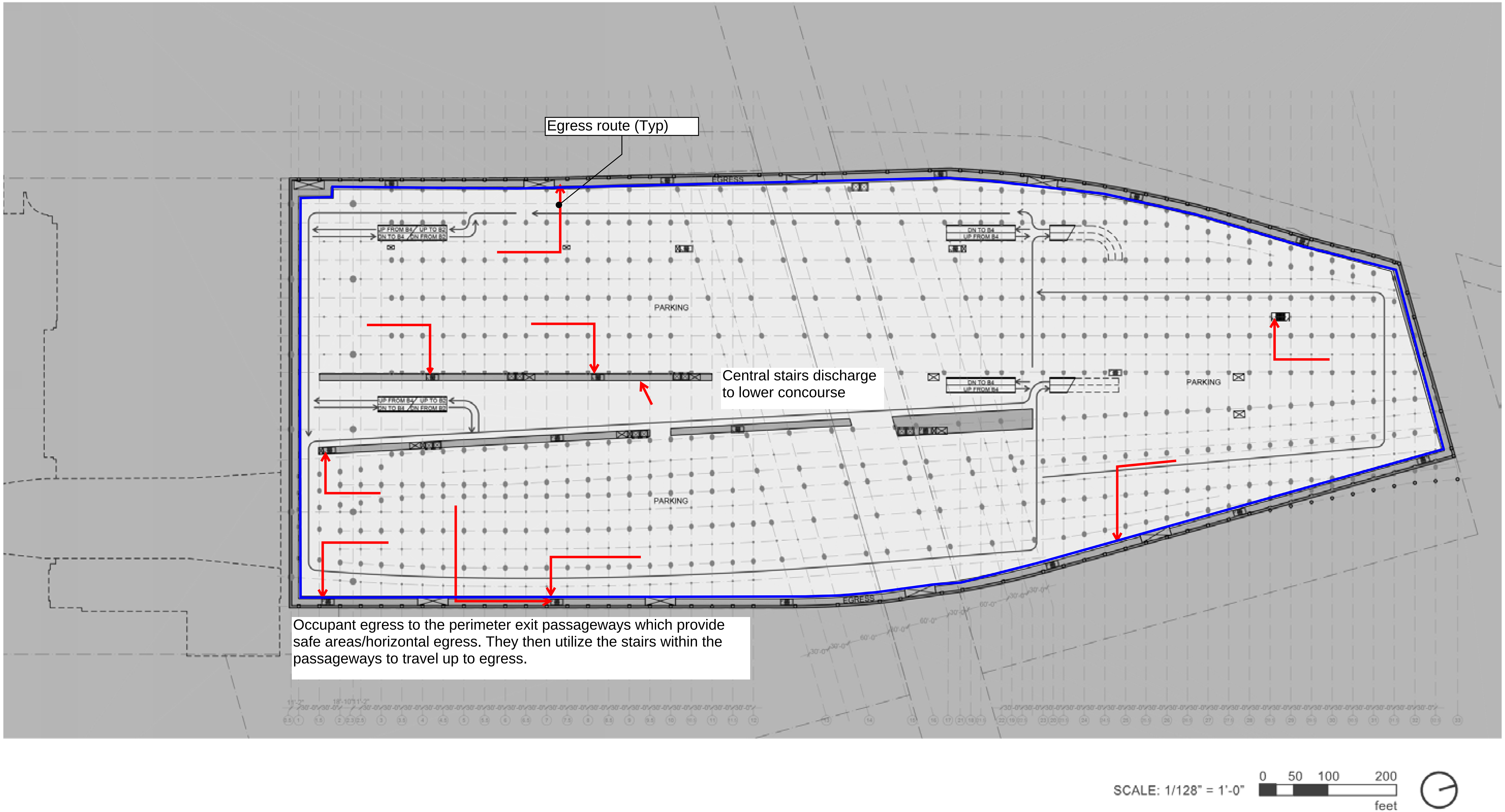
As previously stated, the SEP planning effort has developed fire strategies to address areas which would not comply with prescriptive standards. In all Concepts, the following issues and possible mitigation strategies are listed below:

- Lower Level Passenger Concourses: utilizing an engineered egress solution, possibly including smoke control in the passenger concourses to mitigate extended travel distances from the Passenger Concourse to the exterior of the building.

- Underground Future Below Grade Tracks: a performance analysis would be needed, including dynamic egress analysis and smoke modeling to demonstrate the ability to provide safe egress. The solution may involve strategic application of smoke barriers and exit passageways.

- Exit Discharge from Below Grade Parking: Providing code compliant exit discharge would be challenging due to the limited access to the street along the site perimeter. Some of the vertical stairs would need to collect at passageways that lead to safe areas which would in turn allow access to exit discharge. Dynamic egress analysis would likely need to be performed to validate the ability of occupants to evacuate safely. Historically, exit discharge has been allowed utilizing easements that have been provided for service of buildings, such as the easement along the east side of the rail yard. This easement would also be considered for use as an exit discharge from the Garage.

The SEP design has developed fire strategies to address areas which, due to the confines of the existing site, would not comply with prescriptive standards. The areas and the suggested mitigation strategy are as noted in the following drawings:



WASHINGTON UNION STATION EXPANSION PROJECT

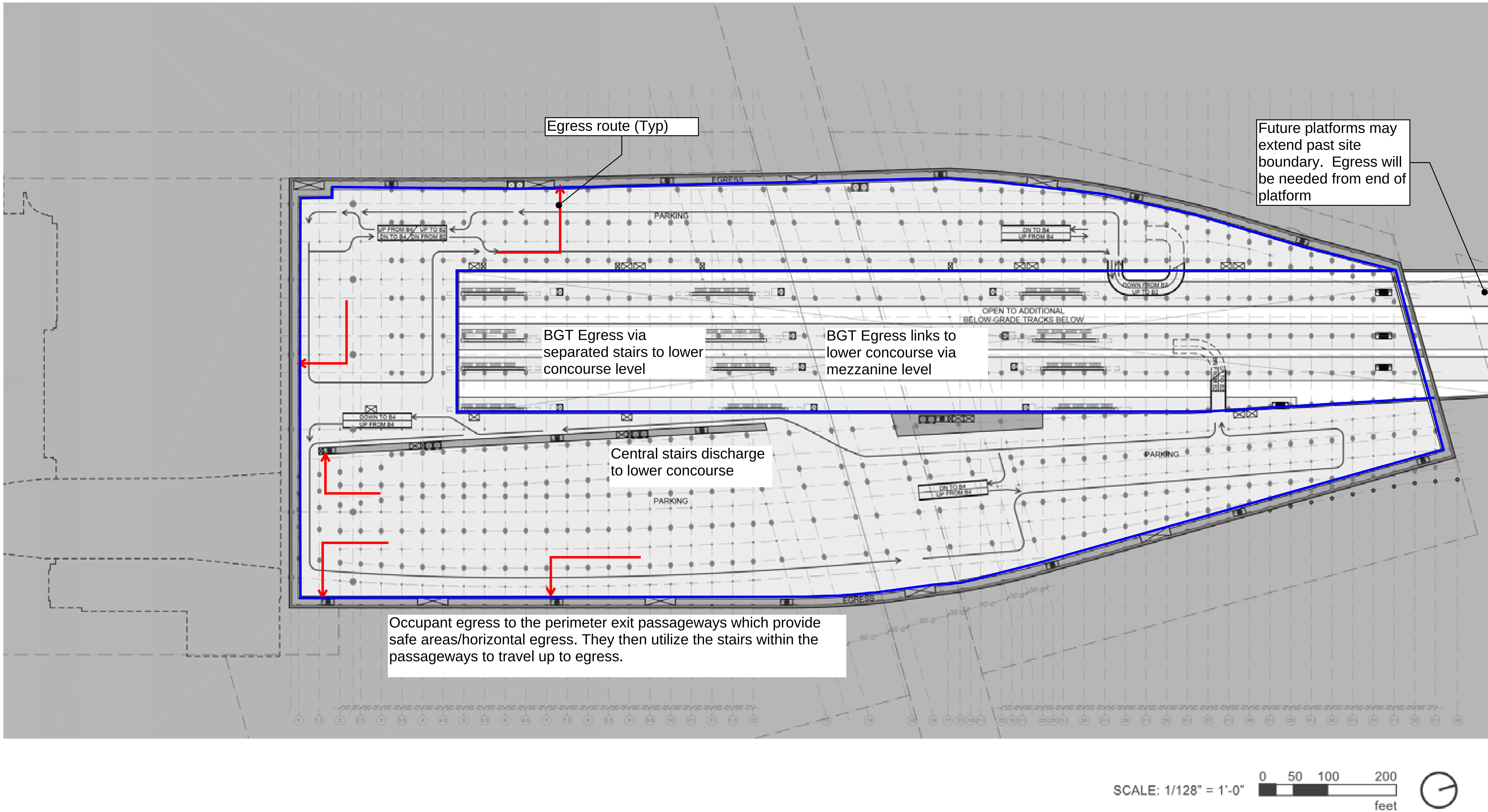
BEYER BLINDER BELLE | GRIMSHAW

B3 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-44 - Egress at B3 Level



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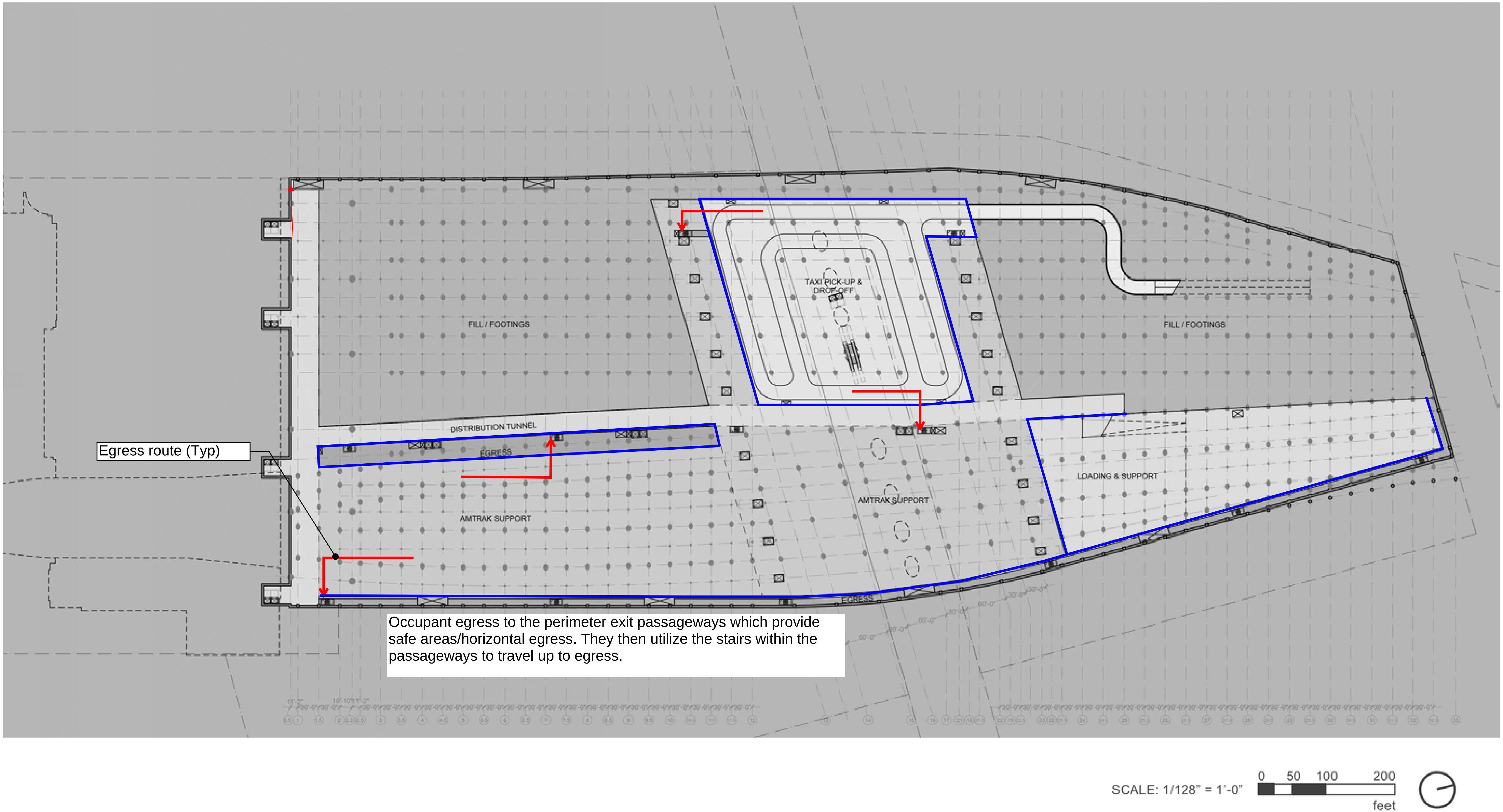
B3 LEVEL PLAN

(WITH ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-45 - Egress at B3 Level



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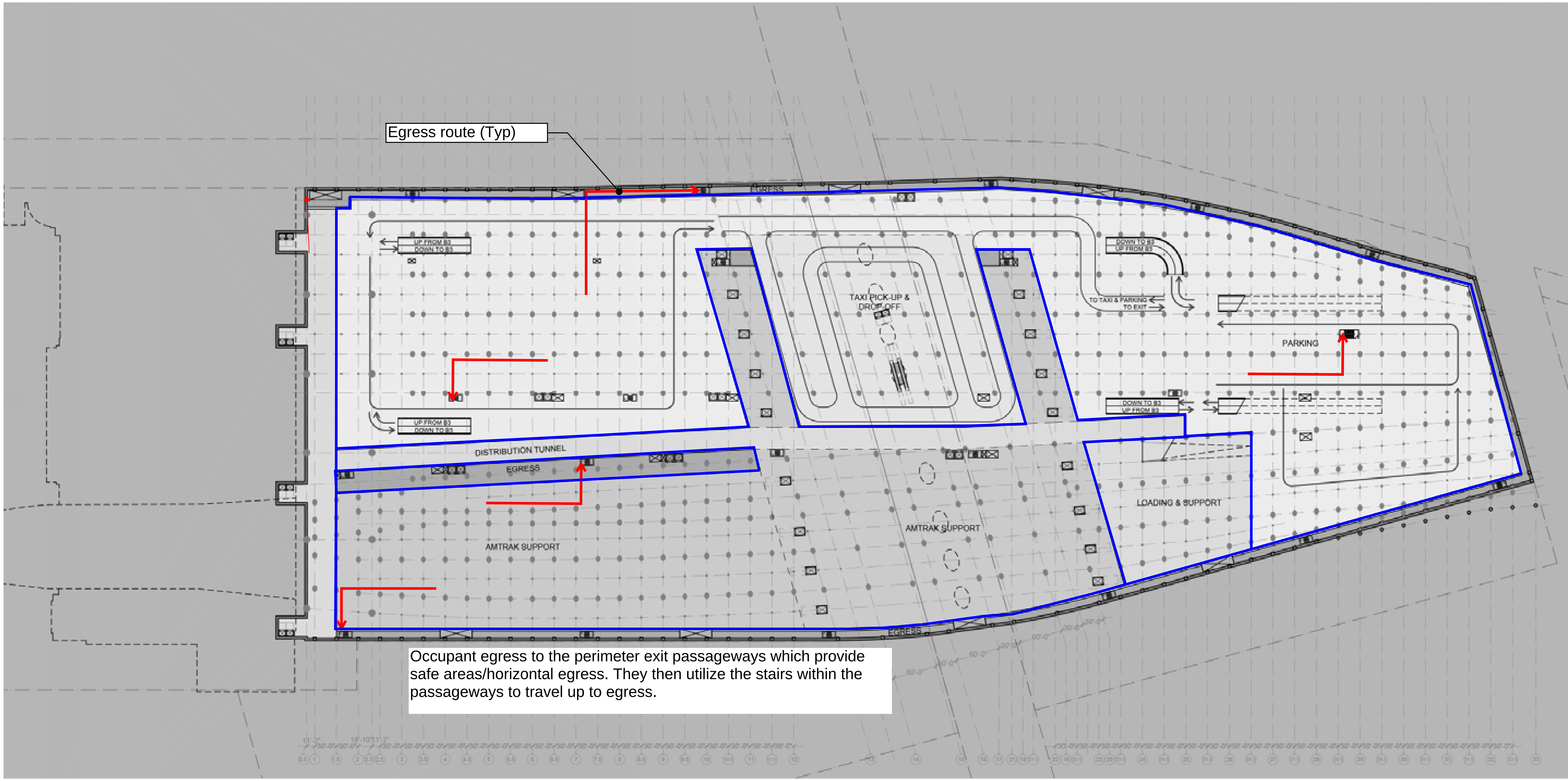
B2 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS AND PARKING)

June 14, 2016

Figure D-46 - Egress at B2 Level



SCALE: 1/128" = 1'-0"   0   50   100   200 feet

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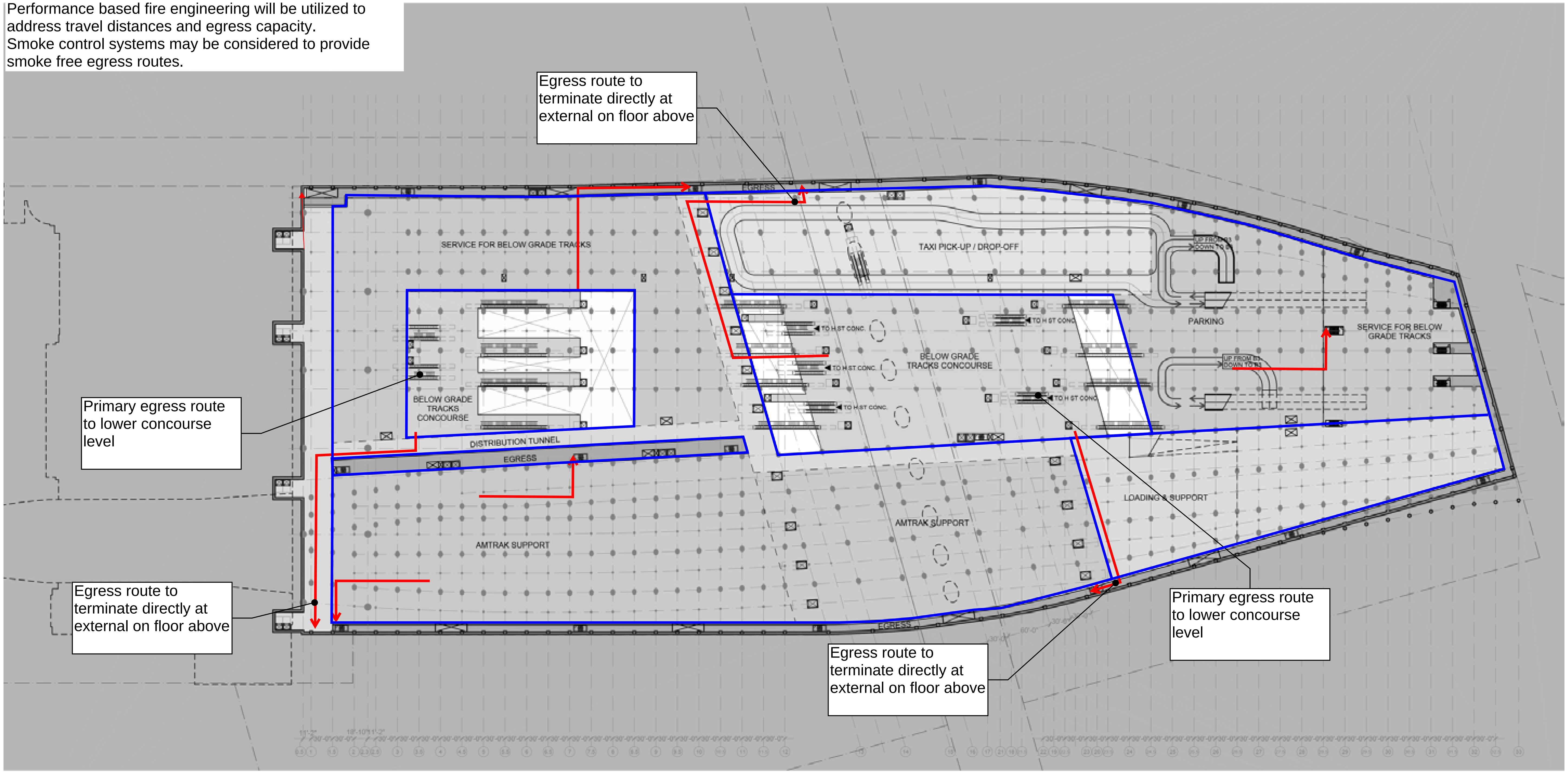
BEYER BLINDER BELLE | GRIMSHAW

B2 LEVEL PLAN

(NO ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-47 - Egress at B2 Level



SCALE: 1/128" = 1'-0" 0 50 100 200 feet

WASHINGTON UNION STATION EXPANSION PROJECT

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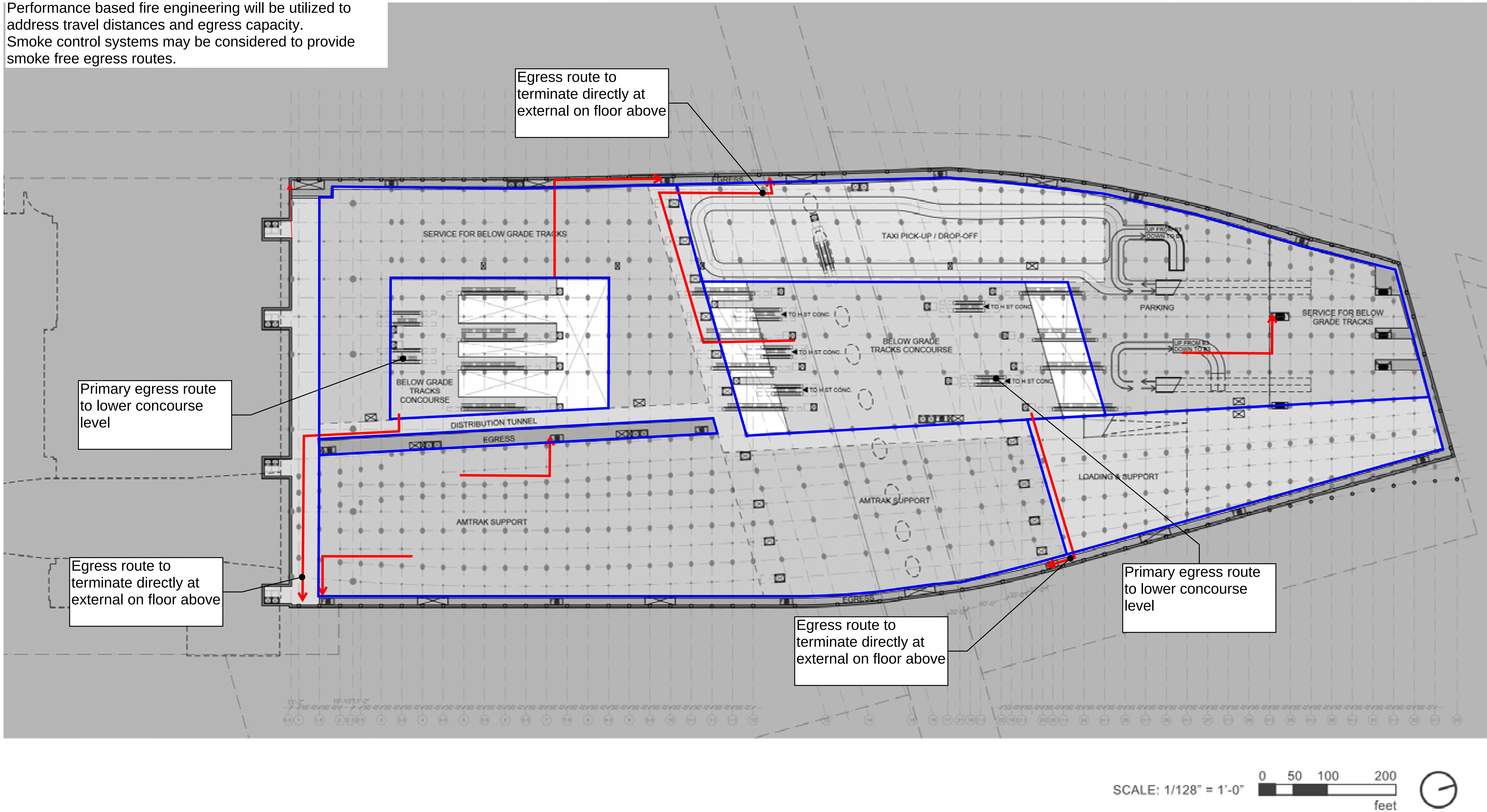
B2 LEVEL PLAN

(WITH ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-48 - Egress at B2 Level



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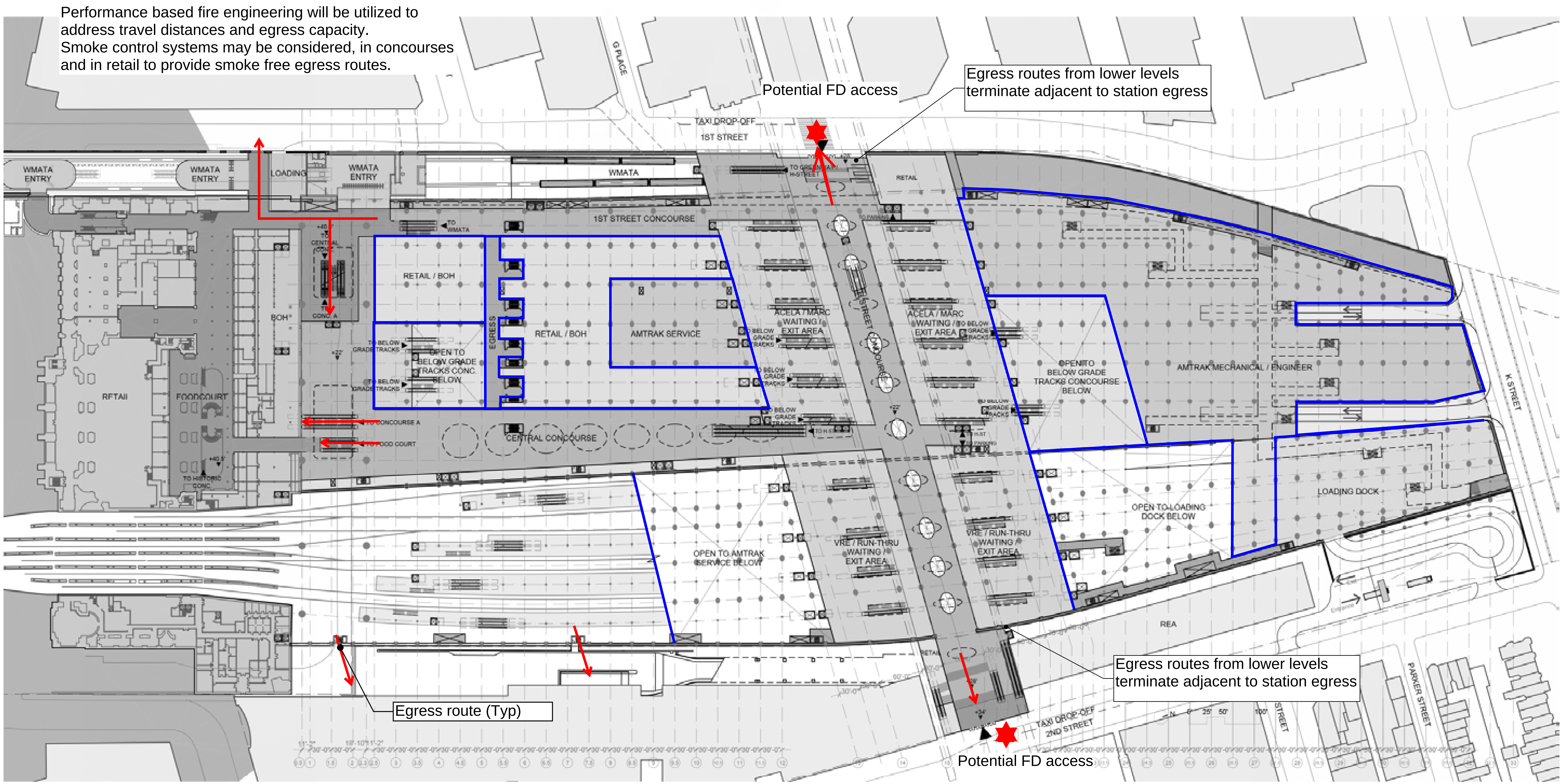
B2 LEVEL PLAN

(WITH ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-49 - Egress at Concourse Level



SCALE: 1/128" = 1'-0" 0 50 100 200 feet

WASHINGTON UNION STATION EXPANSION PROJECT

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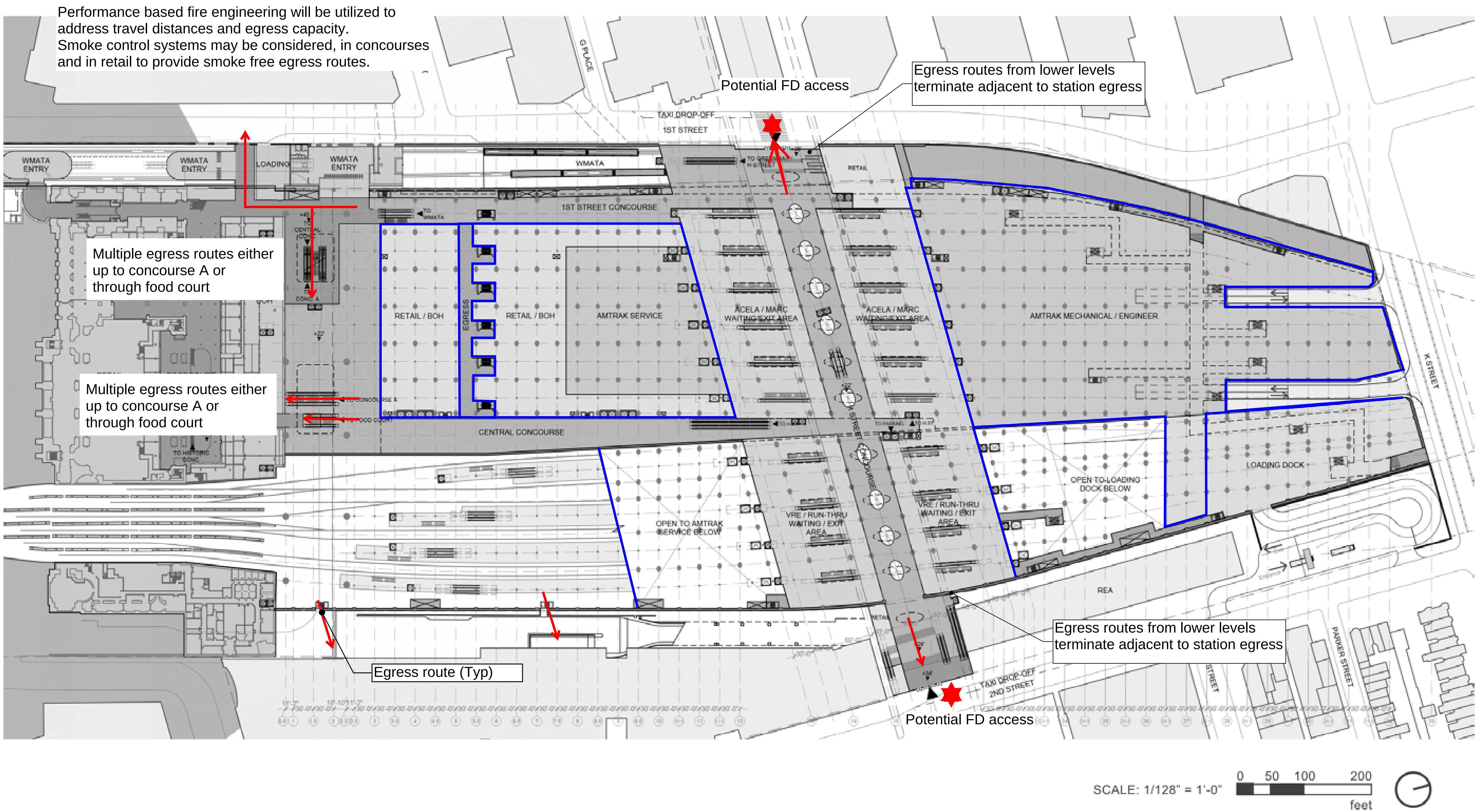
LOWER LEVEL CONCOURSE PLAN

TI OPTION 16 (WITH ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-50 - Egress at Concourse Level



WASHINGTON UNION STATION EXPANSION PROJECT

BEYER BLINDER BELLE | GRIMSHAW

LOWER LEVEL CONCOURSE PLAN

TI OPTION 14 (NO ADDITIONAL BELOW GRADE TRACKS)

June 14, 2016

Figure D-51 - Egress at Concourse Level

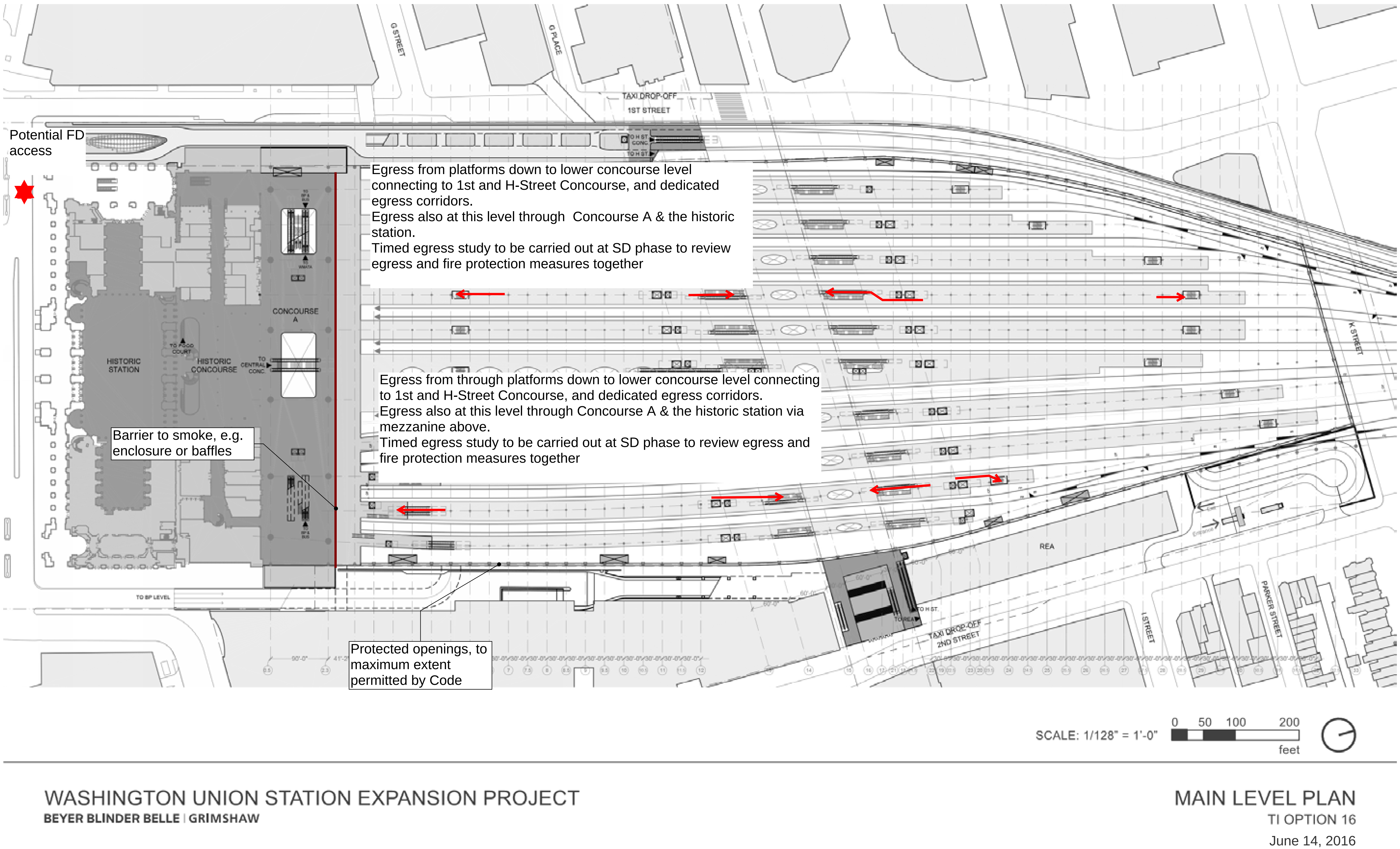
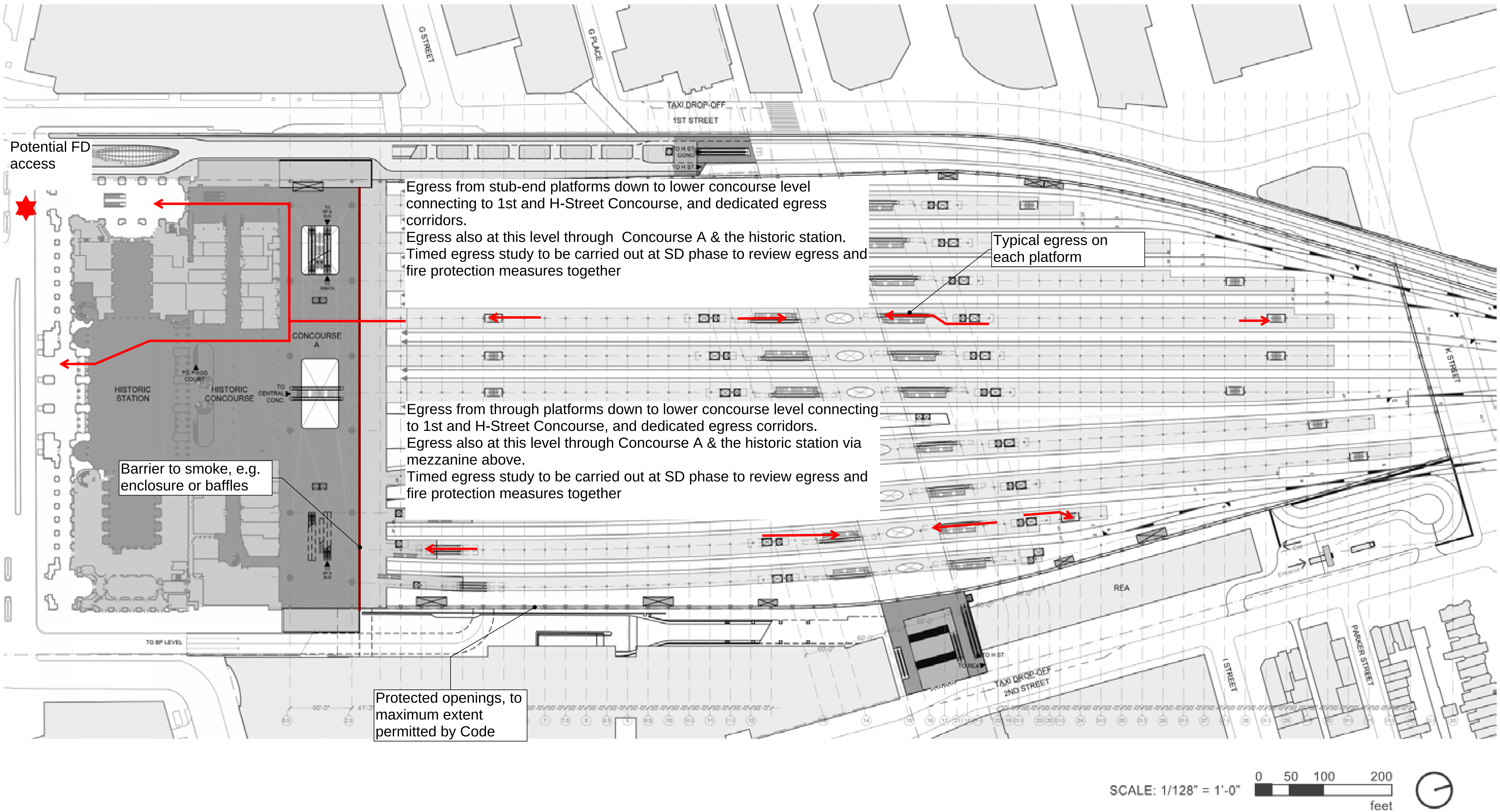


Figure D-52 - Egress at Platform Level



WASHINGTON UNION STATION EXPANSION PROJECT

MAIN LEVEL PLAN

Figure D-53 - Egress at Platform Level

June 14, 2016

Engineering Approaches Considered but Dismissed

The following approached have been analyzed and are deemed to be infeasible.

Bus Terminal located below tracks

Options for a below grade Bus Terminal were considered but dismissed for several reasons. First, the density of requisite columns grids was not compatible with a feasible bus layout that adequately accommodated turning radii. Secondly, TVRA findings supported the placement of above grade buses due to the relative size and effect of a blast event below the tracks and concourses.

Options to accommodate buses beyond the project area were not carried forward due to policy and jurisdictional considerations with adjacent landowners.

Bus Terminal located beyond project area

Options to accommodate buses beyond the project area were not carried forward due to policy and jurisdictional considerations with adjacent landowners.

Reuse of existing bus station and parking building

The USPG is located to the Northwest of existing passenger concourse. It is a six-level structure consisting of post-tensioned concrete floors supported on several story deep steel transfer trusses. The roof is an occupied parking level. Large diameter columns supporting the USPG pass through track level, terminating with piles located below the lower concourse level.