Photo Source: Osman Rana / Unsplash

8. Preferred Alignment and Construction Technology

8. Preferred Alignment and Construction Technology

8.1 Purpose and Background

This chapter summarizes the recommended Preferred Alignment for the NSRL Feasibility Reassessment.

Three NSRL alignments were studied:

- Central Artery (Two- and Four-Track)
- South/Congress (Two-Track)
- Pearl/Congress (Two-Track)

It is noted that all alternatives share common elements, including similar portal locations and portal designs, impacts on Back Bay Station, and signal and junction improvements. For the purposes of comparison, it is assumed that train operations – speed, reliability, and schedules – are similar in all three alignments.

In addition, three different construction approaches were also studied (all of which employ tunnel boring machines):

- 29-foot-diameter single-track tunnel (requiring two parallel bores)
- 41-foot-diameter double-track tunnel
- 51-foot-diameter double-track tunnel

For the Central Artery Four-Track Alignment, two parallel 41-foot bored tunnels are assumed.

The Pearl/Congress alignment must use the 29-foot-diameter tunnel approach. Both the Central Artery and South/Congress can use either the 41-foot-diameter tunnel or the 51-foot-diameter tunnel.

The No Build and South Station Expansion and All-Day Peak Service alternatives are not assessed, as the Feasibility Reassessment is tasked with recommending the preferred NSRL alignment.

Implied in the selection of a preferred tunnel alignment is both a consideration of the construction technology (tunnel diameter, station construction) and the service efficacy (number of trains and passengers).

The previous 2003 NSRL study included a robust Evaluation of Alternatives; those alternatives included non-tunnel alternatives (such as more MBTA rapid transit service) and compared them to the rail project alternative. This Feasibility Reassessment compares various tunnel alignments, tunnel designs and service options (intensities of service) to each other and the surface (no tunnel) alternatives, and to a No Build alternative with maximum feasible train service provided at expanded terminals.

The Two-Track build alternatives "mix and match" different alignments with tunnel designs. The Four-Track build alternative is only paired with the 41-foot tunnel design:

Tunnel Alignment	Tunnel Design	Alternative Tunnel Design
Central Artery – 2 Tracks	41-foot-diameter bored tunnel; mined stations	51-foot-diameter bored tunnel; stations within tunnel bore
Pearl/Congress – 2 Tracks	29-foot-diameter bored tunnel; mined stations	None
South/Congress – 2 Tracks	51-foot-diameter bored tunnel; stations within tunnel bore	41-foot-diameter bored tunnel; mined stations

Table 51 – Two-Track Alignment Alternative

Tunnel Alignment	Tunnel Design	Alternative Tunnel Design
Central Artery – 4 Tracks	41-foot-diameter bored tunnel; mined stations	None

Table 52 – Four-Track Alignment Alternative

Capacity

All Two-Track alignments are assumed to have capacity for up to 24 trains per hour in each direction. In this analysis, it is assumed that two to three of those trains are Amtrak Regional services (other Amtrak services are assumed to terminate at South Station). That leaves 21-22 train "slots" per hour for MBTA services, however upstream constraints limit the actual throughput to 17 trains per hour, per direction from both the northern lines and the southern lines merging at Back Bay Station.

Upstream capacity constraints on the Old Colony Lines only allow about six trains per hour to enter into the tunnel. The Fairmount Line has more capacity – likely another six trains per hour; however, there is insufficient upstream capacity on the northern system to accept more trains beyond those already routed through Back Bay.

Note that in Chapter 4, the Two-Track and Four-Track alternatives required different line pairings to accommodate the additional lines coming through the South portal in the Four-Track alternative, therefore necessitating different levels of service. When comparing the Two- and Four-Track alternatives in this Chapter, the comparison is between the most robust service levels available for each.

Guiding Principles

As part of the Feasibility Reassessment, MassDOT adopted a set of Guiding Principles, designed to provide a framework for the design and review of the NSRL design concepts. These Principles, also discussed in Section 3.3, are as follows:

Primary Principles

1. Design a system to enable service patterns that support the MBTA Focus40 goals and objectives.
2. Increase the capacity of the MBTA's commuter rail network to bring commuters into Downtown Boston and Back Bay during peak commuting hours.
3. Improve the transit accessibility to employment opportunities in Boston's urban core, particularly for residents on the north side of the Boston metropolitan area.
4. Relieve congestion on the MBTA's rapid transit network (in particular on the Orange Line) by directly connecting commuters with their final destination.
5. Improve the MBTA's ability to efficiently maintain its rail fleet.

Secondary Principles

1. Reduce the physical footprint of rail layover facilities (both at the downtown terminals and elsewhere in the urban core), freeing these locations up for higher and better use.
2. Reduce the emissions associated with the commuter rail system in the urban core through the electrification of portions of the network.

8.2 Evaluation Objectives and Methodology

As each proposed alternative was assessed using a consistent and agreed upon methodology, it was also important to understand the priorities of the asset owner and the asset users (MassDOT and MBTA and Amtrak, respectively). The development of the Guiding Principles was a critical first step in this process. Following this, the process includes:

- Agreement on Evaluation Criteria
- Weighting for each criterion to best match the Guiding Principles
- Evaluation and scoring of each alternative against each criterion
- Application of the weighting to each criterion and development of the full score

Evaluation Categories

Pivoting from the Guiding Principles, this chapter proposes to evaluate the alignments and service plans in three broad categories:

- Economy
- Environment
- Equity

More detail on the actual criteria under these categories can be found in Appendix F.

Evaluation Process – Screening

A three-step screening process was used to evaluate and reduce the number of alternatives until a final recommendation was identified. Appendix F identifies 11 criteria grouped into three categories. All 11 criteria are used over the three screening steps, but only the relevant criteria are used in each screening (for example, Two-Track versus Four-Track has little difference in environmental impact).

First-Step Screening – Two- Versus Four-Track Alternatives

The first screen assesses Two-Track versus Four-Track alternatives. The relevant criteria include cost, use and selected impacts, as detailed in Table 53.

The construction cost for the Four-Track alternative (only viable on the Central Artery alignment) is about 90% greater than the mid-range Two-Track alternative. The total ridership is about 11% greater. The number of low-income households – owing to the ability of the Fairmount Line to use the tunnel – is greater with the Four-Track alternative and crowding reductions are also greater with the Four-Track alternative.

Taken together, and using the highest value as the basis for comparison, the screening scores are detailed in Tables 54 and 55.

Category	Criteria	Range	Weight	Total	Percentage
Economy	Estimated Construction Cost	1-5	10	10-50	70%
	Total Commuter Rail Weekday Riders	1-5	4	4-20	
Equity	Low-income Households Served	1-5	2	2-10	30%
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	1-5	4	4-20	

Table 53: First-Step Screening Process

Category	Criteria	Range	Weight	Total
Economy	Estimated Construction Cost	4	10	40
	Total Commuter Rail Weekday Riders	4	4	16
Equity	Low-income Households Served	2	2	4
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	1	4	4
TOTAL TWO-TRACK				**64**

Table 54: Two-Track First-Step Screening – Number of Tracks

Category	Criteria	Range	Weight	Total
Economy	Estimated Construction Cost	2	10	20
	Total Commuter Rail Weekday Riders	4.5	4	18
Equity	Low-income Households Served	3	2	6
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	2	4	8
TOTAL FOUR-TRACK				**52**

Table 55: Four-Track First-Step Screening

Comparing the two scores, the recommendation is to advance a Two-Track alternative. While the Four-Track alternative slightly improves access to low-income households served (because of connecting the Fairmount Line, although the Two-Track alternative also provides good service to northern Gateway Cities) and reduces crowding on MBTA bus and rapid transit lines (because of its slightly greater coverage in the bus and subway service area) over the Two-Track alternative, the Two-Track alternative has a higher score because of its lower overall cost. As a result, the Four-Track Central Artery alternative is rejected. The Central Artery Two-Track alternative continues along with the other two Two-Track alternatives.

Second-Step Evaluation – Construction Technology

After first-step screening, the next step considers the appropriate construction technology, using the same criteria. The three tunneling options considered are:

- 29-foot-diameter single-track tunnel with mined stations
- 41-foot-diameter double-track tunnel with mined stations
- 51-foot-diameter double-track tunnel with stations within the tunnel diameter

The applicable criteria will be used to evaluate the three types of tunnel and project construction impacts:

Category	Criteria	Range	Weight	Total	Percentage
Economy	Estimated Construction Cost	1-5	10	10-50	70%
	Risks – Permitting, Construction Risk, and Operations Risk	1-5	2	2-10	
	Potential for Phasing	1-5	2	2-10	
Environment	Construction Impacts	1-5	2	2-10	30%
	Resilience in Disasters and Events	1-5	4	4-20	

Table 56: Second-Step Screening Process – Construction Technology

Tables 57 through 59 show the scores for the different-sized tunnel bores, as follows:

Category	Criteria	Range	Weight	Total
Economy	Estimated Construction Cost	4	10	40
	Risks – Permitting, Construction Risk, and Operations Risk	1	2	2
	Potential for Phasing	1	2	2
Equity	Construction Impacts	1	2	2
	Resilience in Disasters and Events	1	4	4
TOTAL 29-FOOT-DIAMETER BORE				**50**

Table 57: 29-Foot-Diameter Bore Screening

Category	Criteria	Range	Weight	Total
Economy	Estimated Construction Cost	5	10	50
	Risks – Permitting, Construction Risk, and Operations Risk	1	2	2
	Potential for Phasing	1	2	2
Equity	Construction Impacts	1	2	2
	Resilience in Disasters and Events	1	4	4
TOTAL 41-FOOT-DIAMETER BORE				**60**

Table 58: 41-Foot-Diameter Bore Screening

Category	Criteria	Range	Weight	Total
Economy	Estimated Construction Cost	4.5	10	45
	Risks – Permitting, Construction Risk, and Operations Risk	3	2	6
	Potential for Phasing	1	2	2
Equity	Construction Impacts	3	2	6
	Resilience in Disasters and Events	1	4	4
TOTAL 51-FOOT-DIAMETER BORE				**63**

Table 59: 51-Foot-Diameter Bore Screening

Based on the scoring, the 29-foot-diameter bored tunnel is eliminated, primarily due to its higher cost, relative to the other alternatives. The 41-foot- and 51-foot-diameter tunnels have close scores. The 41-foot-diameter tunnel is slightly less expensive, which is offset by its higher construction risks and impacts, compared to the 51-foot-diameter tunnel, where station construction is within the tunnel diameter and there is less impact on utilities within the city right-of-way (as most access is from adjacent parcels). The 51-foot-diameter tunnel scores slightly better than the 41-foot-diameter in overall scores.

For the purposes of the Feasibility Reassessment, the 51-foot-diameter tunnel is recommended; however, in any environmental document, the 41-foot-diameter tunnel should be considered as an alternative. The main tie-breaking benefit of the 51-foot-diameter tunnel is its reduced impacts on the street rights-of-way and other construction impacts and risk, which have high value in Boston. A downside of the 51-foot-diameter tunnel, aside from the higher cost, is that stations can be less appealing due to the constrained nature of constructing them within the tunnel diameter.

Third-Step Screening – Alignment

With construction method confirmed as the 51-foot-diameter tunnel, this approach is then applied to the three alignment studies. The Pearl/Congress alignment is not capable of using either the 41- or the 51-foot-diameter tunnels. As a result, that alignment is eliminated (there are also other concerns with the Pearl/Congress alignment, including connections to South Station and the ability to phase the system to an eventual four-track service). The remaining alignments are:

- Central Artery Two-Track
- South/Congress

The applicable criteria applied to the two remaining alignments are as follows:

Category	Criteria	Range	Weight	Total	Percentage
Economy	User Benefit (Downtown Catchment Areas)	1-5	8	8-40	70%
	Risks – Permitting, Construction Risk, and Operations Risk	1-5	4	4-20	
	Potential for Phasing	1-5	2	2-10	
Environment	Construction Impacts	1-5	1	1-5	15%
	Resilience in Disasters and Events	1-5	1	1-5	
	Increased Impacts of Commuter Rail Operations	1-5	1	1-5	
Equity	Low-income Households Served	1-5	2	2-10	15%
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	1-5	1	1-5	

Table 60: Third-Step Screening Process - Alignment

The following tables show the scores for the Central Artery Two-Track Alignment and the South/Congress alignment:

Category	Criteria	Range	Weight	Total
Economy	User Benefit (Downtown Catchment Areas)	2	8	16
	Risks – Permitting, Construction Risk, and Operations Risk	1	4	4
	Potential for Phasing	1	2	2
Environment	Construction Impacts	1	1	1
	Resilience in Disasters and Events	1	1	1
	Increased Impacts of Commuter Rail Operations	2	1	2
Equity	Low-income Households Served	2	2	4
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	2	1	2
TOTAL – CENTRAL ARTERY TWO-TRACK ALIGNMENT				**32**

Table 61: Central Artery Two-Track Alignment Screening

Category	Criteria	Range	Weight	Total
Economy	User Benefit (Downtown Catchment Areas)	3	8	24
	Risks – Permitting, Construction Risk, and Operations Risk	3	4	12
	Potential for Phasing	2	2	4
Environment	Construction Impacts	2	1	2
	Resilience in Disasters and Events	1	1	1
	Increased Impacts of Commuter Rail Operations	2	1	2
Equity	Low-income Households Served	2	2	4
	Reduced Crowding on MBTA Bus and Rapid Transit Lines in Low-income Areas	3	1	3
TOTAL – SOUTH/CONGRESS ALIGNMENT				**52**

Table 62: South/Congress Screening

8.3 Summary and Recommendation

Based on the scoring criteria, the South/Congress alignment is the preferred alternative, using the 51-foot-diameter bored tunnel. This alignment has the following advantages:

- More downtown Boston jobs are within easy walking distance of the alignment.
- The South Station placement (tunnel tracks and therefore egress to the street) is closer to existing commuters' jobs, compared to the station placement for the Central Artery Two-Track alignment.
- It makes connections to the Blue, Green and Orange Lines at the proposed commuter rail State-Haymarket Station, saving the cost of additional underground North or Central Stations to make these connections.
- There is less permitting risk, as the Fort Point Channel construction (which requires additional permits) is avoided in favor of a more inland route.
- It has slightly better resilience due to a more inland location that is further from sea level rise (not represented in the scoring, as in 50 years all locations are problematic).
- There is better potential for eventually creating a four-track system. The routing of Amtrak Northeast Corridor and Worcester Lines into the South/Congress alignment west of the existing South Station does not preclude eventually extending the Fairmount and Old Colony routes into a separate Central Artery Two-Track alignment. It should be noted that if the Central Artery Two-Track alignment were selected and it was desired to allow for an eventual Four-Track service, the stations would have to be initially built for four tracks, substantially increasing costs. Envisioning a "South Station complex" with the initial NSRL on the west, surface tracks in the middle and eventual final phase NSRL on the east in the channel allows the eventual incorporation of the Fairmount and Old Colony Lines into a through service but without initial and significant expense.

The cost of the South/Congress alignment is estimated at about $6.7bn in 2018 dollars ($9.5m in 2028), with forecast ridership of about 225,000 daily commuter rail passengers. Following are two views – one of the South/Congress alignment and another showing its possible future extension to a four-track system.

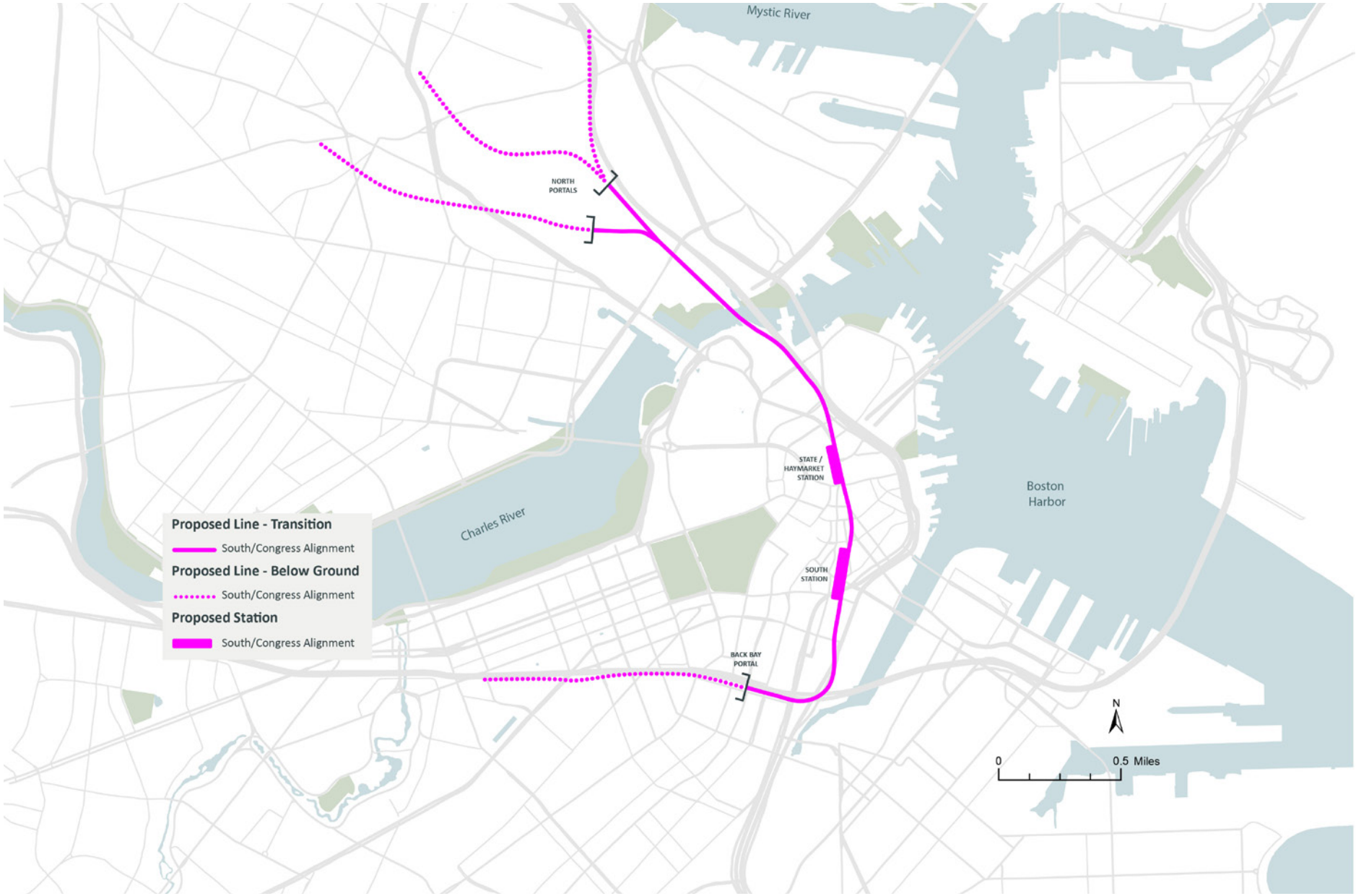

Figure 62: Full South/Congress Alignment

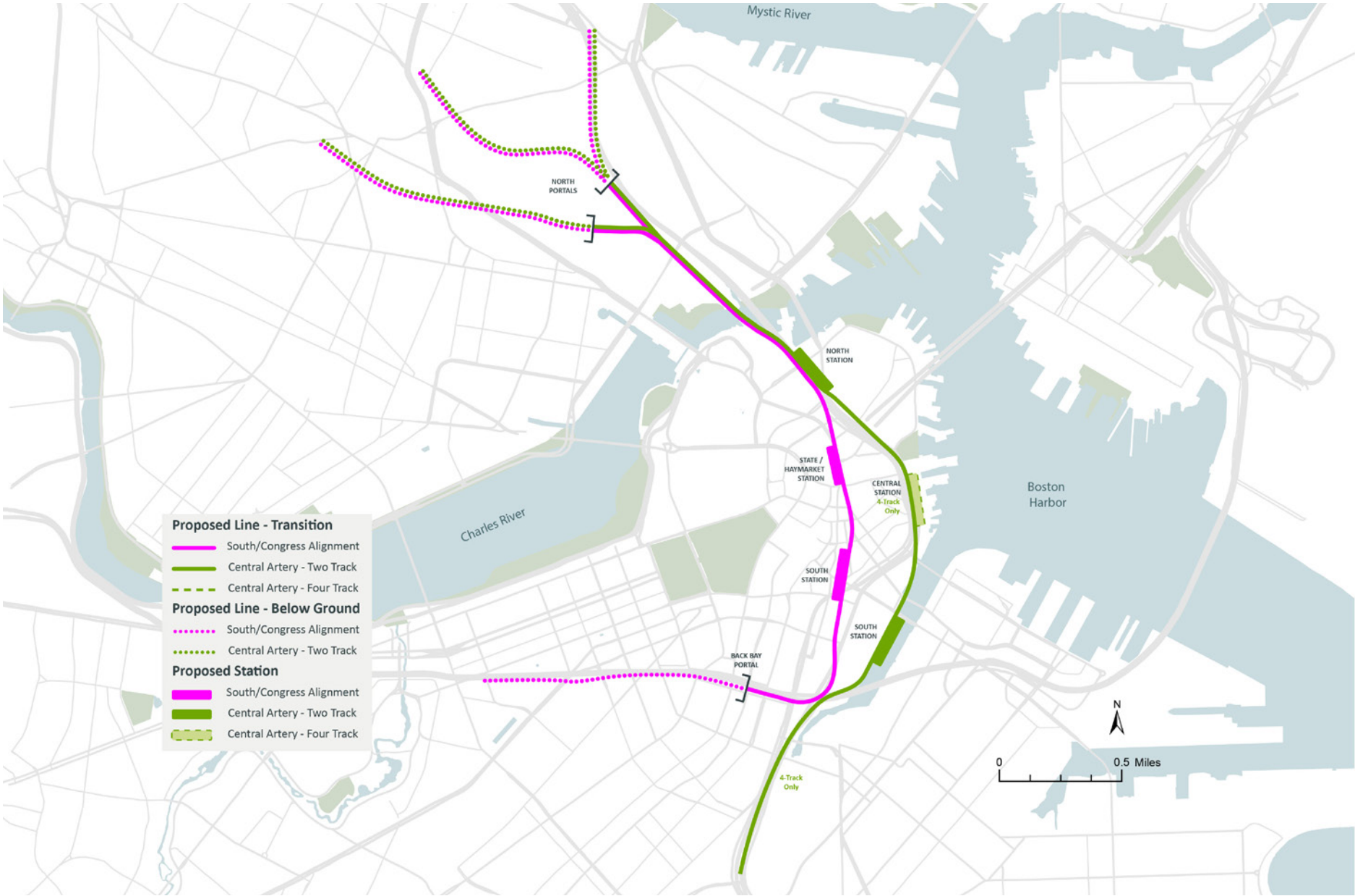

Figure 63: South/Congress Alignment with possible future extension

Views

Figures 64-68 show the South/Congress alignment overlaid on a street map of Boston. The segment maps offer more detail of the exact proposed path of the alignment underneath Boston, from its southern extent to the North portals.

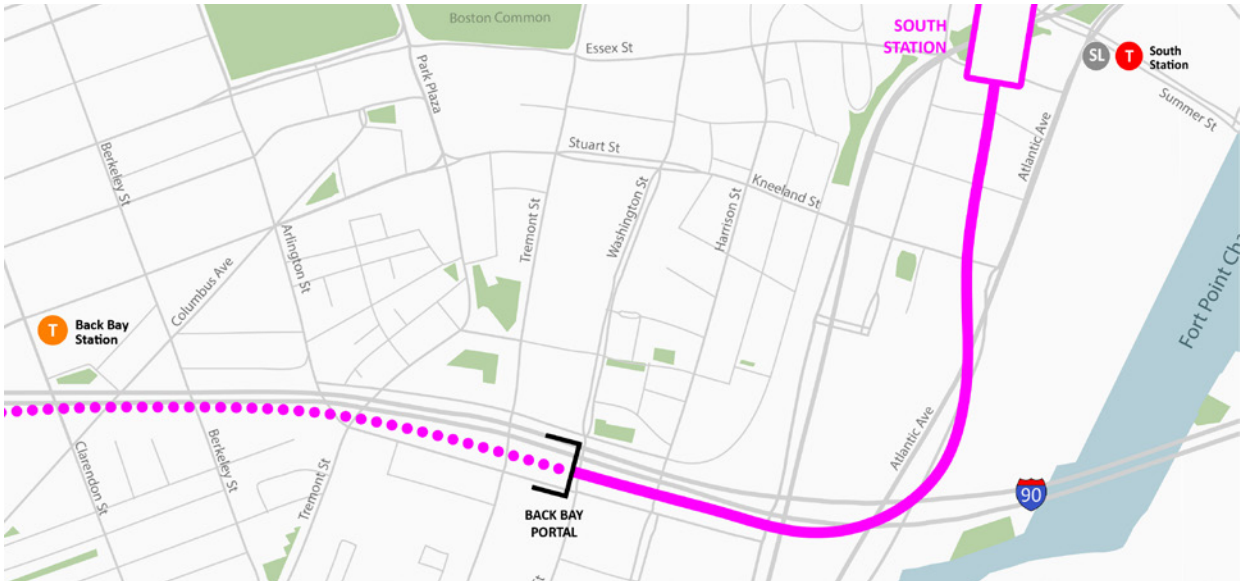

Figure 64: Back Bay Portal to South Station (south end)

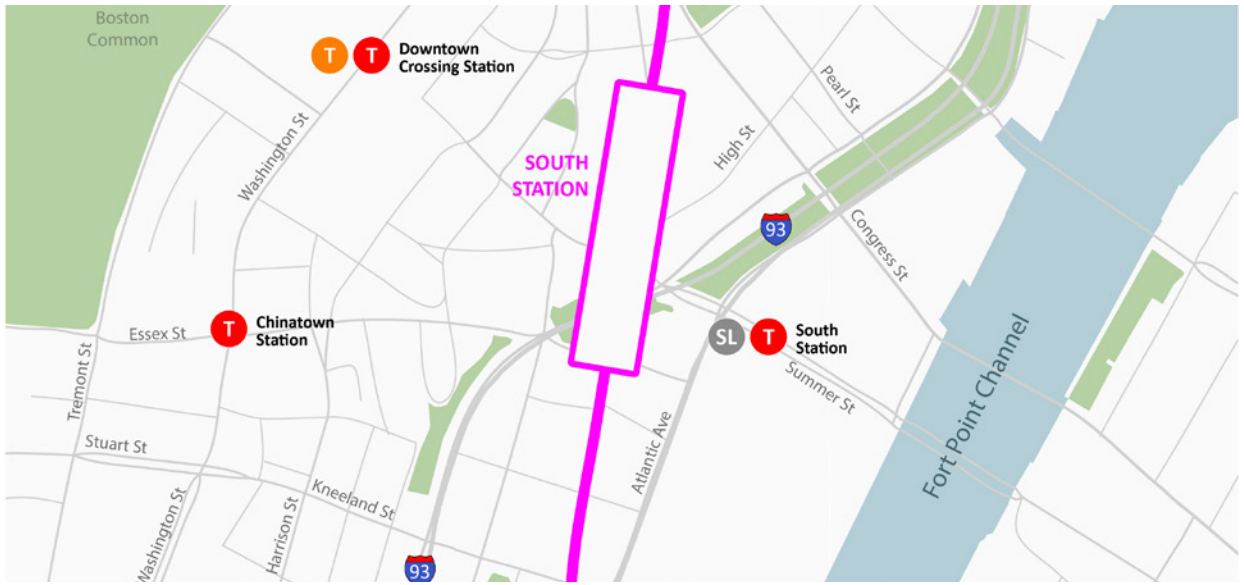

Figure 65: South Station (south end) to South Station (north end/Franklin Street)

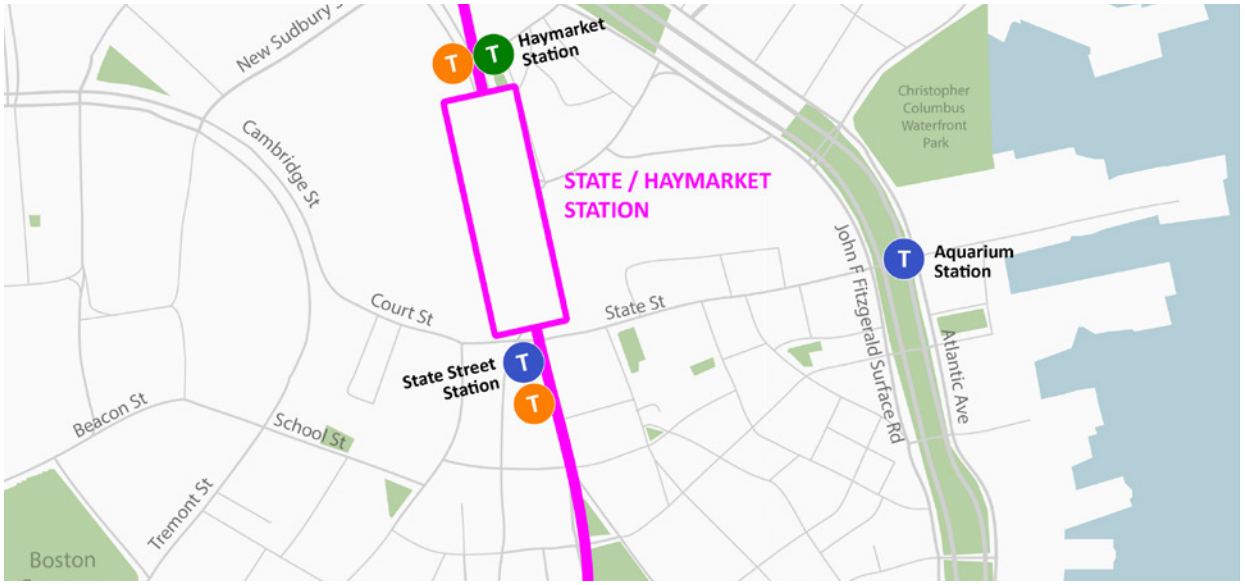

Figure 66: South Station (north end/Franklin Street) to State-Haymarket Station (New Sudbury Street)

Figure 67: State-Haymarket Station (New Sudbury Street) to North Station (Causeway Street)

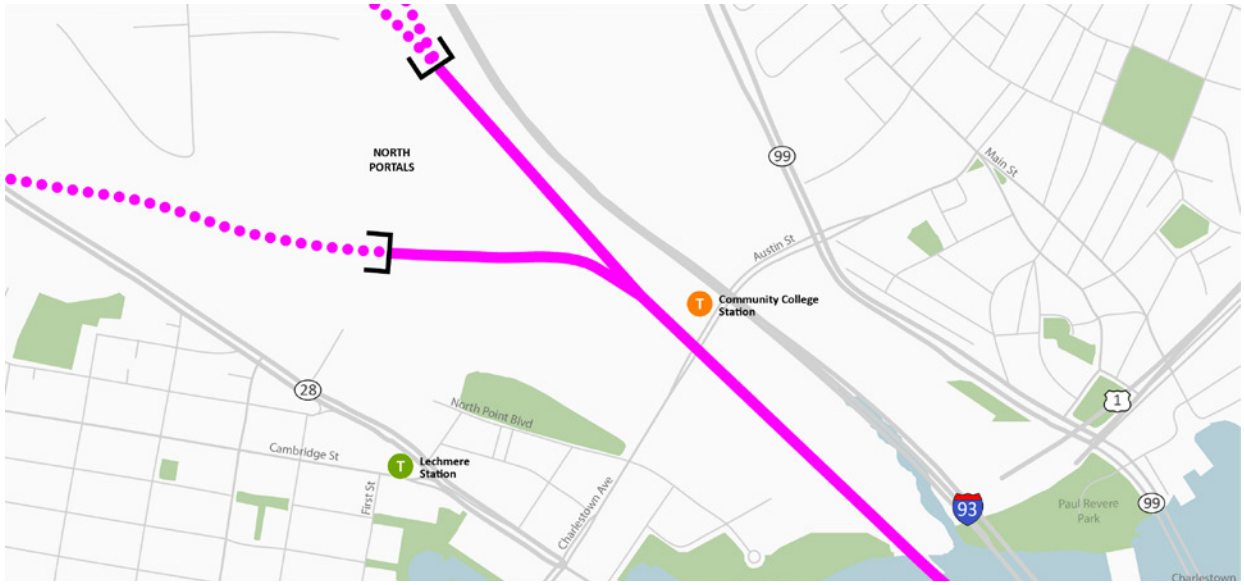

Figure 68: North Station (Causeway Street) to North Portals

Figure 69 shows a rendering of what the tunnel cross-section would look like for the South/ Congress alignment, with the stacked tracks and stations within the 51-foot-diameter bore.

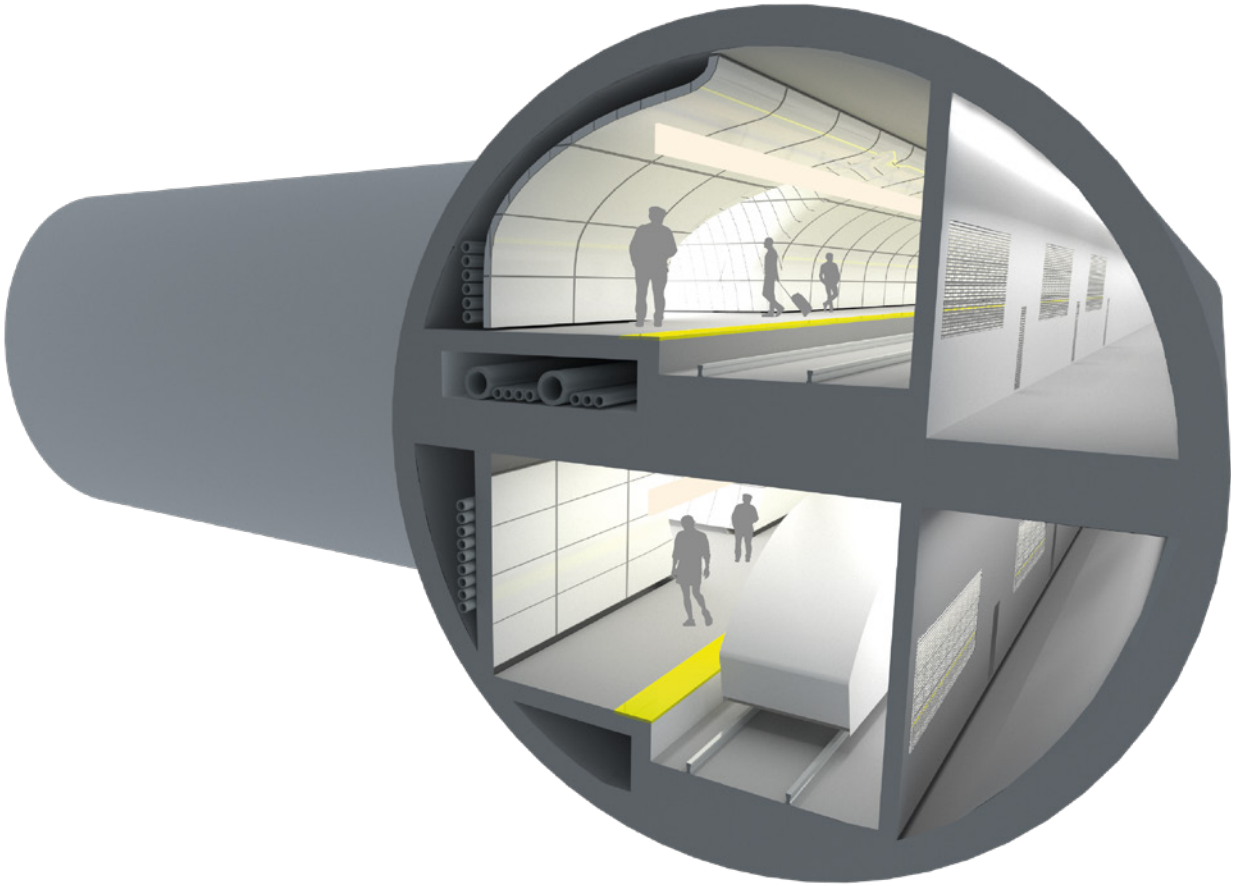

Figure 69: Cross-section of South/Congress Alignment