University Link's big challenge: crossing under Interstate 5 and the Montlake Cut

■ *The twin bored tunnels travel 3.15 miles from downtown Seattle to Husky Stadium.*

By ANDY MENCKE
McMillen Jacobs Associates

Sound Transit's University Link opened on March 19, extending Seattle's light rail system from downtown to the University of Washington. It includes 3.15 miles of twin-bored, 21-foot (excavated diameter) tunnels and two cut-and-cover stations: one at the University of Washington adjacent to Husky Stadium and one in the heart of Capitol Hill.

Mencke

The successful design and construction of the project had its challenges, including varying ground conditions and possible constraints near the surface.

The geology

The success of the tunneling work was set up through Sound Transit's robust subsurface exploration program that was completed in three phases between 2002 and 2008 and included more than 140 borings.

Two critical areas of geotechnical design were the undercrossing of the Montlake Cut and of Interstate 5 near downtown. In both of these areas, the twin bored tunnels passed beneath existing facilities with less than one tunnel diameter of ground cover.

Understanding the local ground conditions in these critical areas was essential for the safety of the tunnel construction due to their shallow depth. In addition, the original construction of I-5 and Montlake Cut presented a possibility of structures left behind (which may get in the way of tunnels), so additional work was done to understand the complete picture at each location.

The design and construction of the University Link twin bored tunnels was split into two contracts: U220 – University of Washington to Capitol Hill Station and U230 – Capitol Hill Station to Pine Street Stub Tunnel.

Crossing below I-5

The U230 contract took on the challenge of tunneling beneath I-5 near downtown.

The initial I-5 corridor through Seattle was constructed in the 1960s. In the vicinity of the tunnel drives, the freeway is supported on the east side by an approximately 35-foot-high wall cut supported by a piled cylinder retaining wall. Three additional piled retaining walls are in this area to support the lower express lanes as well as the west wall.

Early in the development of the University Link tunnel design, it had been proposed that the solution to tunneling through the I-5 retaining wall structures was to excavate four large pits to provide access to the existing cylinder pile walls used to retain the I-5 cut slopes and to cut holes through them for the tunnels to be driven through.

These pits were to be excavated entirely within the I-5 on- and off-ramps at the Olive Street interchange, so resolving and maintaining traffic flow through this very busy corridor became a challenge.

The real issue for the tunnel work was to complete the pit excavations and remove necessary portions of the cylinder walls without compromising the structural integrity of the wall system and to keep I-5 operational.

The design solution was no small feat and involved close coordination between Sound Transit, the design team and WSDOT. The result was a construction sequence to expose and remove the sections of the walls in conflict with the tunnels, including detailed traffic management and a continuous monitoring network to alert the team in real time regarding any excessive movement.

It was realized as the U230 tunnel design commenced that the I-5 preparation work must be ready well in advance of tunnel construction getting to the I-5 crossing to eliminate any construction delays. To assure this, the work was built in a smaller contract, U215, which allowed it to begin prior to the tunnel work and to be bid by a contractor that focused on pit excavation. This led to enhanced competition and reduced total cost.

Construction of the pits didn't go without tense moments. Early on, movement of the 35-foot retaining wall exceeded limits, causing pit work to stop.

Through an evaluation process and working as a team, the issue was resolved and a new approach was developed that included installation of additional supports, additional strengthening of the cylinder pile walls and increased monitoring of the wall. Hold points were also implemented to check the performance before allowing the work phases to proceed.

The collaborative effort proved successful and the project was completed on time without further significant delay.

Below Montlake Cut

The design of the U220 tunnels took on the challenge of balancing the cover needed to pass safely beneath the Montlake Cut. Added to this was the consideration that with each foot of cover reduction under the Montlake Cut there was a direct savings in cost and schedule for the University of Washington Station excavation as it became shallower.

The twin tunnels driven south from the UW Station excavation pass under the Montlake Cut ship canal with approximately 13 feet of cover from the mudline to the crown of the tunnel. Early in the design the depth of cover over the tunnel was closer to 20-25 feet.

Initial stability analyses, based on the results of the geotechnical investigations, showed that the side slopes of the Montlake Cut would remain stable if the alignment was raised. Tunnel buoyancy was evaluated and shown not to be an issue for the raised alignment. However, the higher the alignment was raised, the more potential of hitting obstructions in the area increased due to previous construction in the area.

The Montlake Cut ship canal was originally constructed in the 1910s to connect Lake Union and Lake Washington. A series of slope stability projects were carried out between the 1920s and 1980s to stop sloughing and erosion of the excavated slopes.

These projects installed soldier piles and sheet piles that were left in place. The piles, if located in the path of the tunnels, would cause problems for the tunnel boring machines.

During final design, all available historical documents were reviewed for these types of obstructions along the alignment to validate the raising of the alignment. Based on this information, along with the test results from borings drilled from a barge in the Montlake Cut, it was determined that the alignment could be raised roughly 10 feet. This raise, in turn, allowed UW Station to be raised an equal amount, realizing considerable project savings.

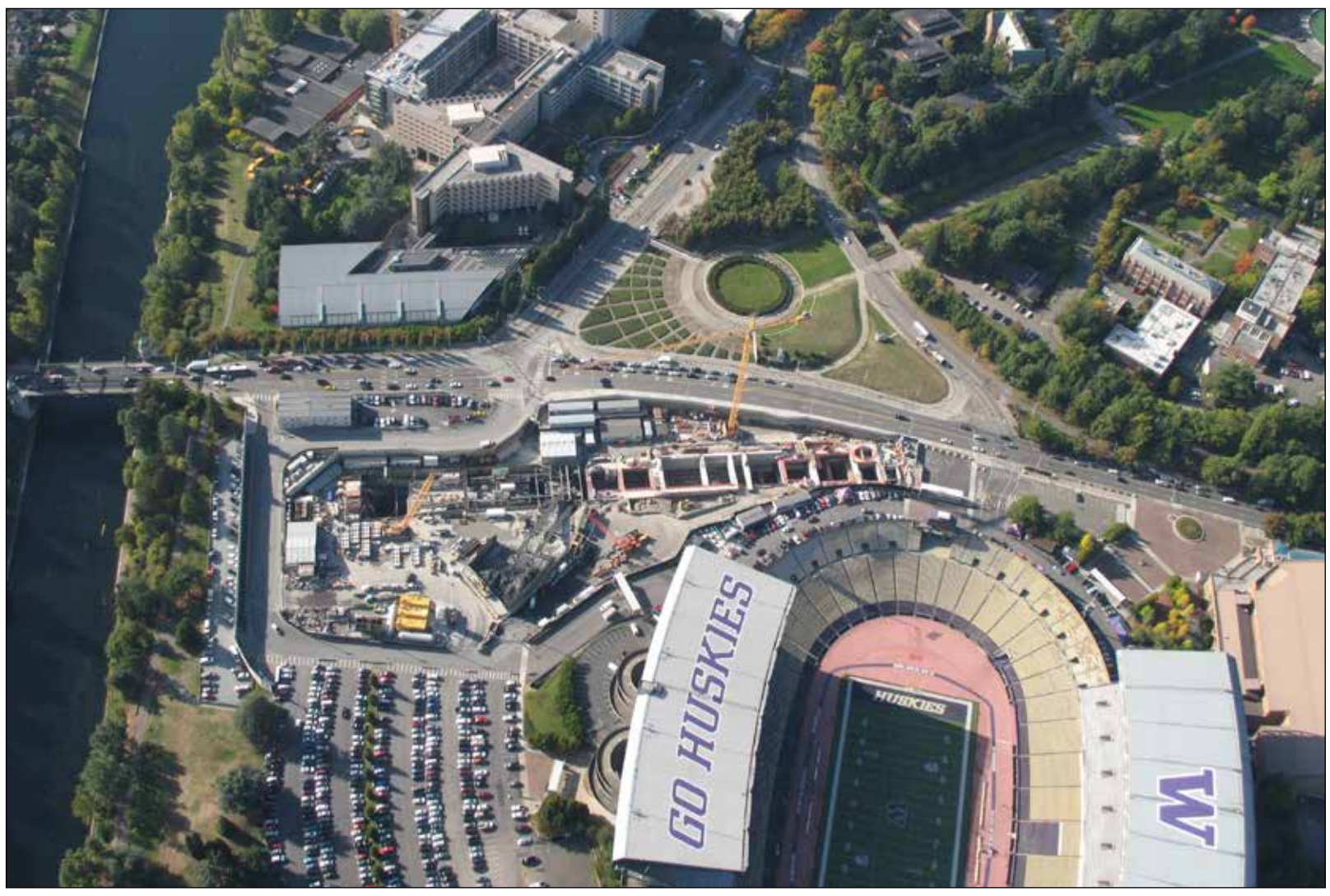
Although the raised alignment was technically feasible, rigorous construction measures were also needed and were included in the contract documents. A hold point was added to the contract and the tunnel contractor was required to complete pre-undercrossing checks of all tunnel data to validate tunnel boring machine performance prior to advancing under the Montlake Cut.

A readiness review meeting of the team was also held to bring all parties together to communicate the status of the operation and the plan for tunneling under Montlake Cut. The result of the collaborative approach was two tunnels successfully driven beneath Montlake Cut without incident.

Early opening

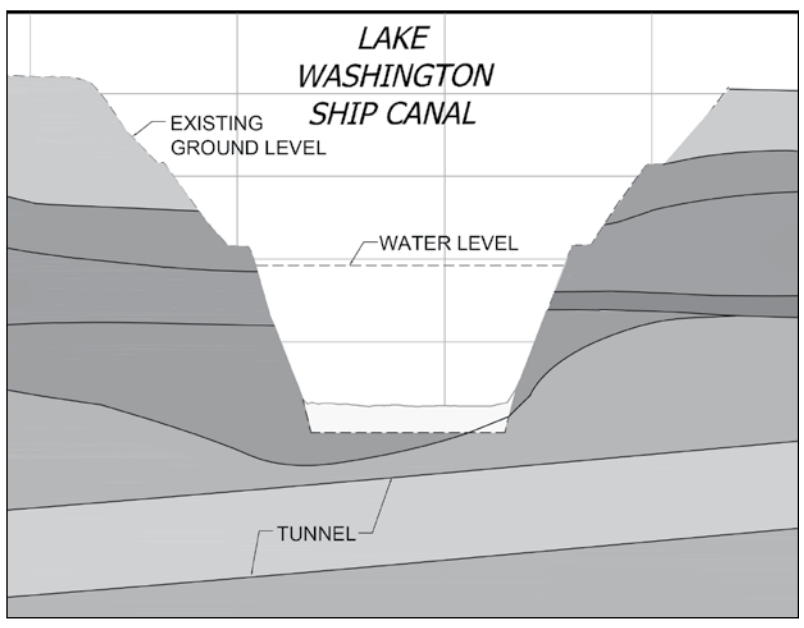
The design and construction of the U Link tunnels presented several unique and interesting challenges for Sound Transit, WSDOT, the design team and the tunnel contractors. By drawing on the extensive knowledge and experience of these parties, these challenges were successfully managed, which significantly contributed to the opening of the U Link line ahead of schedule and under budget.

Andy Mencke, PE, is a member of the McMillen Jacobs Associates led Northlink Transit Partners joint venture design team responsible for the final design of University Link. He has been with McMillen Jacobs for over nine years and was also involved in the firm's final design of Northgate Link.

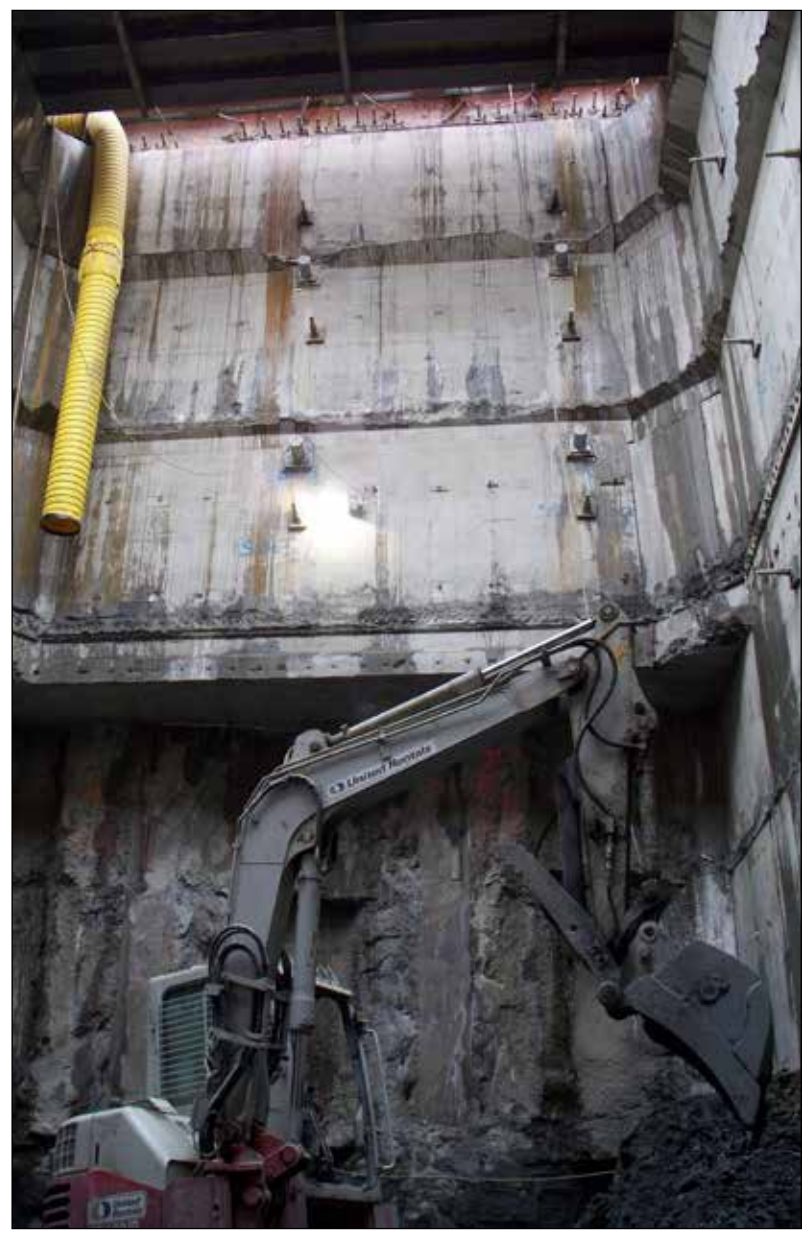


The tunnel crosses under Montlake Cut by Husky Stadium.

Images from McMillen Jacobs Associates



The tunnel's top is just 13 feet from the bottom of Montlake Cut.



This is one of four large pits that were dug to gain access to existing pile walls on I-5. Crews cut holes into the piles for the tunnel.

University of Washington Station brings it all together

■ *The new station is a hub for buses, light rail trains, bicyclists and pedestrians.*

By MARK REDDINGTON
LMN Architects

A new bike/pedestrian bridge connects University of Washington Station to the campus and Burke-Gilman Trail. Copyright Don Wilson

More than a light rail station, Sound Transit's University of Washington Station, designed by LMN Architects, adds multiple facets to the urban fabric at the intersection of Montlake Boulevard and Pacific Street.

Reddington

Knitting together transportation modalities from bike to bus to pedestrians to trains, the multi-disciplinary design of the 156,000-square-foot station creates a unified mobility solution at a problematic street intersection, one of the busiest in Seattle, and provides a unique gateway to the UW campus through its above and below-grade experiences.

The project includes a train platform 100 feet underground, accessed by escalators and elevators from a two-level glass entrance structure at grade. Along the way, users pass through a tall, vertical circulation chamber featuring "Subterraneum," an art installation by Leo Saul Berk, who worked with LMN to blend architecture and sculpture in expressing the geological layers of soil surrounding the station walls.

The station's new bicycle and pedestrian bridge — with stairs, escalators and ramps connecting both levels of the entrance structure — curves gently as it spans over Montlake Boulevard to land on the university campus.

Each element of the project is carefully considered as a component of a larger whole, set within a complex web of uses that encompasses the campus, the surrounding neighborhoods, and important university destinations such as Husky Stadium, Alaska Airlines Arena and the UW Medical Center.

"LMN's work at the University of Washington Station beautifully and intricately navigates an almost unbelievably complex urban node," says Rebecca Barnes, university architect and associate vice provost for campus and capital planning at the University of Washington. "The outcome is a great architectural and urban design achievement borne of many acts of imaginative and insightful civic leadership."

Public space underground

Between the surface and the train platform 100 feet below, circulation paths follow an orchestrated sequence of moments, constantly orienting users to the station's overall volume, structure and internal flow.

Visual connections between levels create a strong sense of place. The glass entrance structure frames views of the surrounding context, including Lake Washington and the Cascade Mountains. The transparency also serves as a light well, allowing daylight to reach down to the mezzanine level.

Colored ceramic wall tiles animate the mezzanine and ticket machine areas with energetic green motion lines. A green overhead service armature — integrating light fixtures and public-address speakers — provides clear wayfinding throughout the circulation path between surface and platform.

Each piece works together and builds up the climactic experience of "Subterraneum" in the central circulation chamber.

Mechanical infrastructure is largely invisible from these public spaces.

Concealed behind the scenes, an emergency smoke ventilation system, track crossover area and associated maintenance spaces are nearly as large by volume as the circulation areas in the station's below-grade footprint.

Two elliptical-shaped ventilation towers emerge above-grade, anchoring each end of the structure, and fade from view through the strategic use of perforated screens. The towers serve the emergency smoke ventilation system for the entire tunnel, along with fans at every station on the line that work in tandem to move air and smoke in the event of an emergency.

Public art

At the heart of the station experience, the escalators and glass elevator pass through a 55-foot-high central chamber, one of the tallest interior volumes in the city.

Working with artist Leo Saul Berk, a UW graduate known for exploring subterranean themes in mixed-media sculpture and installations, "Subterraneum" blends sculpture and architecture in exploring the opportunities of the underground condition. Backlit, perforated metal panels clad the chamber walls, displaying luminous patterns representing geological layers, while suffusing the space with ambient light. The vertical angle of the chamber walls changes along the long axis, creating a twisting volume that offers varying views of the artwork from different vantage points throughout the station.

Four escalators and two glass elevator columns spill through this soaring space, providing a dynamic experience of the art while riding up or down. Various vantage points at the mezzanine and at the bottom of the chamber offer a chance to take in the views, while observing people coming and going to the train platform.

U Link Extension

UW Station is the terminus of Sound Transit's University Link Extension, the first part of the regional light rail system to open north of downtown Seattle. When joined with the Northgate Link planned to open in 2021, the line will comprise 7.45 miles of twin-bored tunnels, followed by 1 mile of elevated track as it approaches the Northgate Transit Center.

University Link provides unprecedented access between downtown and the University of Washington with a travel time of 8 minutes, as opposed to 15-45 minutes by bus or car. The line connects to all points in the current and planned Sound Transit network including the existing Central Link running between downtown and SeaTac Airport, and future links throughout King, Snohomish and Pierce counties opening over a 20-year time frame.

LMN's design work encompasses 13 stations throughout the system, including the design of stations in the Bellevue and Redmond segments of East Link, and stations for Lynnwood Link, both opening in 2023.

Bridge design

The 400-foot-long bike and pedestrian bridge over Montlake Boulevard pushes the limits of the use of post-tensioned concrete in structural engineering. The bridge is a collaborative effort between Sound Transit and the University of Washington, with architects, landscape architects, structural engineers and contractors on each side taking part in its design and execution.

In elevation, the thinness and narrowness of the bridge section made possible by post-tensioning allows a gentle arch for bicycles and pedestrians, while still leaving roadway clearance for buses. Two compound curves create separate lanes for bikes and pedestrians within a 32-foot width, with the two lanes splitting apart at each end.

Where the bridge meets the above-grade station entrance, pedestrians can enter the station directly on the upper level by elevator or escalator, or use a grand staircase to access the station's exterior plaza shared with Husky Stadium.

A vertical circulation chamber features "Subterraneum" art walls by Leo Saul Berk. Photo from LMN Architects

The bicycle lane continues separately in a gradual ramp to the street level, completing a long-desired connection between the Burke-Gilman Trail and the state Route 520 floating bridge.

Public mixing zone

UW Station and its associated public spaces connect a complex of major campus elements and urban pathways, making a civic-centered contribution to the importance of rail transit to the campus community. The station is expected to serve 24,000 transit riders per day, in addition to thousands more bicycles and pedestrians using the bridge, together forming a critical new component of Seattle's transportation network.

The architectural design of the station creates an inspiring public mixing zone that celebrates multiple transportation modes with a many-layered sense of movement and place.

Mark Reddington, FAIA, is a partner at LMN Architects in Seattle. He is a leader in the design of public places including the Washington State Convention Center Addition, Marion Oliver McCaw Hall, Benaroya Hall and UW Station.

Project teams

Capitol Hill Station:
Turner Construction
(contractor)
Hewitt
(architect)
McMillen Jacobs
(structural engineer)

UW Station:
Hoffman Construction
(contractor)
LMN Architects
(architect)
KPFF
(structural engineer)

Tunneling:
Traylor-Frontier Kemper
(Capitol Hill to UW)
JCM U-Link Joint Venture
(downtown to Capitol Hill)
Stacy and Witbeck
(rails and related systems)

Project management:
Northlink Transit Partners, a joint venture led by McMillen Jacobs Associates, was in charge of final tunnel design and the cut-and-cover stations; and overall project management, design and geotechnical engineering. The JV includes Aecom and HNTB.

Linking Capitol Hill to downtown and the UW

Capitol Hill Station serves the busy Broadway area near Seattle Central College. It connects to University of Washington Station to the north and the Downtown Seattle Transit Tunnel to the west.

The $105 million station was built by Turner Construction under a general contractor/construction manager contract. It has art installations "Jet Kiss" by Mike Ross and "Walking Fingers" and "Crossed Pinkies" by Ellen Forney.

A 163-foot-long pedestrian tunnel below Broadway Avenue helps people safely cross the street and get to the new station's mezzanine level. Light rail riders take an elevator or escalator down 80 feet to the train platform.

Capitol Hill Station houses most of the support machinery for the power, communication and ventilation of the tunnels.

Photo from Sound Transit

Construction of the station involved 3.5-foot-thick exterior walls, reinforced concrete strut members spanning the width of the station that were just over 3 feet and 5.5 feet in diameter, and suspended slabs up to 4 feet thick.

The below-ground "station box" or platform area has exposed concrete walls, and the entrances include reveals of exposed concrete to contrast with tile and metal panel finishes.

To create the station box, crews used an out-of-the-box concrete forming system with collapsible steel trusses that spanned the 45-foot width of the station box.

Hewitt was the architect.