DEEP FOUNDATIONS INSTITUTE DFI ®

Deep Foundations

JULY/AUG 2026 THE MAGAZINE OF THE DEEP FOUNDATIONS INSTITUTE

Overcoming Site Constraints

COVER STORY

Zone 13a utility adit with levels 1 and 2 framing

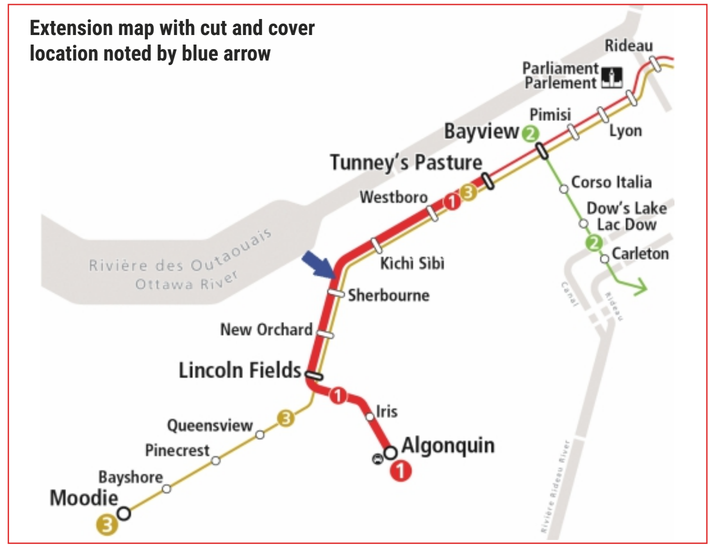
Logistical Site Constraints on Deep Excavation Design

The Kiewit Eurovia Vinci Partnership is nearing completion of the Confederation Line Extension (Ottawa Stage 2) light rail transit project, which was developed using the design-build-finance contract model. The project expands Canada's capital city's transit system east and west from Ottawa's downtown core. The project includes a new 27 km (17 mi) extension of the Confederation Line with 16 new stations, and a light maintenance and storage facility. Additional scope includes 3.4 km (2 mi) of cut and cover tunnels and significant highway widening and structures. The partnership subcontracted various design firms, including Brierley Associates, to provide temporary support of excavation (SOE) system design for various segments of the open cut trench excavation through soils and rock.

This article focuses on the cut and cover portion in the west extension, and in particular zones 12 and 13a of the Parkway cut and cover tunnel, as the tunnel alignment transitions from running along Richmond Road and Byron Linear Park to running along the Kichi Zìbì Mìkan Parkway adjacent to the Ottawa River. Zone 12 SOE was designed as free draining, internally braced soldier pile and lagging walls. Zone 13a was designed as a watertight secant pile wall system with a combination of internal and external bracing systems to account for various site constraints and unbalanced loading.

AUTHORS Anna Crockford, P.Eng., Kristopher Burnham, P.E., and Charles Luxford, P.E., S.E., P.Eng., Brierley Associates, and Hamid Batenipour, Ph.D., P.Eng., P.E., PMP, Kiewit Engineering Group Canada

Project location



Extension map with cut and cover location noted by blue arrow

Site Conditions

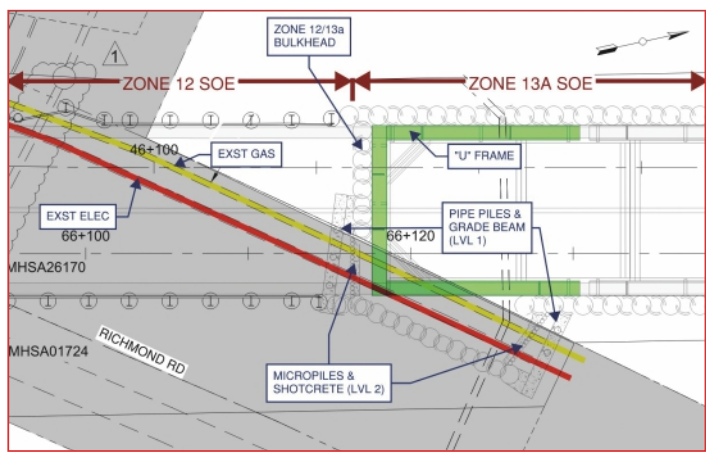
The Parkway cut and cover tunnel within zones 12 and 13a presented several site constraints and challenges that needed to be accounted for in the SOE designs, including: temporary and permanent right-of-way restrictions, restrictions on groundwater drawdown in zone 13a/b, existing and proposed utilities to be accommodated (with several crossing the excavation at high skew angles), and traffic sequencing.

The tunnel extended up to about 13 m (43 ft) below existing grade and about 10 m (33 ft) wide. Heavy traffic on Richmond Road and contract requirements restricted the sequencing of the work to limit traffic disturbances. In addition, protection and support of underground utilities during construction were necessary.

Zone 12 geology consisted of urban fills, medium-dense to dense sands and dense glacial tills. The groundwater table was typically at or below the bottom of excavation. Near the zone 12/zone 13a interface, a clay crust was encountered below the urban fill. The groundwater level in this zone was up to 8 m (26 ft) above the bottom of excavation, at El. 57 m (187 ft), heavily impacted and fluctuating with the water level in the adjacent Ottawa River.

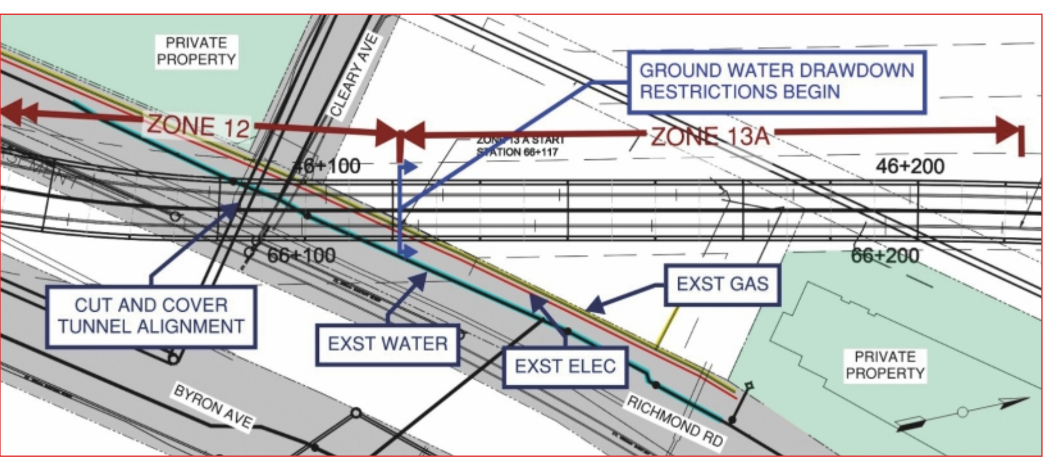
Support of Excavation Design

The zones 12 and 13a SOEs cross an existing 200 mm (8 in) gas line and two existing electric lines at the bulkhead between the two zones. The contract for this area of the project required that the excavation in zone 13a be an impermeable SOE system in order to minimize water drawdown in surrounding sensitive soil layers. In this case, secant piles were selected for the SOE system, which could be installed into the underlying till unit. However, secant piles could not



Zones 12 and 13a bulkhead and utility configuration

Parkway zones 12 and 13a site contraints



As the utilities are at an oblique angle to the excavation, the conflict zone results in a very wide opening.

be installed where the utilities conflict with the wall layout, so an alternate design was required in the conflict area to minimize gaps. As the utilities are at an oblique angle to the excavation, the conflict zone results in a very wide opening. Additional restrictions were the presence of a watermain to the south of the electric lines, and the proximity to Richmond Road, which could not be closed to traffic during construction.

Zone 13a – Utility Accommodations: The main SOE system for zone 13a consisted of secant piles with internal braced steel frames for the southern half of the excavation, adjacent to zone 12. These braced frames consisted of W-section wales and HSS (hollow structural section) pipe struts for most of level 1 and for all of level 2 (strut levels numbered from top to bottom, in order of installation, i.e., level 1 representing the topmost level). A small portion of the level 1 south wall was supported with a concrete wale and tiebacks due to the unbalanced loading from the south wall onto the north wall, as well as presence of an existing building. At the bulkhead, a U-shaped brace frame was used to absorb the lateral loads from the bulkhead and transfer the loads to the north and east secant pile walls. Beyond the bulkhead frame, a typical H frame was used to resist the lateral loads from the north and south secant pile walls.

The utilities spanned approximately 15 m (49 ft). The geometry in the southeast corner presented a challenge to install wall elements as adequate space to follow the excavation perimeter was not available. To address this, the SOE perimeter was modified to be as orthogonal to the utilities as possible, creating an adit to the excavation. Where parallel to the utilities, a secant pile wall was used, and a combination of pipe piling and lagging above the water table with a tangent micropile wall below the water table connected the adit to the primary excavation. Concrete grade beams and diaphragm slabs at each bracing level were provided to eliminate the complex framing geometry otherwise required by steel.

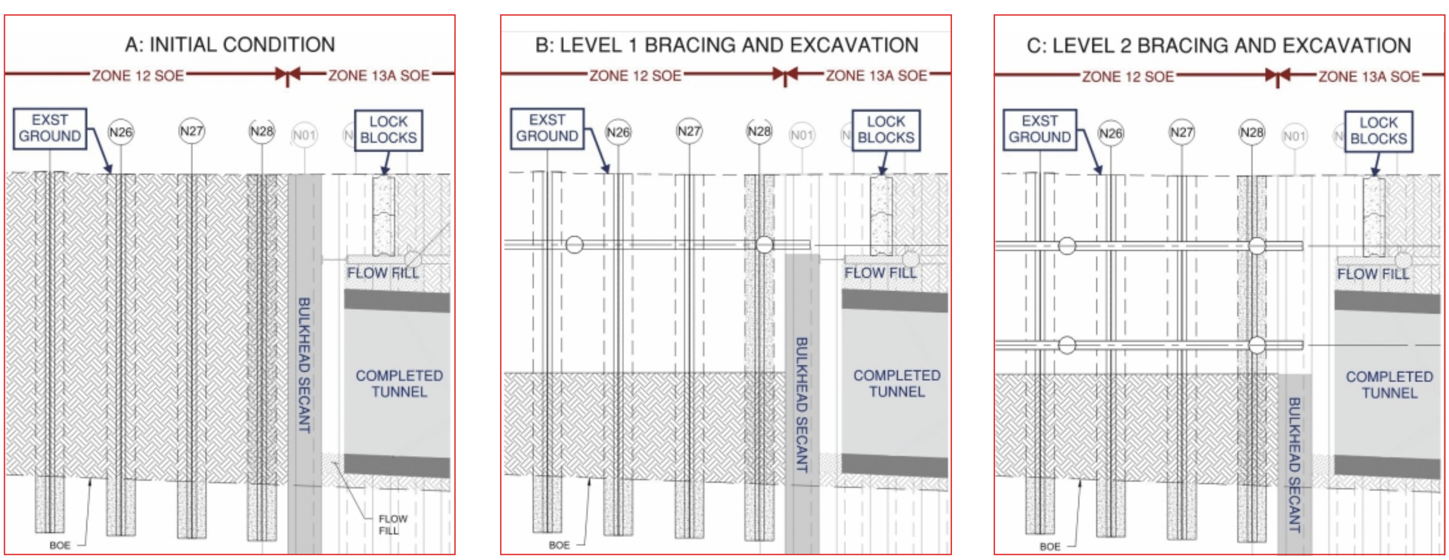
The diaphragm slabs were secured to the adjacent piles using dowels in the secant piles and headed studs welded to the micropiles, along with embedded angle iron kickers. The slab was reinforced with 15M (US #5) bars at 200 mm (8 in) spacing each way. To prevent surface water ponding from occurring, the slab had a slight slope to allow water to drain off through embedded pipe sleeves. These sleeves also served to vent any trapped air when slurry backfilling.

During the placement of each slab diaphragm, the free ends or free edges were fitted with embedded plates having headed rebar. These embedded plates were cast in place and would become the load path from the internal braced frames to the diaphragm. Once the slab concrete reached the required strength, the internal brace frames were installed and the connections provided the vertical support and shear load transfer.

Zone 12–South of Bulkhead Wall: Zone 12 SOE was designed during the zone 13a construction phase and constructed after most of the work was completed in zone 13a. In order to tie in zone 12, careful consideration had to be taken for detailing demolition sequencing of the bulkhead separating the two zones.

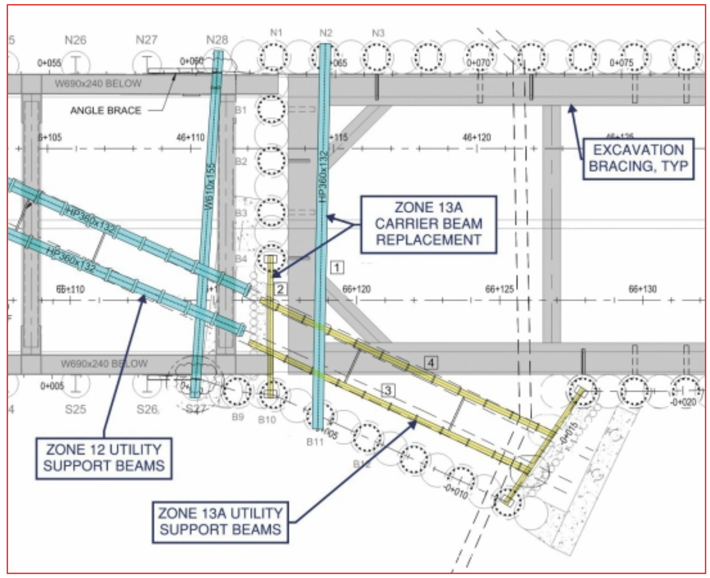
The zone 13a permanent structure was completed to within 1 m (3 ft) of the face of the bulkhead. The remaining portions of the zone13a adit bracing were left in place to provide support for the gap between the bulkhead and the permanent structure. Concrete lock blocks were installed near the end of the tunnel heading to retain backfill placed above the completed structure. Flowable fill was then placed between the invert slab of the permanent tunnel and bulkhead. The bulkhead was excavated and demolished concurrently with the excavation to install the zone 12 upper wale frame. This frame was also extended into gap next to the bulkhead to provide lateral support to the walls. After installation of the zone 12 bracing, the remaining zone 13a bracing could be removed. A similar construction sequence was followed to install the zone 12 second level bracing frame and complete the excavation.

Zone 12/13a bulkhead removal sequence



Prior to the demolition of the bulkhead, the original carrier beam supporting the existing electric and high-pressure gas utilities was replaced, as it was supported on one end by a secant piling of the bulkhead to be demolished. A new carrier beam spanning the full width of the completed zone 13a excavation was installed, then the utility support beams were lifted slightly with jacks to transfer the weight. During this transfer continuous monitoring of the framing was required to minimize disturbance.

Where the electric and gas utilities crossed the zone 12 SOE perimeter, the skew and minimal spacing between the two utilities created an 11 m (36 ft) wide "window" for the perimeter vertical elements. Smaller 500 mm (20 in) diameter pipe piling was installed between the existing utilities at various offsets from the typical excavation face in this area. Steel HP packing was installed to connect these piling to the wale framing. The area behind this wall was restricted to a lower construction surcharge as larger elements could not be accommodated.



Zone 12/13a utility support beam configuration and replacement

Construction

As the project was being delivered on a compressed schedule, installation of the zone 13a secant piles started in advance of final design of bracing elements. Adjustments to the design based on changing conditions were common; these included substituting member sizes based on materials availability to the installation contractor, detailing of the concrete diaphragm slabs based on actual installed locations of perimeter members, sequencing based on logistical considerations, lessons learned, and more.

Overall, the construction of the utility zone for zone 13a was successful with minimal water infiltration observed and no adverse impacts to the overlying utilities. The sequencing of the excavation and SOE installation was carefully performed to ensure that utilities were properly protected and supported in place, and that the SOE system provided adequate lateral support and groundwater control.

The utilities were exposed using hydro vacuum excavation methods prior to the installation of vertical elements to reduce risk of a strike. The exposed electrical conduits were encased in a timber box structure to reduce the risk of accidental contact. The utilities were then supported with ratchet straps to overhead carrier beams.

The exposed electrical conduits were encased in a timber box structure to reduce the risk of accidental contact.

Once utilities were secured, excavation proceeded to a depth adequate to allow overhead clearance of micropiling installation equipment to install the remaining piling that could not be installed from the surface (due to conflicting with the utility) and casting the level 1 concrete diaphragm slab. During excavation, it was determined that the micropiling was not as tangent as anticipated, and a shotcrete lagging was added to minimize water infiltration.

The level 1 slab was poured prior to the installation of the internal frame, which then required significant shims to connect to the steel frame. For level 2, the sequence was modified to have the bracing frame in place prior to the diaphragm slab pour, such that full contact was ensured.

During excavation below the anticipated design water table, it was determined that the actual elevation in the vicinity of the bulkhead was lower than expected. Some elements of the original sequencing were able to be reduced, no longer needing to account for full design load in interim conditions.

Zone 12 – South of Bulkhead Wall: As the excavation of zone 13a proceeded in advance of zone 12, information gathered from the work on zone 13a was incorporated into the zone 12 design. Most notably, observations of the ground conditions from the zone 13a excavation allowed for the zone 12 SOE to be optimized for better soil conditions and a lower groundwater table.

The zone 12 restricted work area and project logistical considerations (e.g., construction traffic directions, public access areas, etc.) required reconsideration of construction equipment surcharge restrictions behind the pipe piling at the utility intersection of the north wall. With the additional information about existing ground conditions, additional analysis permitted larger surcharge loads during specific stages to better accommodate construction operations.

The as-encountered locations of the existing utilities in zone 12 required several field modifications. The actual location of the electrical conduits resulted in the utility being highly eccentric to the support beam for about half of the length of one of the spans. As a result, an additional support beam was installed to mitigate lateral pull of the support strapping.

Zone 12 had additional utilities crossing the alignment in addition to the electrical and gas lines. The locations were determined based on as-built records and limited potholing. Once the full extent was exposed in the excavation, it was determined that the utilities conflicted with the zone 12 upper brace level. Unfortunately, the utility conflicts also occurred in the vicinity of the noted construction surcharge restrictions, which limited remedial options. Redesign and reconfiguration of several wale frames were required to install them between existing utilities, avoid conflict with the roof slab and minimize vertical span for the piles.

Summary and Conclusions

To date, the permanent light rail transit tunnel at zones 12/13a has been fully constructed and backfilled. Some works (utilities, mechanical, electrical, etc.) are ongoing and nearing completion.

The construction process involved numerous iterative adjustments to the design based on site conditions and logistical considerations. Despite the complexities involved, the construction proceeded generally on schedule with minimal disruptions or downtime, and the SOE systems functioned effectively to protect the surrounding environment and utilities. We would like to acknowledge the Kiewit Eurovia Vinci Partnership's role in facilitating a collaborative project environment where the entire team was able to communicate frequently and effectively to deliver a successful outcome.

Zone 13a utility adit with level 1 and 2 diaphragm slabs installed

The actual location of the electrical conduits resulted in the utility being highly eccentric to the support beam for about half of the length of one of the spans.

Zone 13a utility adit during installation of the base slab

Despite the complexities involved, the construction proceeded generally on schedule with minimal disruptions or downtime ...

Anna Crockford, P.Eng., is an associate at Brierley Associates, specializing in rock engineering and project delivery. Crockford has more than 15 years of technical design experience in heavy civil and mining projects and served as project manager for Brierley Associates on the Ottawa Light Rail Transit project.

Kristopher Burnham, P.E., is an associate at Brierley Associates, specializing in geostructural engineering. Burnham has more than 15 years of technical design experience in heavy civil projects and served as the design leader for Brierley Associates on the Ottawa Light Rail Transit project.

Charles Luxford, P.E., S.E., P.Eng., is a principal and director of engineering for Brierley Associates, a specialty geostructural engineering firm. With more than 25 years' experience in delivering heavy civil projects across North America, he provided technical oversight as Engineer of Record for this project and numerous other complex support of excavation designs.

Close proximity of utilities and excavation support elements

Hamid Batenipour, Ph.D., P.Eng., P.E., PMP, is a senior geotechnical engineer with Kiewit Engineering Group Canada, specializing in heavy civil geotechnical engineering. With more than 15 years of experience in technical design, construction support and applied research, he has contributed to complex projects across Canada, taught geotechnical engineering courses at several universities in Toronto, and has published in areas including support of excavation, pile design and permafrost-related embankment performance.

Photos courtesy of Kiewit Eurovia Vinci Partnership and Brierley Associates.