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Subject: Highway 95 Kicking Horse River Bridges Replacement Project
Geotechnical Input for Block Walls

Tetra Tech Canada Inc. (Tetra Tech) was retained by Urban System Ltd. (URS) to provide geotechnical engineering design services for the Highway 95 Kicking Horse River (KHR) Bridges Replacement Project.

We understand that three (3) block walls, from the Ministry’s Recognized Products List (October 1, 2023, Edition, or later) for “RETAINING WALLS (Supporting Loads) – (up to 5m in Height) Concrete Faced Walls”, will be used in the project. As per the Ministry’s Technical Circular T-01/10, rock (or dry) stacked walls “are not allowed 1) on/or adjacent number[ed] highways and 2) in situations where failure of the wall would not allow adjacent or dependent structures to perform their intended function”.

Brief descriptions of the three walls are provided as follows:

- The first wall is located on the south side of the river, between about Sta.101+58 and Sta.101+80. The wall has a maximum height of about 1 m.
- The second and third walls are located on the north side, from about Sta.103+56 to Sta.103+70 and Sta. 103+82.260 to Sta. 103+86.984, respectively. The walls have a maximum height of about 0.8 m.

This report provides geotechnical input for the design of these walls.

Use of this technical memorandum is subject to the conditions outlined in the Limitations of this Report which follows in Appendix A and forms an integral part of this document.

1.0 GEOTECHNICAL INPUT

1.1 Site Conditions

Detailed descriptions of the soil conditions are presented in the Factual report prepared by Tetra Tech (2022, Title: Geotechnical Factual Data Report – Phases 1 and 2). In general, the soil stratigraphy encountered at the site consists of a layer of granular fill underlain by sand and gravel to depths of about 40 m. Below the sand and gravel is a mixture of sand and silt that are considered to have small influence on the geotechnical design of these walls.

The groundwater level is expected to vary with the water level in the river as a result of seasonal changes. The data obtained from the 2020 and 2021 subsurface explorations indicate that the groundwater level was located at a reasonable average elevation of El. 788 m. For the wall design, a groundwater level located at about 1 m depth below ground surface is recommended.

1.2 Soil Parameters

Soil parameters to be considered for the foundation of these walls are presented in the table below.

Soil Type	N_{60}	Unit Weight (kN/m ³)	ϕ' (°)	E_s (MPa)
Fill	> 50	19	38 – 40	50 – 100
Sand and Gravel with Cobbles	30 – 60	19	38 – 40	30 – 60
Gravel	> 40	19	38 – 40	40 – 130

1.3 Code and Standards

The following design codes, guidelines and specifications are to be used to develop the design. The design codes, guidelines, and specifications are presented in the order of hierarchy (if applicable) as presented below:

- Canadian Highway Bridge Design Code (CHBDC), CAN/CSA S6-19, 2019.
- BC MoTI Bridge Standards and Procedures Manual, Volume 1, Supplement to CHBDC S6-19, 2022.
- AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017.
- FHWA GEC 11 NHI-10-024/025, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes. Vol. 1 and 2 (Berg et al. 2009)
- Canadian Foundation Engineering Manual (CFEM), 4th Edition, 2006.

1.4 Service Life Requirements

As per BC MoTI Supplement to CHBDC CAN/CSA-S6-19 C1.4.2.3, for any calculations which are time-dependent including but not limited to fatigue, corrosion and creep, the length of time has been considered as 100 years.

1.5 Global and External Stability Evaluation

Load and resistance factors within CHBDC CAN/CSA S6-19 Tables 3.3 and 6.2 were considered for the evaluation of external stability of the proposed wall. For global stability the Factor of Safety values within the BC MoTI Bridge Standards and Procedures Manual, Volume 1, Supplement to CHBDC S6-19 Table 6.2b were considered given the additional guidance available that is not included in the base CHBDC.

Bearing, sliding and overturning failure modes were evaluated considering static and seismic cases considering the load and resistance factors within CAN/CSA-S6-19. Based on the geometries and methods considered, the factored resistance against bearing, sliding and overturning failures is adequate for the minimum reinforcing lengths recommended by CAN/CSA-S6-19. The external stability should also be checked again to evaluate its adequacy by the proprietary wall designer.

The evaluation of the global and external stability is described in the following sections.

1.5.1 Global Stability

The global stability of the proposed walls under both static and seismic conditions was evaluated using the Slope/W (GeoStudio 2023.1) program. The results show acceptable safety factors considering the area immediately around the wall.

1.5.2 Bearing Resistance

The ultimate bearing resistance for the wall foundation was estimated using the general procedure recommended in CAN/CSA S6-19. For a minimum embedment of 0.6 m and an assumed foundation width of 0.3 m, the ultimate bearing resistance is estimated to be about 550 kPa. Using a geotechnical resistance factor of 0.5 combined with the typical consequence factor, the factored geotechnical resistance at ULS is 275 kPa.

The SLS pressure corresponding to a settlement of about 25 mm was estimated to be about 300 kPa, based on the drained moduli presented above. With a geotechnical resistance factor of 0.8, the factored geotechnical resistance at SLS is estimated to be 240 kPa.

1.5.3 Sliding Resistance

For evaluating the sliding capacity at the base of the wall, the angle of friction between pre-cast concrete block and the foundation soils is taken to be 22 degrees.

1.6 Design Recommendations

In addition to the Design Recommendations provided by Tetra Tech (2023, Title: Geotechnical Design Report, 100% Detailed Design), the following input should be considered for the design of these walls:

- Traffic load (for static loading conditions) = 16 kPa
- Include drainage at the back of the wall as required to avoid any potential water pressure
- Unit weight of the retained fill = 22 kN/m³
- Friction angle of the retained fill = 34°
- Friction angle at wall base = 22°
- A typical minimum embedment depth of 0.6 m is required. A frost penetration depth of 2.5 m should also be considered depending on the type and details of the selected wall.
- Minimum length of reinforcement, if required depending on the type of block wall and to meet stability requirements, should be 70% of the wall height or 2.5 m, whichever is greater. If a non-reinforced option is selected, stability requirements should be checked by a geotechnical engineer as outlined in Sec. 1.5 above.
- As presented in Sec. 1.5, an Ultimate Limit State (ULS) geotechnical bearing resistance of 550 kPa is recommended. Using a geotechnical resistance factor of 0.5 combined with the typical consequence factor, the factored geotechnical resistance at ULS is 275 kPa. An SLS bearing resistance of 240 kPa is recommended.
- Post-construction settlement should be limited to less than 25 mm, and differential settlements to less than 1%.
- The blocks forming the wall facing should be built on a clean, compacted, granular bedding layer placed on a subgrade free of soft, organic, and deleterious materials. Prior to placing the granular bedding layer, the subgrade should be inspected by a geotechnical engineer.

- Horizontal PGA at the base of the wall is 0.120g for the 2475-year design earthquake. Vertical PGA is 0.080g (considered as 2/3 of the horizontal).

2.0 LIMITATIONS OF REPORT

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3.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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Enclosure: Appendix A – Limitations on the Use of this Document

**PERMIT TO PRACTICE
TETRA TECH CANADA INC.
PERMIT NUMBER: 1001972**

APPENDIX A

LIMITATIONS ON THE USE OF THIS DOCUMENT

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GEOTECHNICAL

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Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address or consider and has not explored, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historical environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional exploration and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.