Mr. Brian Kinzie
Town of Canmore
Canmore Civic Centre
902 7 Ave.
Canmore, AB T1W 3K1

CC: Declan Jensen

February 3, 2022

Project Number: 2021-133

**RE: Retaining Wall Condition Assessment**
**Below Prospect Heights in Canmore AB**

Dear Mr. Brian Kinzie,

As requested by the Town of Canmore (ToC), Taylor Geotechnical Ltd. (Taylor) has conducted a retaining wall assessment of the rock faced retaining wall located on the downstream side of the path adjacent to Prospect Heights in Canmore, AB. The purpose of the investigation was to inspect the existing failure area to determine the failure mechanism, and to assess the potential for further failures across the wall. Based on Taylor's interpretation of the information, comments and recommendations pertaining to the rehabilitation of the retaining wall are provided herein.

The scope of work for this project was provided in the proposal (quote number 1123), dated November 9, 2021. Authorization to proceed was given by Mr. Brian Kinzie on November 15, 2021.

It should be noted that the scope of this report is limited to the geotechnical assessment of the retaining wall and does not include any investigation, analytical testing, or assessment of possible soil and groundwater contamination, archeological or biological considerations or sediment control measures. This report should be read in conjunction with the "***Disclaimer and Limitations"*** which are appended following the text of this letter. The reader's attention is specifically drawn to this information as it is essential for the proper use and interpretation of this report.

## 1.0 PROJECT UNDERSTANDING

The retaining wall location is presented in Figure 1, with a general site plan presented in Figure 2. The retaining wall structure is approximately 200 m long and varies in height, with an average height of approximately 2 to 3 m. The ground surface at the toe of the retaining wall is moderately to steeply sloping, with a tributary stream at the toe of the slope. The confluence of the tributary and Bow River is southeast of the retaining wall. The Three Sisters Commuter Trail is directly above the retaining wall.

ToC has identified one section of the wall that has failed and is of main concern. The identified failure is outline in red in Figure 2. It is understood that the ToC requires a detailed assessment of the retaining wall to determine the likely failure mechanism and to recommend a repair strategy. ToC would also like to understand the potential for further failure across the length of the wall.

## 2.0 FIELD WORK

The geotechnical investigation was carried out by Taylor personnel on December 7, 2021. The field work involved a detailed inspection of the retaining wall where signs of distress and/or movement were identified and photographed. The retaining wall assessment included a review of both the wall itself and the surrounding terrain, including the overlying pathway.

## 3.0 CONDITION ASSESSMENT OF RETAINING WALL

The following section summarizes observed features of the retaining wall at the time of the investigation. Annotated photographs of the features described below are presented in the Photo Plate following the text of this report.

- The retaining wall ranges in height across its length, with the middle of the wall being the tallest. The north and middle segment of the wall have an average height of 2 – 3 m with 3 to 4 rows of rock units, and the southern section has an average height of 0.5 – 1 m with 1 to 2 rows of rock units.
- The terrain at the toe of the wall is moderately to steeply sloping. Signs of ground instability could not be assessed due to snow cover at the time of the investigation.
- The northern segment of the retaining wall, north of the identified failure location as outlined in red in Figure 2, is showing signs of movement.
    - Sand and gravel material was observed to have migrated through various voids in the wall and at the toe of the wall. See Photo 1 for reference.
    - The geofabric within the retaining wall appears to have reached or exceeded its capacity and is bulging, allowing material to mobilize from behind the wall. Localized tears in the geofabric were observed.
    - Rocks within the wall appear to have shifted, creating a bulge-like feature as identified in Photo 2.
    - Various boulder sized rocks are present on the slope and in the tributary, which are believed to be sourced from within the wall. See Photo 3 for reference.
    - The slope at the toe of the wall appears to have sediment build up; however, snow cover made it difficult to identify the material type and source. See Photo 4 for reference.
- The area of failure identified by ToC, as highlighted in Figure 2, has experienced loss of at least one rock unit from the middle of the wall.
    - A boulder of approximately 1.5 m by 0.7 m has fallen out of the wall, coming to rest approximately 2 m down slope of the wall. See Photo 5 for reference. The loss of the unit has caused the overlying units to shift and rotate inward. See Photo 6 for reference.
    - The geofabric from behind the unit is now exposed and is the main source of support for the underlying material. The geofabric appears to be degrading.
    - The loss of the unit has allowed the overlying geogrid to slump (assuming the geogrid was originally placed near horizontal).

  - A build-up of sediment at the toe of the wall has created a mound-like feature adjacent to the failure location. It is suspected that this material was sourced from behind or beneath the wall. See Photo 7 for reference.
  - A fan-like feature comprised of fine to gravel sized sediment was observed at the toe of the slope, where the slope meets the tributary. It is assumed that the sediment was sourced from behind the wall at the failure location.

- The retaining wall south of the failure location appears to be in better condition than the northern segment of wall. Evidence of this included the rock units being better aligned, and less sediment deposition. Sediment deposition, however, was still observed throughout the retaining wall, indicating that material mobilization is occurring. The retaining wall in this area is shorter than the northern segment of wall, composed of only 1 to 2 rows of rock units.
- It appears that the overlying pathway has not yet been affected by the underlying retaining wall failure. Snow cover on the pathway prevented a detailed assessment; however, no major signs of distress were observed on the pathway.

## 4.0 SUMMARY OF RETAINING WALL DISTRESS

The retaining wall can be divided into three zones: failed or expected to fail in the short term, experiencing distress or degradation (i.e., material migration), and generally stable. An approximation of the three zones can be seen in Figure 3, identified in red, yellow, and green respectively.

The northern segment of the retaining wall, including the existing failed area, is experiencing movement. It is expected that active earth pressure acting on the back of retaining wall has exceeded the capacity of the wall. The excess earth pressure is causing the lower boulder units to shift forward, and subsequent movement of the above boulders. As larger void space develops between the rock units, the geofabric material containing the backfill soil experiences loss of support and is more exposed to environmental factors which cause accelerated degradation to the geofabric. As such, migration of the backfill material occurs. On-going migration of the backfill results in further movement of the boulder facing units.

This is apparent in the existing failed area where the earth pressures forced the lower units forward, which led to the middle unit falling out of the wall entirely. The displaced unit left a large void space in the wall, causing the overlying and adjacent units to shift and begin to overturn. Shifting of the units comprises their ability to interlock, ultimately impacting their ability to support the soil slope. The soil slope behind the void is now being supported solely by the geofabric, which is not an effective means of stabilization considering the near-vertical slope.

The southern half of the wall is in a more stable condition. This is likely attributed to its lower height, as it's therefor retaining a lesser volume of soil. Correspondingly, lower active earth pressures are applied to the structure.

Construction records or drawings of the retaining wall structure were not available at the time of this study. Based on site observations, it appears that retaining wall construction involved placement of limestone boulders in roughly horizontal rows commencing on a prepared ground surface. Backfilled soil was encapsulated in geofabric to prevent migration soil through voids in the rock facing. Uniaxial geogrid was placed between the rows of boulders to provide additional strength to the backfilled material.

Embedment lengths for the geotextile and geogrid were unknown, as well as the product information. The face of the retaining wall appears to have been constructed near vertical. Embedment of the toe of the retaining wall was not apparent.

The lack of capacity of the wall to retain the soil slope can be attributed to the placement, size, and shape of the rock units. Based on visual inspection, it appears that the retaining wall is not embedded into the ground surface. Embedment of the toe of the retaining wall provides resistance for the structure against sliding and overturning failure. The size of the rock units on the upper rows appears to be small in comparison to the amount of soil they are meant to retain. Further, the shape of the units prevents them from efficiently interlocking. Without proper interlocking of the blocks to ensure support exists between the blocks, the units are less effective than an engineered multi-segmental retaining wall solution. Lastly, the facing angle for the retaining wall was likely constructed at too steep of an angle to ensure long-term performance of the structure.

## 5.0 GEOTECHNICAL COMMENTS AND RECOMMENDATIONS

Based on the results of the investigation, it is Taylor's opinion that the retaining wall has failed and will continue to experience movement including failure within the identified red and yellow zones along the length of structure if remedial measures are not implemented. The segment of structure in the "red zone" identified in Figure 3 is considered unstable in its current configuration. Replacement of the structure is required for the overlying pathway to remain in use. Within the "yellow zone", it is expected that failure will continue to accelerate through in a short time period (i.e., around 5 years). ToC can consider staging the replacement of the retaining wall. This would include replacement in the red zone and ongoing monitoring of the yellow zone with time until replacement is required. Replacement of the "green" zone isn't anticipated. However, periodic monitoring of the structure should continue.

It is Taylor's opinion that repair of the structure is not a feasible option. Instead, Taylor recommends the disassembly of wall followed by the construction of a new retaining wall structure. Two replacement options are recommended and are summarized below.

1. Reinforced slope with riprap facing (similar to the current retaining wall style). The existing near-vertical soil slope would require regrading to a more stable configuration. A slope of 1 vertical to 1 horizontal (or 45 degrees) is the expected required slope angle. The regrading of the slope paired with the addition of geosynthetics including geogrid and geofabric will be incorporate to stabilize the slope. Detailed stability analysis would be necessary to confirm these requirements.
2. If a near-vertical slope is required to maintain the existing width of the pathway, an engineered mechanically stabilized earth retaining wall solution is recommended. Options for multi-segmental retaining wall products include but are not limited to concrete lock blocks (or lego blocks), Magnumstone, Allan Block, and gabion basket. Taylor can provide additional input on product options and alternatives upon request. Additionally, Taylor can undertake detailed geotechnical analyses and design for the proposed structure once products are selected.

## 6.0 CLOSURE

It is trusted that this letter report meets your present requirements. Should you have any questions or need additional information, please do not hesitate to contact Heather Taylor at 403-707-5082 or heather@taylorgeotechnical.com to discuss.

Kind Regards,

**TAYLOR GEOTECHNICAL LTD.**

Prepared By:

Regan Mahoney
Junior Geotechnical Engineer

Reviewed By:

PROFESSIONAL ENGINEER ALBERTA
HEATHER TAYLOR

2022-02-03

Heather Taylor, MSc, P.Eng.
Senior Geotechnical Engineer

**PERMIT TO PRACTICE**
**TAYLOR GEOTECHNICAL LTD.**
RM SIGNATURE:
RM APEGA ID #: 169143
DATE: 2022-02-03
**PERMIT NUMBER: P014061**
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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The interpretations of site conditions in this report are based on the conditions at sample locations on a specific site at one point in time, and the opinions and recommendations provided are only valid to that extent.

The interpretation of site conditions involves inherent and unavoidable risks. The identification and classification of soils, rocks, geological units, materials and quantities of the same is inherently judgemental in nature. The investigative practice means that some conditions may not be detected or that actual conditions may vary from sample points. Comprehensive investigations conducted according to the applicable standards by experienced personnel with appropriate equipment can still fail to locate some site conditions.

As conditions may change over time, this report is intended for immediate use. The Client should provide Taylor Geotechnical with any changes to site conditions or new information that becomes available after the date of this report and have Taylor Geotechnical re-consider its opinions and recommendations prior to the Client or Third Parties making decisions based on this report.

**REGULATORY CONTEXT**

This report was prepared in the context of government regulations and policies in effect and generally promulgated at the time and, unless specifically noted, does not consider any government regulations or policies that were not in effect and generally promulgated at the time it was prepared. Unless specifically stated, this report provides no advice on regulatory issues associated with the site or project.

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Opinions and recommendations in this report are based on Taylor Geotechnical's interpretations of information obtained through a limited investigation within a defined scope of services. Taylor Geotechnical is not liable for the independent conclusions, interpretations and decisions of the Client or any Third Parties based on this report. This limitation includes any decisions to purchase, sell, develop, lease or rent land or buildings.

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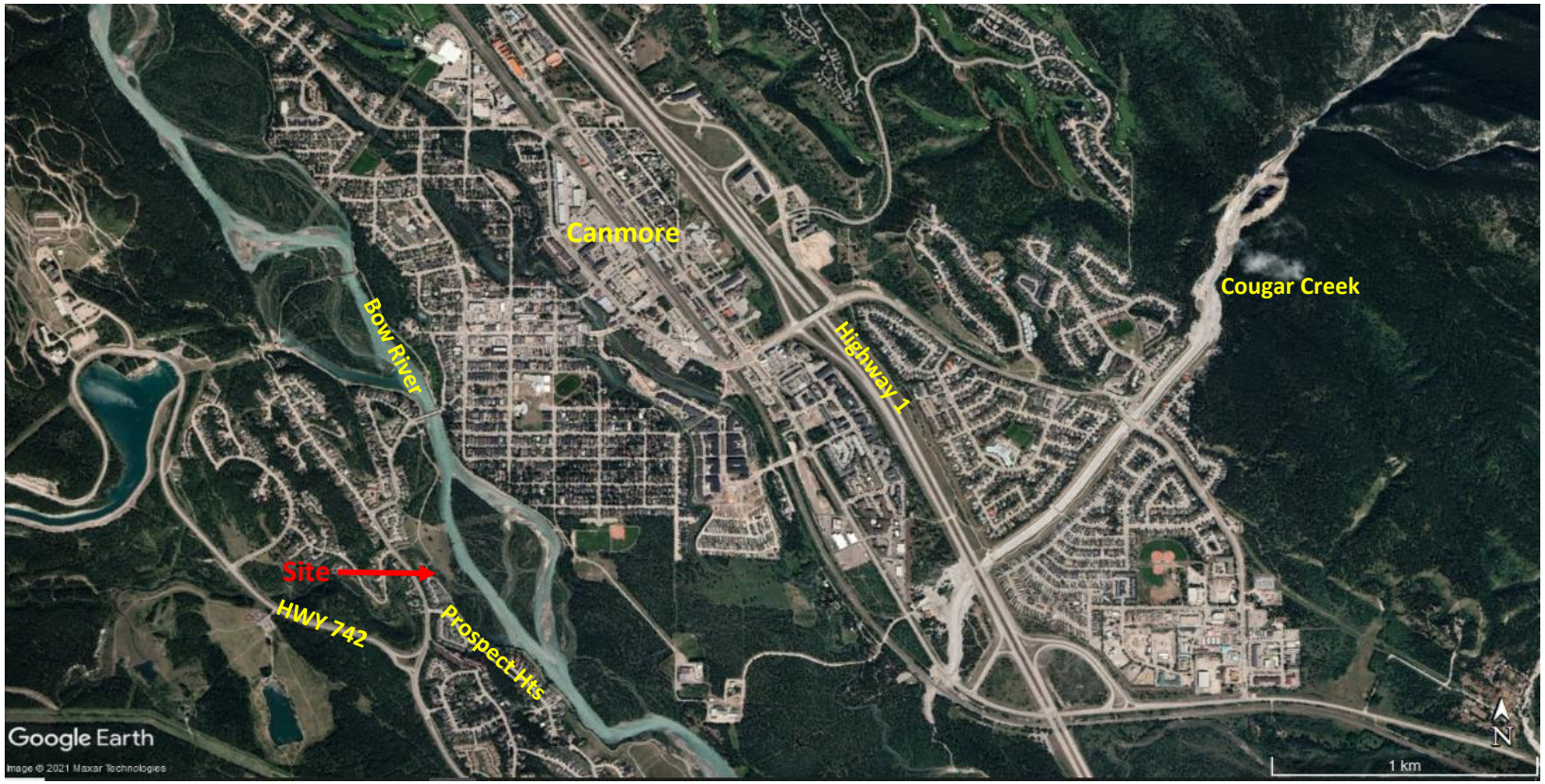
These further services may be necessary for Taylor Geotechnical to provide letters of assurance as required by regulatory bodies in some jurisdiction.




Reference: Google Earth Pro (2021)

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| APPROVED: | HT |

TAYLOR GEOTECHNICAL

CLIENT: **Town of Canmore**

PROJECT: **Prospect Heights Retaining Wall**

TITLE: **Location Plan**

| PROJECT #: | FIGURE: | REV.: |
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TAYLOR GEOTECHNICAL

CLIENT: **Town of Canmore**

PROJECT: **Prospect Heights Retaining Wall**

TITLE: **Location Plan**

PROJECT #: 2021-133 | FIGURE: 2 | REV.: 0


Reference: Google Earth Pro (2021)

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TAYLOR GEOTECHNICAL

CLIENT: **Town of Canmore**

PROJECT: **Prospect Heights Retaining Wall**

TITLE: **Zones Identification Based on Stability**

PROJECT #: 2021-133 | FIGURE: 3 | REV.: 0

# APPENDIX A: SITE PHOTOGRAPHS

**Photo 1:** Material deposition between rock units on north segment of wall.

**Photo 2:** Shifting of rock units creating bulge-like feature in wall

**Notes:** Photo taken near north end of retaining wall, looking approximately southeast down the wall.

**Photo 3:** Select boulder sized rocks in tributary, as highlighted in red, appear to be sourced from within wall

**Photo 4:** Sediment build-up at toe of wall

**Notes:** Sediment potentially sourced from behind wall. Photo taken near north end of wall, looking approximately southeast down the wall.


**Photo 5**: Boulder that fell out of wall in failure location.

**Notes:** Approximately 1.2 m by 0.7 m.

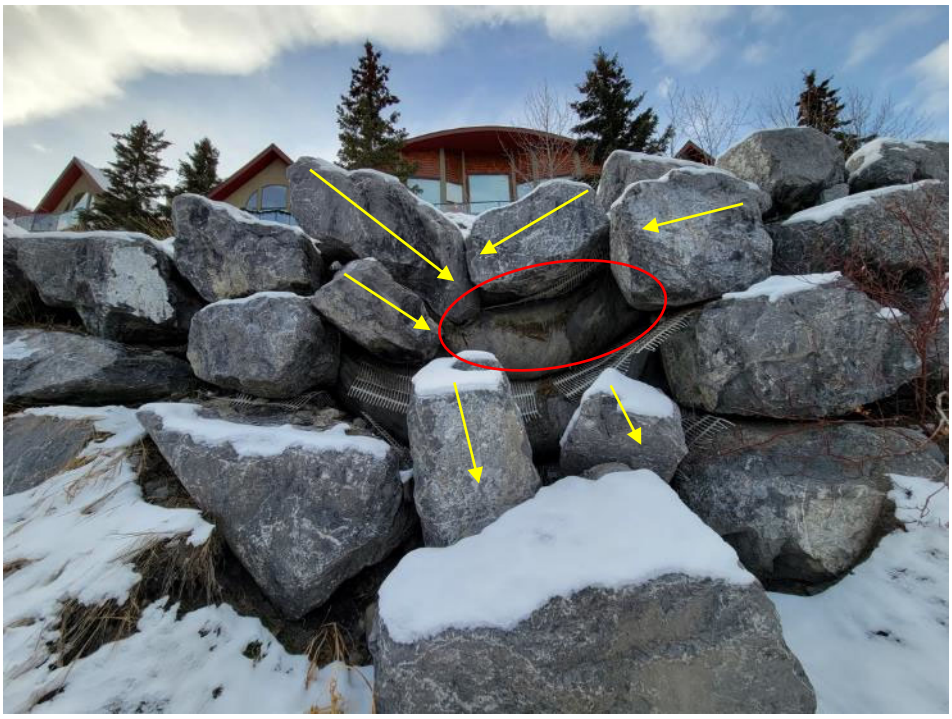

**Photo 6:** Retaining wall failure.

**Notes:** Large void created by boulder falling out of wall (red). Soil now being held back by existing filter fabric. Adjacent and overlying units shifting (yellow arrows showing suspecting direction of movement, assuming units were placed horizontal)

**Photo 7:** Build-up of material at toe of wall, adjacent to failure.

**Notes:** Photo taken at failure location, looking approximately southeast down the wall.

**Photo 8:** Location of fallen boulder relative to wall.

**Notes:** Photo taken standing above wall looking down.


**Photo 9:** Location of wall relative to overlying pathway and upper retaining wall.

**Notes:** Pathway edge approximately 2 m to back of wall units.