TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Teri Camery (CBJ)	**Date:**	April 27, 2022
c:	Alix Pierce (CBJ)	**Memo No.:**	1
From:	Rita Kors-Olthof, Vladislav Roujanski, Shirley McCuaig	**File:**	704-ENG.EARC03168-01 / 704-ENG.EARC03168-02A
Subject:	Landslide Mapping Accuracy and Modelling Downtown Juneau Landslide and Avalanche Hazard Assessment		

1.0 INTRODUCTION

This technical memo addresses some of the comments and questions that arose from Tetra Tech Canada Inc.'s (Tetra Tech) Issued-for-Review (3rd Draft) Report, Downtown Juneau Landslide and Avalanche Assessment, dated May 28, 2021, and the Landslide and Avalanche Hazard Public Meeting that took place on July 21, 2021.

The City and Borough of Juneau (CBJ) has requested a response for each of three key points, as described in CBJ's email dated July 27, 2021. This memo responds to the commentary from a local representative of the U.S. Forest Service and a mapping consultant/software/data vendor, about landslide mapping accuracy and lack of modelling.

2.0 LANDSLIDE MAPPING ACCURACY AND LACK OF MODELLING

Two sets of comments were received from these commenters:

- Comments dated July 21, 2021, received during the question-and-answer session of the Neighborhood Meeting (copied below).
- Comments dated August 8, 2021, received via email (summarized below).

Question/Comment #1: Quinn Tracy's maps and Tetra Tech's summary is clear, but the accuracy of the maps is a serious problem. Specific to the landslide hazard mapping portion of the study, there was no indication of any modern landslide modelling techniques. The references cited are over 30 years of age. Clearly efforts were focused on simply using a combination of old landslide maps and new LiDAR. Modern landslide evaluations include statistical models (calling this a statistical effort is inaccurate) and physically based models. Many models are used in the Pacific northwest and Alaska and could have been used in this study. Technically sound scientific examination of landslides, including debris slides and debris flows, would include analysis of hydrologic contributing area and evaluation of the sediment volumes in initiation and runout zones. An understanding of these parameters would aid in the understanding of landslide runout. My question to CBJ: Will you add modern landslide modelling to serve the community of Juneau?

Question/Comment #2: Tetra Tech's analysis provides "low, moderate, high, severe" landslide hazard zones without any quantitative description of what those hazards mean. To make rational and defensible zoning decisions requires consideration of the costs and the benefits of those decisions: comparison of the costs of precluding housing versus the probability of preventing property damage and loss of life. Why was a useful quantitative analysis conducted for snow avalanches while such an analysis was not conducted for landslides? Quantification of landslide occurrence includes utilization of the physical parameters controlling initiation and runout of landslides, establishing

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probabilities of landslide initiation and runout, and an analysis of the costs entailed when an event occurs, in both dollar amount and the costs in human lives. Further, a system is needed to better inform the public of high-risk precipitation events associated with enhanced landslide activity, i.e., an early warning system for landslides.

Response: The first comment reflects four primary concerns, including mapping methodology and accuracy of the mapping, the age of the references, the perception that the mapping simply used a combination of old landslide maps and new LiDAR, and the lack of landslide modelling techniques. These were briefly addressed during CBJ's recorded Question-and-Answer (Q&A) session following Tetra Tech's presentation for the Landslide and Avalanche Hazard Public Meeting on July 21, 2021. The second comment reflects the desire for a quantitative analysis, a risk analysis, and an early warning system. These concerns are addressed as follows:

1. Mapping methodology and accuracy of the maps:

    a. As described in Tetra Tech's report, the mapping was completed in PurVIEW, an add-on to ArcGIS that allows the mapper to view three-dimensional (3D) air photo images on the computer screen in spatially-accurate locations. Mapping can then be completed for various air photo years with a high level of confidence in the location of the various features. For example, surficial geology was mapped at a scale of 1:2,000 to 1:4,000. This scale is a significant improvement over the scales that were available to previous mappers. For example, Swanston (1972) and Miller (1972 and 1975) would presumably have had access to air photos from 1948 at 1:40,000 scale, and from 1962 at 1:21,600 scale. Mears et al. (1992) would also have had access to some higher-resolution air photos: 1977 at 1:6,000 scale, and 1988 at 1:4,800, and appear to have used the 1977 air photos in two of their figures. However, none of these references identify the air photos used, and most do not acknowledge the use of air photos. Any images listed in Tetra Tech's Table 1.1 after 1988 would not have been available to either Swanston or Mears et al.

    b. Digital air photos were acquired from CBJ, Quantum Spatial, Inc. (QSI), the U.S. Department of Agriculture (USDA), and the U.S. Geological Survey (USGS). The air photos were georeferenced and aerially triangulated for viewing in PurVIEW. Hardcopy air photos were first scanned at high resolution (12 µm) for this purpose, and then georeferenced in 3D. Satellite and LiDAR images of the Study Area were supplied by CBJ. No mention is made in Swanston (1972) or Mears et al. (1992) of aerial imagery being ortho-rectified for use in mapping, which would have been necessary for them to reliably identify and control the locations of observed features. For example, stereo-pair images that are not ortho-rectified can have significant distortions in the images, including "compressed" or "elongated" terrain when hillslopes are viewed from different angles. This results in images that can be difficult to compare even within the same air photo year, let alone with imagery from different years. Therefore, because the old mapping was not based on ortho-rectified imagery, it was not possible for Tetra Tech to reliably overlay "old" and "new" mapping. In contrast, Tetra Tech's mapping was based on georeferenced images, allowing very accurate overlays of the different years of imagery.

    c. Surficial geology was mapped using the 1948 air photos to provide a baseline for the maps that extends as far back in time as the air photo coverage of the Study Area allows. Given the limited capabilities of photographic equipment in 1948, the 1962 air photos were used to check the base historical mapping and the surficial geology mapping. Then, the 1962 and later air photos and satellite images were used to determine slide activity visible on the dates of those images, using lack of vegetation as a proxy for slide activity.

    d. The LiDAR bare-earth hillshade model images were primarily used to refine and show the locations of such major terrain features as gullies and debris flow fans. Due to the high resolution of the LiDAR data, it was possible to map a large number of gullies. Gully erosion, as a hazardous geomorphic process, was given close attention in this landslide hazard assessment study because gully erosion plays a significant role in mass movement on the slopes, with some of the gullies being conduits for conveying debris flows, debris slides, and wet avalanches.

   e. Historical records and incident reports, as well as contemporary photographs and news reports, were used to supplement the mapping in specific localities. However, the main components of the mapping are based on the historical air photo record review, the LiDAR images review, and the fieldwork completed by Tetra Tech.

   f. Preliminary field maps were prepared for use during the site reconnaissance visit and were updated in accordance with the observations made in the field.

   g. The site reconnaissance included the following tasks:

      i. A helicopter fly-over of the Study Area was conducted to provide a wider perspective of suspected areas of slope instability, to target specific areas for ground-truthing, and to provide access to otherwise inaccessible or difficult-to-access areas.

      ii. A foot-traverse inspection of a large portion of the Study Area was done for field mapping of landslide areas and ground-truthing of geomorphic features/hazards (e.g., landslides), key terrain features, and vegetation damage (slope instability-related) identified from air photo and LiDAR data analysis.

      iii. Measurements, photographs, and Global Navigation Satellite System (GNSS such as GPS/GLONASS) data were collected for landslide initiation and runout zones to help define hazard types and mechanisms.

      iv. Additional emphasis was placed on field observations in residential areas, resulting in a much greater density of field observations and time spent in residential subdivisions, e.g., the Behrends, White, and Starr Hill Subdivisions.

   h. Several landslide events that occurred subsequent to the completion of Tetra Tech’s mapping served to confirm the accuracy of the mapping.

2. The references cited were over 30 years of age:

   a. Numerous references cited are less than 30 years of age.

   b. Age alone is not considered a valid reason to reject the use of references that provide valuable information for the project. For example, some of the older references provided very useful historical context that would have otherwise required considerably more research to acquire.

   c. All references, including those that were over 30 years old, were evaluated for quality in accordance with the technology that was available at the time, and used or referenced (or not) as appropriate for the goals of the current mapping project.

3. The perception that the mapping simply used a combination of old landslide maps and new LiDAR:

   a. It is clear from the description of the actual mapping methods presented in the report, and from the summary provided above, that this perception is incorrect.

   b. This is not to say that the old mapping was ignored in the production of the new mapping. The old mapping, from several sources, was reviewed to confirm that landslides presented in the older work were either represented in the new mapping (and appropriately updated to the present day, if/as required); *OR* that specific features had been reviewed and, on the basis of findings using higher-resolution technology, considered not applicable.

4. Lack of landslide modelling techniques:

   a. Landslide modelling was not in the project scope.

b. Geotechnical drilling was not in the project scope.

c. For a landslide model to provide an estimate of landslide runout more convincing than that already provided by the direct evidence seen on the ground or from air photos would require significantly more effort than was feasible with the available project funding. This judgment is confirmed by the comparison of Tetra Tech's mapping with a set of slope stability models prepared by others for a local Juneau watershed.

d. If Tetra Tech were to carry out landslide modelling on selected debris slides, debris flows, rockfalls, or rockslides (for example), the scope would require not just modelling, but the collection of additional supporting field data, including, but not limited to:

  i. Detailed engineering geology mapping for rockfalls or rockslides, including identification of structural domains, faults, discontinuity sets/orientations, rock mass quality;

  ii. Collection of detailed topographic data, preferably including a topographic survey; information on surface conditions including vegetation, surface drainage, signs of ponding or erosion, tension cracks, observations of ground deformations etc.; field identification of initiation and runout zones; characteristics and performance of adjacent or nearby slopes; identification of landslide terrain that contributes to debris flows; noting possible changes since the previous inspection;

  iii. Detailed characteristics of suspected or known debris flow gullies, such as upslope gradients and/or terrain stability class; stepped gully configuration (i.e., sediment stored in debris wedges); debris flow levees, avulsions; fan destabilization potential as indicated by number of channels, degree of incision; water transport potential as indicated by channel width, size/presence of woody debris, maximum sediment particle size; consideration of headwall/sidewall failure potentials based on slope gradients and surficial materials, gully geometry potential for debris flows based on sidewall slope lengths and channel gradients;

  iv. Geotechnical drilling and/or testpitting, potentially with several testholes at each site location. Depending on location, achieving access could require tracked drills or heli-portable drills;

  v. Collection of soil/rock samples from boreholes or test pits. Successful sampling will depend on the anticipated materials to be sampled and on the choice of sampling method, e.g., drill type;

  vi. Installation and long-term monitoring of instrumentation such as slope inclinometers, piezometers, and remote access data acquisition systems;

  vii. Laboratory index testing to classify and determine engineering properties of soils, and strength testing on selected samples (soil or rock);

  viii. Analysis and modelling, potentially including (depending on the type of landslide):

    1. Visual slope retrogression analysis based on air photos and current site observations;

    2. Semi-quantitative slope analysis, beginning with back-analysis to determine the slope parameters (several models available for evaluation); and/or

    3. Debris flow analysis (several models available for evaluation).

  ix. A detailed geotechnical investigation, instrumentation monitoring and analysis/modelling program could require an additional budget ranging from $250,000 to $1,000,000 per site to be investigated, depending on the complexity of the landslide and access, the type of drill required and where it is mobilized from, and the instrumentation to be installed. Each site also requires long-term monitoring and data analysis, at an additional annual cost that could reach $125,000 to $500,000. Tetra Tech notes that mobilizing a suitable drill from Whitehorse, Anchorage, or further away, would entail significant costs. For example, for two Alaska Department of Transportation projects with challenging access conditions (the Juneau Access Road and a new section of the Sterling Highway), a geotechnical drilling contractor from Washington State conducted the exploration work. It is anticipated that to further investigate and analyze even a few sites would rapidly result in a budget exceeding several million dollars; and

x. It is noted that Tetra Tech conducted a semi-quantitative analysis specifically to compare various geotechnical parameters and associated landslide prevalence against the hazard designation categories. This was not intended to be a detailed statistical analysis, for example, such as could have been prepared based on the results of a much more extensive field investigation throughout the map area, including a geotechnical drilling program in selected locations. Accounting for the high resolution with which the surficial geology and landslide mapping was accomplished, and the proven accuracy of that mapping as seen from later landslide events that confirmed the mapping, the semi-quantitative analysis is considered to have been a value-added contribution to the mapping process.

5. Lack of quantitative analysis:
   a. Determination of “the physical parameters controlling initiation and runout of landslides” requires the acquisition of additional site-specific information, which was not in the project scope.
   b. See Item 4 above.
6. Risk analysis:
   a. A risk analysis includes not only an assessment of hazards; but also consequences, e.g., costs related to property damage, injury, or loss of life; and the resulting risk.
   b. Determination of the probabilities of landslide initiation and runout is a task that would be greatly facilitated with the acquisition of more site-specific information, which was not in the project scope (see Items 4 and 5 above).
   c. This task would also entail a magnitude-frequency analysis, which was not in the project scope.
   d. The determination of consequences and risk were not in the project scope.
7. Early warning system:
   a. The development of an early warning system would require a detailed analysis of climate and climate change, which was not in the project scope.
   b. Development of the early warning system itself was not in the project scope.

3.0 LIMITATIONS OF REPORT

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4.0 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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LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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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 report, at or on the development proposed as of the date of the Professional Document requires a supplementary 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 investigate, address or consider and has not investigated, 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 and methods 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 historic 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 investigation 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

There is a direct correlation between construction activity and 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 are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as 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

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. 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.

1.16 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses 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 assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed 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.