TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Teri Camery (CBJ)	**Date:**	April 27, 2022
c:	Alix Pierce (CBJ)	**Memo No.:**	2
From:	Rita Kors-Olthof, Vladislav Roujanski, Shirley McCuaig	**File:**	704-ENG.EARC03168-01 / 704-ENG.EARC03168-02A
Subject:	Landslide Designations and Boundaries – Bathe Creek and Highlands 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 commentary from a local avalanche expert, as well as from other residents with questions about the Bathe Creek and/or Highlands mapping areas.

2.0 LANDSLIDE DESIGNATIONS AND BOUNDARIES

Some detailed commentary about the mapping was provided to CBJ in a letter dated July 26, 2021. The writer deemed the avalanche mapping generally accurate and well-done. The remaining commentary was mostly concerned with landslides, offering some general critique for the overall landslide mapping, as well as some specific observations in the Bathe Creek and Highlands areas. Questions and concerns have been documented below in a question-and-answer format beginning with general mapping questions, followed by Bathe Creek/Highlands-specific questions from several people. In cases where questions were similar or related, these have been combined for the response.

Overall Landslide Mapping:

1. **Question/Comment:** Incorrect classifications based on recorded return intervals:
    a. Areas shown as *Severe* that have recorded frequencies in the *High* range; and
    b. Areas that have become inactive as drainages have changed, suggesting that they should be designated as *Moderate* to *High*, instead of *Severe*, if the stated standard of mapping for current conditions is followed.

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Response: As noted in Section 1.2.4.2.5 of the main report, the analysis of magnitude/frequency was *not* part of this high-level study. There appears to be reasonably good correspondence between the levels of historical activity identified and typical event probabilities, particularly in many of the highly-active landslide features. For that reason, Tables 1.3, 1.4, and B.1 in the main report include some very high-level estimates that could be helpful for visualizing the differences between the hazard designations. These estimates have now been revised to correspond more closely to the format of the estimates used in the avalanche study. However, it should be noted that these estimates are based solely on the level of activity observed in slope movement features and gully erosion features identified from the historical air photo record analysis and the LiDAR data analysis, as well as field observations and, where available, incident reports. A magnitude-frequency analysis will be required to produce more reliable estimates for event probabilities than is currently possible. See "A Guide to Avalanche and Landslide Hazard Designations" for additional information and examples (Technical Memo #4 in Appendix C of the main report; Tetra Tech 2022d).

It should also be noted that the frequency or return period of an event (or the mapping proxy of visual evidence of repeated slide activity) does not mean that an event of a specified size or severity will return every X number of years. For example, a debris flow of a certain size typically depends on two events coinciding: a storm event large enough to mobilize debris in a gully, and enough debris accumulated in the gully from previous events to mobilize the debris. Furthermore, a 1 in 30-year rainstorm event (for example) could happen at *any* time in a 30-year period. It could happen this year, and it could also happen again next year. (Though if it keeps happening, the meteorologists might eventually decide that the new normal for that size of storm is a 1 in 10-year event.)

In general, the hazard designation mapping is not intended to indicate event probability (whether an event is likely to occur within a specified number of years), but rather whether a hazard is expected at some point in the future, generally based on evidence that it has already done so in the past. These maps provide the locations of hazardous areas, which is important information for planning purposes. More detail, such as determining the potential frequency and magnitude of the events that could occur in those areas is a logical next step; however, it is not without significant cost.

Additionally, an area is given a hazard designation of *Severe* if:

- A cone or fan of colluvium is present at the base of a slope, no matter how old it is, because the hazard still exists (Howes and Kenk 1997); and/or
- Evidence of slope instability (exhibited on air photos as a lack of vegetation in a formerly vegetated area with an obvious downslope movement component; incident reports; and/or field observations) is identified within the same feature in more than one air photo/LiDAR year and/or field investigation year.

Note that numerous gullies show evidence of slope instabilities in several years (sometimes every year) of imagery, incident report data, or field observation data that was reviewed.

In one area, located southeast of Snowslide Creek near the top of slope, visual evidence of bedrock movement seen at ground surface during the fieldwork indicated the possibility of an impending deep-seated bedrock slide that could reach Gastineau Channel. Because it has not yet failed, a level of activity could not be determined for that site but, due to the very large size of the feature and the notable consequence of its failure, it was given a *Severe* hazard designation.

For changed drainages, or map areas that appear not to have had an obvious slope instability for decades, e.g., 60 years, this does *not* mean that the area is now "inactive." Also, there may be other factors that account for the feature being designated as a higher level of hazard, including the type of feature and the amount of historical instability on the slopes above it.

Debris cones (steeper conical features) and fans (more gently sloping fan-shaped features) develop by the accumulation of unconsolidated surficial material (debris) that is transported and deposited in ever-shifting flow channels that migrate from one side of the cone/fan to the other. This is how the fan or cone shape forms. A debris flow entering at the top ("apex") of a cone is capable of flowing *anywhere* on that cone, even if it has flowed for many years in the same incised channel. A new debris flow provides its own, sometimes very viscous clayey/silty soil matrix, which can incorporate or entrain boulders and large woody debris, and it can block its own direction of movement with that material. Unless the flow can be controlled and diverted from the very top of the feature (usually an expensive proposition), what happens below the apex is not entirely predictable. The behaviour of debris flows that are not well-incised is even less predictable. The smallest disruption in the ground surface, like a fallen tree or a bit of debris blocking the usual flow direction, can result in an abrupt change of flow direction, or a splitting of the flow into several channels.

2. **Question/Comment:** Placement of very different hazard designations together, e.g., *Severe* next to *Low*, rather than the designations progressing downslope from *Severe-High-Moderate-Low*, that the writer would have expected with the higher frequency of smaller, shorter-running slides.

   Response: Landslide hazards are generally not downgraded in a downslope direction. If there is a history of slide activity, or if it is a runout zone (i.e., a deposition zone), an area is considered to pose a *Severe* hazard. Note that not all landslide events begin at the top of the mapped feature, nor do they necessarily extend to the bottom of the feature, which can be seen clearly in the historical air photo record and LiDAR data analysis, in both the slope movement features (Figures 1.4a to 1.4c) and the gully erosion features (Figures 1.5a to 1.5c). Landslide modelling could be used to refine the runout zones and potentially downgrade the designated hazards in some locations. However, as noted in Technical Memo #1 (in Appendix C of the main report; Tetra Tech 2022a), landslide modelling was not part of the scope of this project.

3. **Question/Comment:** Mapping polygons appear oddly-shaped, not corresponding to the lobate flow features or runouts expected in areas without strong topographic controls. Areas of criticism include "odd little pointy bits," and abrupt changes in direction.

   Response: In several instances, the apparent odd shapes of some of the terrain units result from the shapes of the adjacent terrain units. One example is the Bathe Creek drainage above Irwin Street and Gold Creek, where the shape of the east edge of the colluvial cone/fan is affected by an area of bedrock (shown in purple and marked Rr/Cv on Figure 1.3b). Immediately upslope of the bedrock area is another area of colluvium marked Ca|dr that apparently encroaches into the Bathe Creek drainage. So, even though the Bathe Creek fan/cone looks a little odd on the east side, the adjacent landforms are the cause of this peculiar boundary (see excerpts of the figures in Item 6 below).

4. **Question/Comment:** Deglaciation was relatively recent in our region, and the retreat of the ice was followed by a period of enhanced mass wasting, as the glacially-oversteepened slopes came to a new equilibrium and became vegetated. Most of the present-day colluvium dates back to that period. The bulk of the fan area of concern would appear to be from then. The volume exceeds what would have likely come from Bathe Creek; it is far more likely that the bulk of the material came from the steep slopes directly above Evergreen, than from cross-slope movement from Bathe Creek. It is a more reasonable interpretation that the recent activity apparent from air photos and LIDAR is the surface veneer, showing only the most recent activity, now obscured by development.

   Response: Tetra Tech respectfully disagrees, given the amount of activity seen in the historical landslide mapping. If a series of small debris slides or flows occurs in the same area repeatedly, there is a hazard. It may be smaller than the hazard of major slides or flows that are very old, but it is still a hazard to the slopes below. Loose material builds up on the slopes with each small event, eventually leading to a larger event that incorporates that material and adds some of its own. Whether a landslide consists of a debris slide or a debris flow, and regardless of the source of the materials (e.g., “old” colluvium or “new” colluvium), it is a significant hazard to the slopes below and should not be downgraded.

Questions/Comments – Bathe Creek along Irwin Street and up Highlands:

To document their local knowledge of the Bathe Creek / Irwin Street / Highlands area, the writer reported that they have lived since the early 1990’s on the upper part (northeast end) of 12th Street. Due to the lack of mapping at that time, the writer explored the slopes above this area, as well as the slopes throughout the Highlands area, during their house-hunting efforts. The following site-specific questions/comments were provided.

5. **Question/Comment:** Bathe Creek is known to produce debris flows, but the historical frequency is only in the 10- to 30-year range, not the 1- to 10-year range suggested in the report for a *Severe* designation. The writer suggests that the historical frequency is high enough to even out possible anomalies and that the return interval is the most reliable basis for mapping hazard.

   Response: See response to Item 1 above for general remarks about frequency and historical activity. Specific to Bathe Creek, this feature is a very active debris flow gully, according to the historical air photo record and LiDAR analysis, and it is therefore rated *Severe*.

6. **Question/Comment:** The mapped boundaries [of the *Severe* hazard zone] are noted to be irregular, with curlicues and projections on the [east] side that do not resemble the mapped lobate avalanche boundaries, which may better define the landslide hazard area.

   Response: See response to Item 3 above regarding the irregular “curlicues and “projections.” Bathe Creek is an example of where adjacent terrain units affect the shape of this terrain unit. In general, because the processes are not the same, avalanche path boundaries should not be expected to match landslide hazard boundaries. Compare the excerpts from the avalanche path and hazard mapping in Figures 2.2c and 2.3a (Figure 1 below) with the surficial geology and major gully features in Figures 1.3b and 1.5b (Figure 2 below). The boundaries of wet avalanches might sometimes approximate the boundaries of debris flows in the same terrain feature, a resemblance that would necessarily depend on the size and mobility of each event. In this case, they could be similar but not identical.

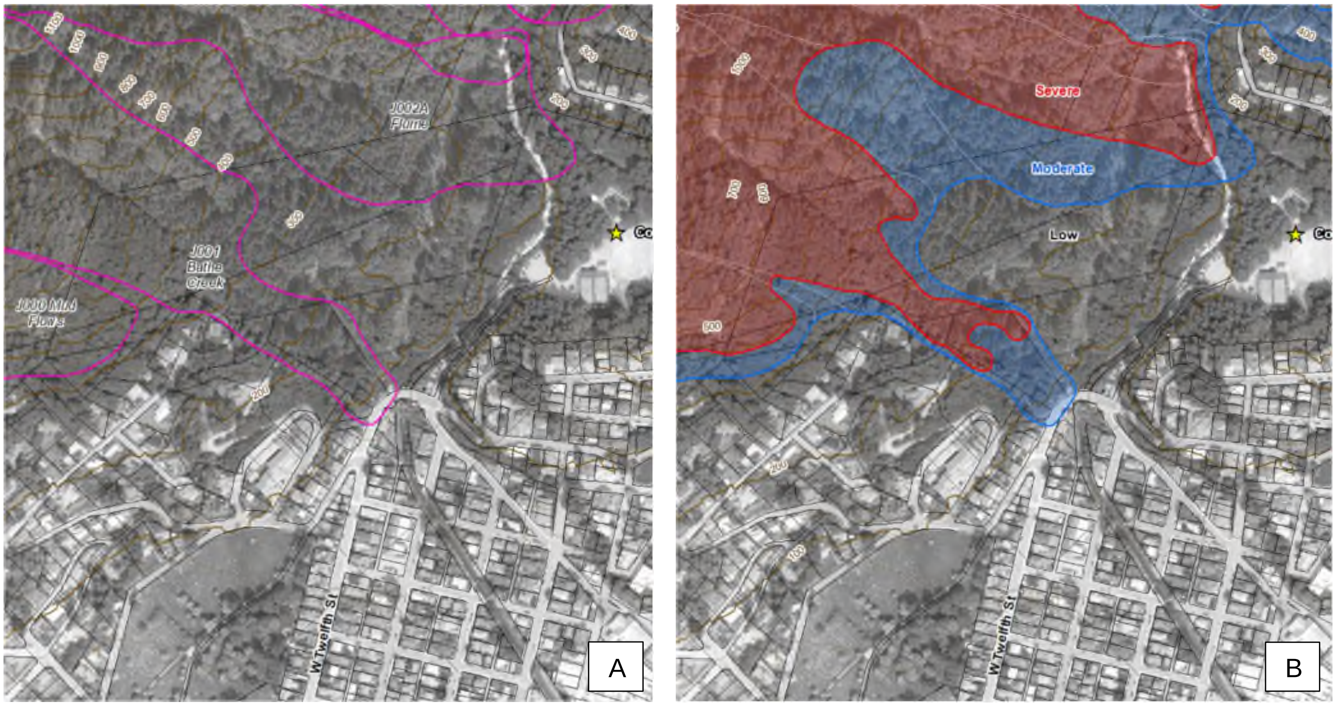

Figure 1: Excerpts from Figure 2.2c Avalanche Path Mapping Detail (Figure 1A) and Figure 2.3a Avalanche Hazard Designation Mapping Overview (Figure 1B).

Compare the surficial geology and the major gully features shown in excerpts from Figures 1.3b and 1.5b (Figures 2A and 2B below). In the case of Bathe Creek, the shape of the *Severe* area reflects the shape of the cone/fan and the upslope gully that is the source of the debris, as shown below in the excerpt from Figure 1.6c (Figure 2D). Finally, even though the fan itself only displays occasional activity (remobilization of old debris flow material), as shown in the excerpt from Figure 1.4b (Figure 2C), the debris flows originating from upslope govern the hazard designation, as they are what has formed the fan and what will continue to do so in the future.

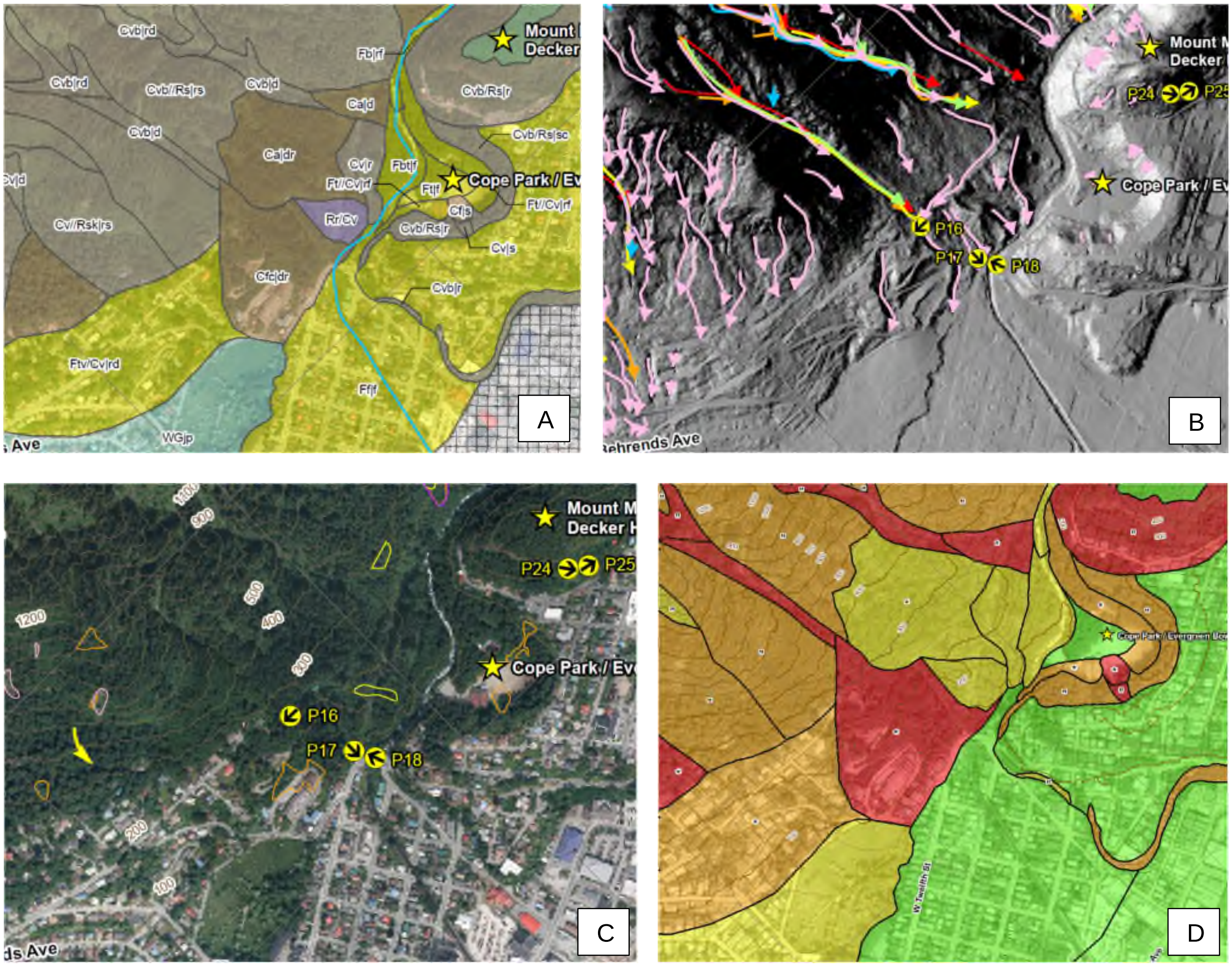

Figure 2: Excerpts from Figure 1.3b Surficial Geology (Figure 2A) and Figure 1.5b Historical Air Photo Record and LiDAR Data Analysis – Gully Erosion Features (1948-2013) (Figure 2B), and excerpts from Figure 1.4b Historical Air Photo Record – Slope Movement Features (1948-2020) (Figure 2C) and Figure 1.6c Landslide Hazard Designation Mapping (Figure 2D).

7. **Question/Comment:** Swanson's study seems to indicate that flow from Bathe Creek was turning sharply enough to make that south and west area part of the runout, either when he did his 1972 study, or in the recent past. But the topography at the mouth of the Bathe Creek canyon is now incised enough that it would take a major change to divert it south and west again. This mapping is supposed to be for current conditions and topography, not speculation on how it might change in the future.

   Response: See the last paragraph in the response to Item 1, which describes how debris flow cones and fans are formed. Specific to Bathe Creek, the mouth of the creek is not the location where the most significant changes in flow direction are likely to occur. Instead, it would be the apex of the cone/fan, i.e., above Evergreen Avenue. See Item 6.

8. **Question/Comment:** Residents of the area extending from above the east end of upper Evergreen Avenue downslope through Hermit Street, Rheinhardt Street, and Irwin Street, are concerned about the *Severe* hazard designated for this area as a result of the new mapping, instead of the *Moderate* hazard that applied before in most (but not all) of the subdivision. The changes in assumptions between the 1987 adopted hazard maps and

the proposed 2021 maps are not well understood, resulting a lack of confidence in the results. A few residents thought that the new study was based on the old study. Some residents stated that they would not have purchased their property if they had known that it was in a *Severe* hazard zone. Another resident on Hermit Street owned a house whose original owner had a site-specific review done prior to construction for their proposed building site, due to the previous mapping (Swanston 1972) that had identified a hazard in the area. The current owner has commented that they might do the same.

Some residents also noted that they were not aware of a landslide event that had affected their address, nor did it seem to them that there had been a change in topography or vegetation in the area over the years. Other residents acknowledged the presence of the nearby Bathe Creek gully but felt that the topography protected the residential areas from landslides or avalanches. A few residents wondered if existing structures or trees would reduce the likelihood of impacts from landslides or avalanches.

How can homeowners in this area reconcile the old mapping with the new mapping, and better understand what the new mapping means?

Response: Additional areas of *Severe* and *High* hazard were added to the hazard map, because of the types of landforms and the amount of landslide activity that was seen on the air photos, on the LiDAR images, and during the fieldwork. A *High* or *Severe* hazard designation is not always well represented by what one sees happening (or not happening) on the slopes adjacent to one's property. The hazard designation may have been assigned because of what is happening on the slope well upslope of a particular property. This is true for Bathe Creek and the surrounding terrain. See the last paragraph of the response to Item 1, and also Items 4 and 7. The debris flow potential of the slope above is one part of the rationale that results in the *Severe* hazard designation for this area. The debris flow paths on the fan/cone can easily be shifted by a debris flow if something happens higher up near the fan/cone apex that changes the direction of flow. This area was reviewed in detail during the field work.

The debris initiation and runout zones appear to have been missed in the Swanston (1972) study, although the main gully was identified as being a *High* hazard path (the same as the 1987 *Severe* hazard designation) from the east end of Evergreen Avenue all the way to Gold Creek. Swanston identified superimposed deposits along the main gully that showed repeated landslide activity. He also commented on two debris flows that ran an hour apart down the gully, badly damaging a home and filling Irwin Street with debris. Swanston further noted that there were two smaller gullies that led down into the gravel quarry (now the residential area) above Martin Road. Tetra Tech notes that this residential area has all the hallmarks of a runout area, since it is downslope of the initiation and transition zones of a prominent and very active debris slide/debris flow path.

It seems possible, if not likely, that the presence of the former gravel pit obscured some of the signs of the debris flow fan at the time of Swanston's study. However, a soils study conducted prior to the development of the Westridge Condominium project, carried out by R&M Engineering in 1980 and 1981, encountered 10 feet of silty sand colluvium upslope of the project, at about 160 feet above sea level. The back of the condo project was noted to be at about 140 feet elevation. Ten feet of colluvium is not an insignificant amount of material. Beneath the colluvium was sandy gravel of glaciofluvial/deltaic origin, which would have been the type of material preferred for gravel pit operations. Notably, if the residential area is located within the former gravel pit (as it is understood to be), R&M Engineering would not have encountered the colluvium there, because it would have been stripped off the site before excavating the gravel for use. Once again, the presence of a hazard from upslope was not recognized.

Further consultation did not reveal any further reasons for caution (Swanston 1990), since the 1972 study had been intended for use as a planning-level tool, not a site-specific investigation. He also felt that the "alluvial cone deposits" beneath the property, and the bedrock-controlled gully would keep avalanches or debris flows away from the site. Swanston (1990), understandably, stated that the "results and recommendations derived from more detailed site investigations by competent, licensed engineering geologists or geotechnical engineers" should govern.

Knowing what we know now, however, it is important to remember that a debris flow can occur *anywhere* on a colluvial cone, not just in the current incised channel. Furthermore, existing structures and even very large trees do not reduce the hazard; instead, trees and structures are often simply broken or crushed and entrained into the debris. It is important to recognize the true hazard represented by the debris flow terrain, and the *Severe* hazard designation was not arrived at lightly.

9. **Question/Comment:** The [west] side of the *Severe* hazard zone is noted to include a large area of colluvium in the Irwin Street to Highlands area, despite no recorded slide history since houses were built there. If the Swanston (1972) study is intended to support the *Severe* designation, maps and quotes from that study should be included in the report.

   Response: The basis for the *Severe* hazard designation is not Swanston's report, but rather Tetra Tech's independent determination of the characteristics of the terrain units based on surficial geology mapping, historical air photo record analysis of slope movement features and gully erosion features, as well as incident reports and field observations. See also responses to Items 1 and 4 above. Specific to the *Severe* areas mapped in this part of the study area (Figure 1.6b and 1.6c), these are all colluvial areas (Figure 1.3b) that receive debris from several active gullies upslope (Figure 1.5b), including the previously mentioned Bathe Creek gully (see Figure 2 above), and several active gullies above Behrends Avenue and the west end of Highland Drive (see Figure 3 below). Several of the two dozen debris slides that occurred in various years in the immediate map area (Figure 1.4b) happened within gullies (compare Figures 3B and 3C below). The excerpt from Figure 1.4b (Figure 3B below) is also a good example of an avalanche track (area with no trees) that does not correspond perfectly with landslide activity and location.

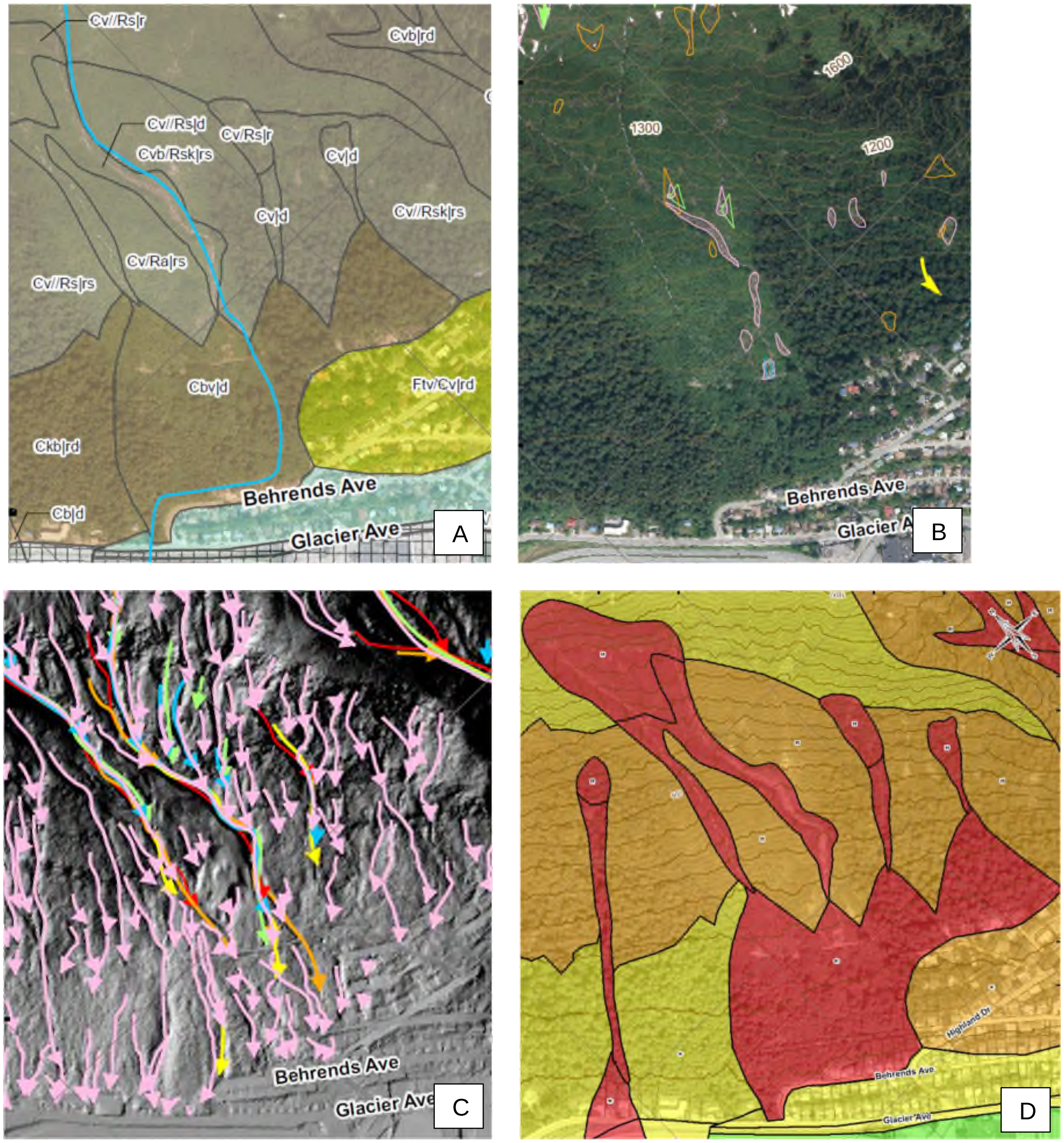

Figure 3: Excerpts from Figure 1.3b Surficial Geology (Figure 3A) and Figure 1.4b Historical Air Photo Record – Slope Movement Features (1948-2020) (Figure 3B), and excerpts from Figure 1.5b Historical Air Photo Record and LiDAR Data Analysis – Gully Erosion Features (1948-2013) (Figure 3C) and Figure 1.6c Landslide Hazard Designation Mapping (Figure 3D).

While it is possible that houses have stood in one location for many years without being affected by a landslide, it does not mean there is nothing going on above them on the slope. If that activity has not reached a particular house yet, the resident may just have been lucky so far.

These are hazard maps, which indicate areas that are potentially hazardous. If there was a lot of potentially hazardous geomorphic process activity on a slope, or if new activity was identified in the field, that area was mapped as having a *Severe* hazard. For instance, debris could be building up on the slope directly above a house, or in a location where debris can potentially run towards a house (see Figure 4 below), and where it could become a more serious hazard in the future. Smaller debris slides and debris flows tend to accumulate debris and store it in wedges within gullies. Eventually, when a critical level of debris is reached, or a rainstorm of a particular size occurs, all that stored debris is scoured out of the gully, potentially resulting in a very large debris flow event. Similar events can occur on open slopes where slide debris piles up in lobes over days, months, or years, sometimes separated by channels of faster-flowing debris. These debris lobes can slowly be creeping downslope, until the critical moment when there is enough mass and enough water to make the debris flow rapidly downslope.

Figure 4: Looking down towards the Gold Creek Flume Trail from the Bathe Creek debris flow gully. Note the large amount of debris in and alongside the gully, as well as the scarring on the tree beside the road that extends to at least 6 feet above ground surface. This gully is very active, and the debris that is deposited at the road crossing is regularly cleaned up. This road crossing has the potential to divert debris flows into the residential community downslope and to the west, especially if more than one surge of debris occurs before the debris can be cleaned.

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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,
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Enclosure: Limitations on Use of this Document

REFERENCES

Tetra Tech. (2022a). Technical Memo #1. Landslide Mapping Accuracy and Modelling, Downtown Juneau Landslide and Avalanche Hazard Assessment. Prepared for CBJ. Tetra Tech File: 704-ENG.EARC03168-02A. April 27, 2022.

Tetra Tech. (2022d). Technical Memo #4. Guide to Avalanche-Landslide Hazard Designations, Downtown Juneau Landslide and Avalanche Hazard Assessment. Prepared for CBJ. Tetra Tech File: 704-ENG.EARC03168-02A. April 27, 2022.

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GEOTECHNICAL

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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.

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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.