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BGC Project Memorandum

To:	**Town of Canmore**	**Doc. No.:**	**TC13-008**
Attention:	**Andy Esarte, P.Eng**	**cc:**	**Blair Birch, P.Eng.**
From:	**Matthias Jakob**	**Date:**	**December 2, 2013**
Subject:	**X, Y, and Z Creeks, Forensic Analysis – FINAL**		
Project No.:	**1261-001**		

1.0 INTRODUCTION

The southwestern Alberta mountain front was affected by a high intensity/duration rainstorm between June 19 and 21, 2013. Direct runoff coupled with meltwater released from rain-on-snow caused sudden and prolonged high flows in the Bow, High, and Ghost Rivers and their tributaries originating in the Rocky Mountains. These flows resulted in high rates and volumes of sediment transport, bank erosion and avulsions on alluvial fans.

Almost all of the steep gradient tributaries to Bow River within the municipal boundary of the Town of Canmore were affected by the combined storm and snowmelt runoff, including X, Y, and Z Creeks, the focus of this memorandum. The Town of Canmore has requested that BGC Engineering Inc. (BGC) conduct a forensic review and preliminary hazard assessment of “X”, “Y”, and “Z” Creeks (all unofficial names), including documentation of damage incurred as a result of the June 2013 event. A meteorological analysis of the June 2013 storm is not provided here-in, but is provided under separate cover (BGC, 2013).

1.1. Scope of Work

BCG is retained by the Town of Canmore under the terms of a Master Consulting Agreement dated July 15, 2013 (the Contract). The BGC scope of work for X, Y, and Z Creeks includes the following tasks:

1. Visual inspection of the watershed and fan by helicopter and a limited foot traverse of some fan sections and creek channel.
2. Location, documentation and categorization of sites that suffered some form of damage during the June 2013 event.

3. Conduct a preliminary debris flow frequency analysis using historical air photographs.
4. Provide conceptual short and long-term risk reduction options against property damage and/or loss of life from future debris flows.

This memorandum summarizes the results from the four tasks listed above.

The observations reported here are assumed to be factual, and it is on this basis that preliminary recommendations on conceptual mitigation measures are provided herein. However, it must be understood by the Town of Canmore that further information gathering and assessment are required and that the recommendations provided herein may be modified on the basis of new information through the remainder of 2013 and 2014.

1.2. Terminology

Steep mountain creeks are typically subject to a spectrum of mass movement processes that range from clear water floods to debris floods to debris flows in order of increasing sediment concentration. There is a continuum between these processes in space and time with floods transitioning into debris floods and eventually debris flows through progressive sediment entrainment. Conversely dilution of a debris flow through partial sediment deposition and tributary injection of water can lead to a transition towards debris floods and eventually floods.

Debris flows typically require a channel gradient in excess of some 30% for transport over significant distances and have volumetric sediment concentrations typically in excess of 50-60%. The distinction between floods, debris floods and debris flows is important, as they differ in flow mechanics and potential consequences.

A debris flood can be defined as: “a very rapid surging flow of water heavily charged with debris in a steep channel” (Hungr et al., 2001). In North America, the term debris flood is not widely accepted and has been challenged, especially by researchers from the USGS, who prefer to use the term hyperconcentrated flow because it can be defined on the basis of sediment concentration (Pierson, 2005). Pierson defines a hyperconcentrated flow as “a type of two-phase, non-Newtonian flow of sediment and water that operates between normal streamflow (water flow) and debris flow (or mudflow)”. Transitions from water flow to debris flood / hyperconcentrated flow and vice versa occur at minimum volumetric sediment concentrations of 3 to 10%, but this range depends on the overall grain size distribution and the ability to acquire yield strength[1]. Debris floods typically occur on creeks with channel gradients between 3 and 30%.

[1] The yield strength is the internal resistance of the sediment mixture to shear stress deformation; it is the result of friction between grains and cohesion (Pierson, 2005).

It appears at this time that the June 2013 event that impacted X, Y, Z Creeks is best described as overland flow (flooding) by the time it reached urban development. Given that there is a continuum between these processes and since no one measured sediment concentration during the flow, this division is somewhat arbitrary. The gradients along the mainstem channels of X, Y, Z Creeks are certainly steep enough to convey debris flows and future larger events may reach the development as debris flows.

X, Y, Z Creeks have developed a series of interfingering composite fans since deglaciation of the area in the order of 10,000 years ago (Figure 1-1). An alluvial fan is a fan shaped deposit of sediment crossed and built up by streams where they flow from a steep mountain channel onto the dramatically reduced gradient of a valley floor, in this case the kame terraces flanking the Bow River. This location contrasts, for example, the Cougar Creek or Three Sisters Creek fans that interfinger with the Bow River floodplain deposits. Exact process attribution to fan formation is often difficult to achieve since multiple processes (rock fall, debris flows and debris floods) may have contributed to its evolution. In this case, the term “composite fan” is more appropriate. Steeper accumulations of debris as found below steep bedrock gullies are referred to as colluvial cones and are largely produced by rockfall.

Streamflows and associated transported sediment passes through a single point source at the apex of the fan. As the stream loses confinement and the channel gradient decreases, it deposits coarse-grained material. This aggradation reduces the capacity of the channel and forces it to change direction, thereby gradually building up a shallow conical fan shape. Over time, the creek moves to occupy many positions on the fan surface.

In general, the grain size of fan materials diminishes downstream with the distal fan portions often characterized by small sandy gravels or coarse to medium sands where they interfinger with floodplain deposits. However, this downstream fining is not continuous because principal fan channels can convey larger grain sizes even to the more distal fan portions.

Figure 1-1. Google Earth satellite image of fan complex of X, Y and Z Creeks above the Grassi Peaks subdivision. The fan boundaries are approximate and require field verification.

2.0 WORK UNDERTAKEN TO DATE

BGC visited X, Y, Z Creeks on July 23 and July 25, 2013 approximately one month after the debris flood event. A helicopter overflight of the watersheds was conducted on July 23, while sections of the fan were traversed on July 25.

BGC personnel present during both site visits included Dr. Matthias Jakob, Ph.D., P.Geo., and Hamish Weatherly, M.Sc., P.Geo. Soe Moe Kyaw Win, Ph.D., P.Eng., P.Geol., of BGC and Andy Esarte, P.Eng., and Blair Birch, P.Eng., engineers with the Town of Canmore, were also present on the helicopter flight.

3.0 PHYSICAL SETTING

X, Y, and Z Creeks rise from their colluvial fans south of the Grassi Peaks subdivision from an elevation of approximately 1400 m to a peak elevation of 2682 m at Mount Lawrence Grassi. Drawing 1 shows the watershed and fan boundaries for the three creeks.

3.1. Watershed

The watersheds of X, Y, Z Creeks are characterized by limited sediment sources which is due partially due to relative low rates of weathering and rock fall production and partially due to the fact that frequent snow avalanches likely transport lose debris to lower elevations (Photo 3-1 and Photo 3-2). This supply limitation reduces the possible amount of debris that can be entrained in debris flows unless debris is derived from deep fan scour. Deep fan scour has been observed in some cases on creeks in the Canmore area, but it is impossible to predict its likelihood and location.

Photo 3-1. Overview of X Creek watershed showing a dendritic channel network characterized by a high frequency of snow avalanches that will likely displace much of the loose debris to lower watershed elevations. This watershed has a high runoff coefficient and will thus convey stormwater rapidly into the lower channel system where it may evolve into a debris flow. BGC photograph of July 23, 2013.

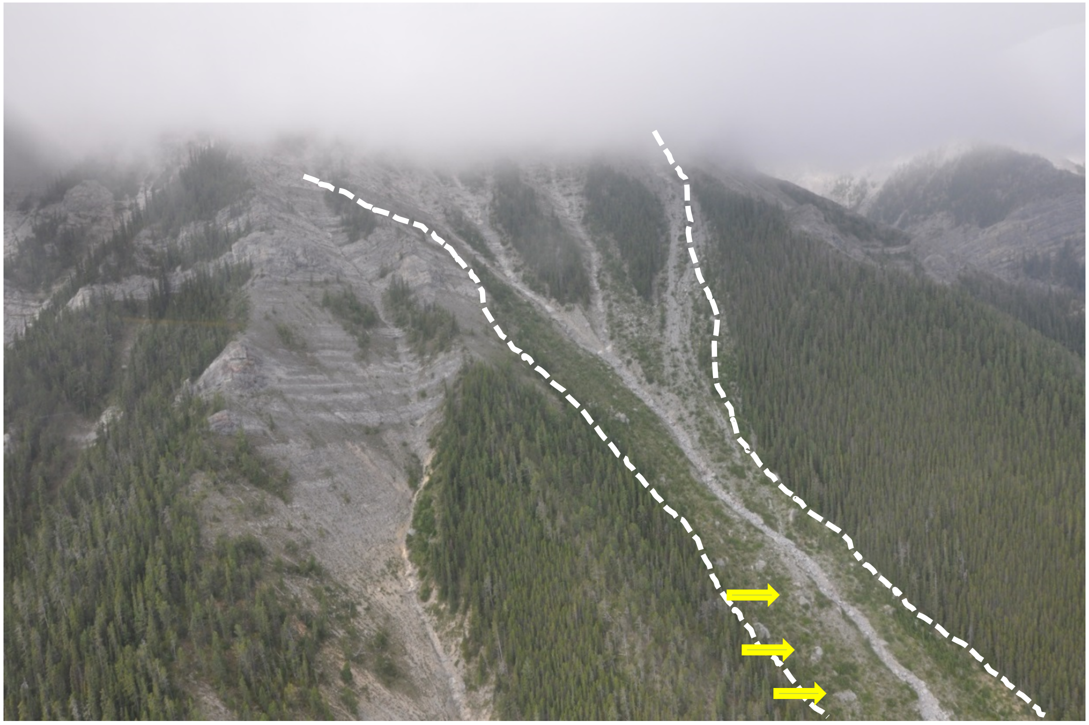

Photo 3-2. Aerial view of Y Creek showing a well pronounced avalanche path (delineated in white dashed lines) and several very large rock fall boulders (arrows). This channel has significantly more debris storage than X Creek and could thus produce larger debris flows. BGC photograph of July 23, 2013.

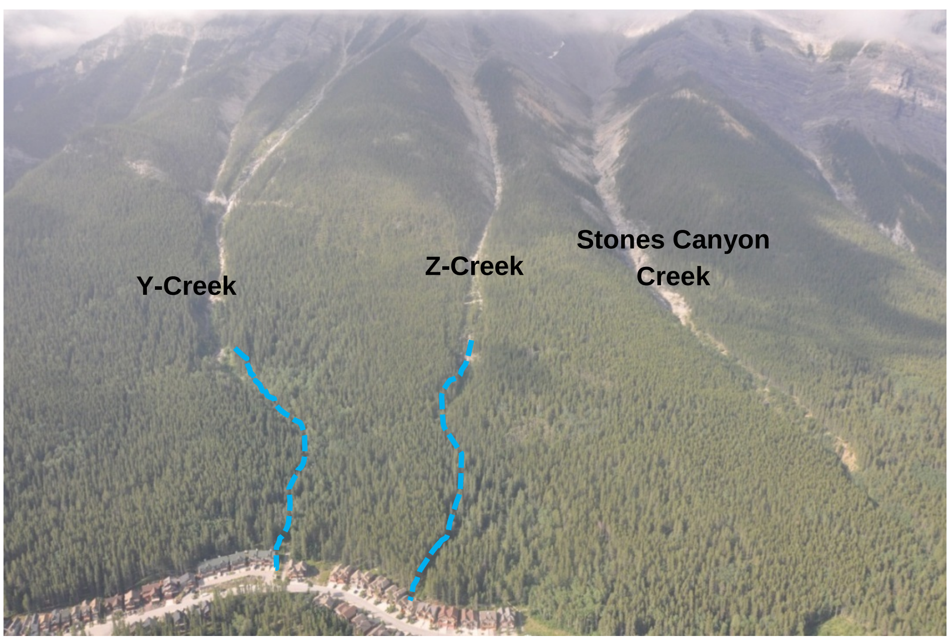

Photo 3-3. Overview of Y and Z Creeks upslope of the Peaks of Grassi subdivision, which is located on the distal fan. The creek outlines are approximate. BGC photograph of July 23, 2013.

X, Y and Z Creeks reach their fan apex between approximately 1500 and 1600 m from where they spread into their respective fans. Given their close proximity, the fan areas of Y and Z Creeks have merged (Photo 3-3). It is unclear at this point if channel avulsions could occur in the upper fan reaches of X, Y and Z Creeks which could significantly increase the amount of available water in any of these creeks leading to more severe flooding and scour in their downstream channel reaches. This potential should be investigated as part of a more detailed hazard investigation.

The watershed characteristics are summarized in Table 3-1 below.

Table 3-1. Watershed Characteristics of X, Y, and Z Creeks

Characteristic	X-Creek	Y-Creek	Z-Creek
Watershed area[1] (km^2)	2.65	0.45	0.25
Fan area (ha)	24	8.4	6.0
Maximum elevation (m)	2650	2510	2430
Minimum elevation[2] (m)	1535	1530	1500
Mean elevation (m)	2115	1930	1820
Average gradient mainstem (%)	32	54	55
Average gradient on fan (%)	18	24	25

1 As measured above the fan apex.

2 As measured at the fan apex.

All three of the creeks are prone to debris flow activity, as partially evidenced by their average channel gradients above the fan apex, which exceed 30% in all cases and the fans are sufficiently steep to sustain transport for larger events.

3.2. Fan Area

The fan areas of the three creeks are shown on two separate drawings. Drawing 2 is a shaded, bare earth Digital Elevation Model (DEM) of the fans and surrounding terrain, while Drawing 3 is an orthophoto of the area with the DEM contours overlain. The DEM and orthophoto were generated from a LiDAR survey conducted by LiDAR Services International Inc. (LSI) on June 28, 2013. LSI processed the LiDAR data and provided BGC with a 1 m x 1 m post spacing file, which was then used to generate the hillshade DEM and contours shown on Drawings 2 and 3. The fan area delineated on these drawings has been interpreted by BGC based on the LiDAR data. The fan boundaries as drawn are approximate and delineate the interpreted landform. The boundaries should not be construed as a hazard map, nor do they show the maximum spatial extent of potential flooding. Future landscape alterations, as well as additional assessments and major future debris flows or floods (and their associated sediment deposition and erosion), may change the fan boundaries in some areas.

The distal fan margins of Y Creek and Z Creek are currently mapped as encroaching on existing development along Wilson Way: four buildings on Y Creek and 20 buildings on Z Creek. However, it should be stressed that the fan margins end on ice marginal (kame) terrace features and, therefore, it is very difficult to delineate the fan boundaries precisely based on topographic information alone. The fan aggradation processes also mask the dominant channel which can easily shift during or immediately following debris flow events. When reaching the Peaks of Grassi subdivision, flows are believed to be very thin (less than 30 cm) and largely unchannelized. Photo 3-4 is an example of a thin debris flow deposit on X Creek associated with the June 2013 event.

Photo 3-4. Recent (June 19-21, 2013) debris-flow event on X Creek. Flows on Y and Z Creek are believed to be similar in appearance by the time they reach the Peaks of Grassi development. BGC photograph of July 25, 2013.

4.0 SITE VISIT

BGC traversed the entire mountain slope upstream of the development from east to west and then returned along Wilson Way to observe drainage conditions along the road.

As illustrated by Photo 3-4, a debris flow did occur on X Creek during the June 19-21, 2013 period. Photo 4-1 is an aerial view of the watershed, on which the debris-flow path is evident. Fortunately development on the fan of X Creek is limited and BGC is not aware of any damage incurred.

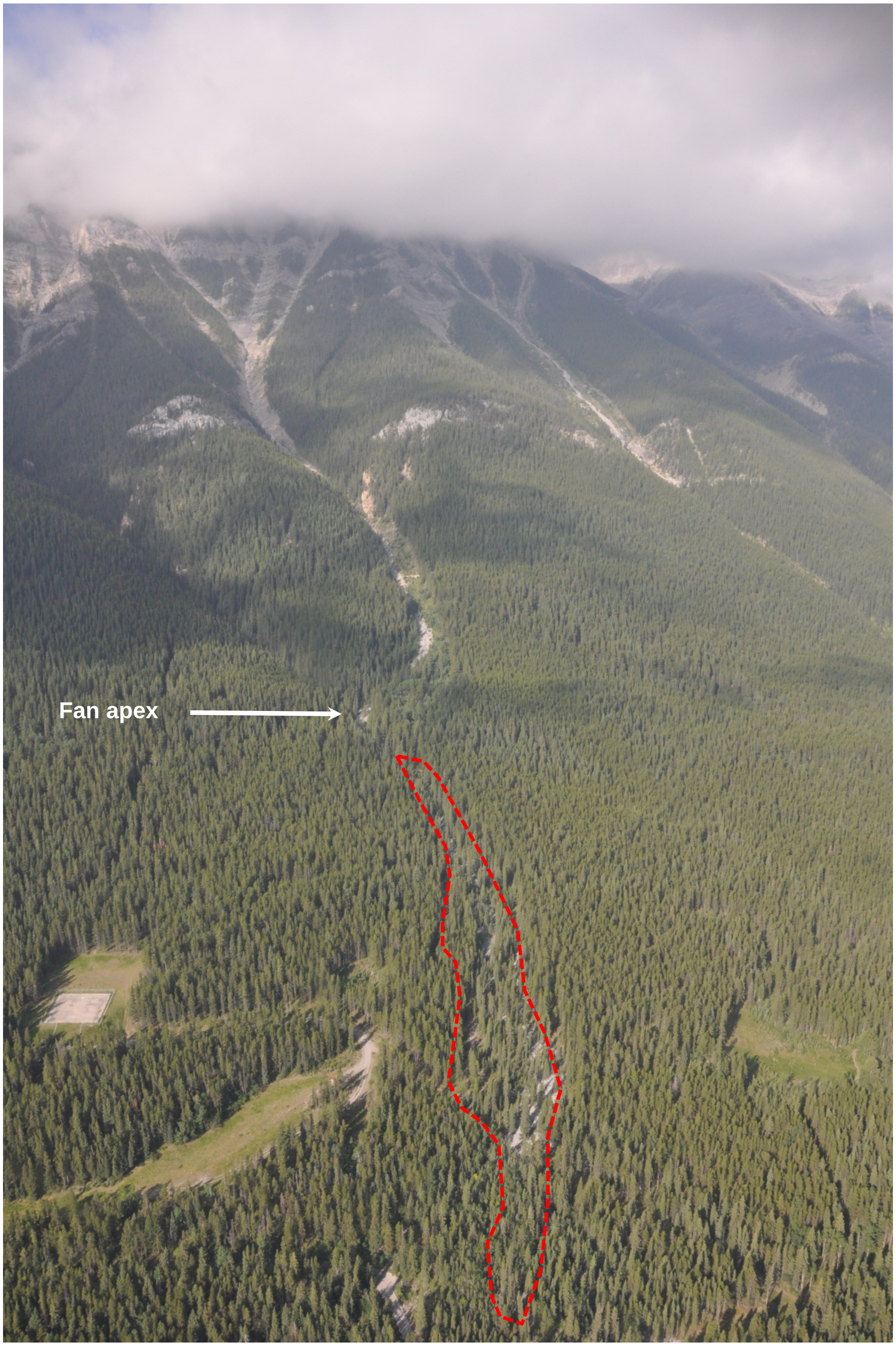

Photo 4-1. Aerial view looking south of the X Creek watershed. The approximate depositional zone of the June 2013 debris flow is delineated by the red dashed line. BGC photograph of July 23, 2013.

It is currently unknown whether a debris flow occurred on the upper fan reaches of Y Creek during the June 19-21, 2013 storm. However, overland flooding has occurred in the past. The original subdivision design included wooden drainage diversion structures and riprapped channels to manage flash flood flows and divert them safely into existing storm water management infrastructure. The approximate extents of these structures are delineated on Drawing 4.

On July 13, 2012, a heavy rainstorm in the watershed resulted in overland flooding to the usually dry stream channels above Wilson Way (Town of Canmore, 2012). The longest diversion structure shown on Drawing 4 was not long enough to capture all of the flow, however, and this resulted in the flooding of several yards. Residents worked to direct the flows between homes to minimize damage to the structures and prevent basement flooding. Because of the volume of water and steep grades, a large quantity of landscape material was washed from the yards and onto the street where it was carried to downstream manholes. The manholes plugged, resulting in flooding of the street. Following this event, the existing lined and riprapped channel that is diverted by wooden posts and beams was extended by about 40 m to protect an additional five homes (Photo 4-2 and Photo 4-3).

Photo 4-2. Lined and riprapped interception channel on Y Creek above Wilson Way. The riprap and liner were placed following the July 2012 storm. BGC photograph of July 25, 2013.

Additional wooden deflection barriers have been constructed at Y and Z Creeks. At the two locations shown on Drawing 4, short wooden barriers about 1 m high have been constructed in a V-shaped pattern. The walls are about 25 to 30 m in length and the intent is to convey overland flow into a shallow, riprap-lined channel about 2 m wide (Photo 4-4). The riprapped channels are about 50 m to 60 m in length and discharge into grated, drop culverts underneath Wilson Way (Photo 4-5). Both walls are located where one might expect overland flows from Y Creek and Z Creek to discharge (based on aerial images); however, BGC did not observe an incised or identifiable channel upslope of either of the V-shaped wooden walls. There are also no easily identifiable channels observed on the LiDAR imagery (Drawing 2) for these two creeks.

Photo 4-3. Photograph along Wilson Way looking upstream. One lot was left unoccupied to allow water flow in the riprapped channel which then enters a culvert below Wilson Way. BGC photograph of July 25, 2013.

Photo 4-4. V-shaped, deflection wall installed upstream of development on Wilson Way. This structure is located along Y Creek, although no identifiable channel was observed upslope of the wall. BGC photograph of July 25, 2013.

Photo 4-5. Upstream view of riprapped channel installed downstream of the V-shaped wooden wall shown on Photo 4-4. BGC photograph of July 25, 2013.

5.0 FREQUENCY ANALYSIS

As an initial assessment of debris-flow frequency, BGC reviewed available historic aerial photographs. Aerial photos reviewed by BGC are summarized in Table 5-1 and a chronosequence of air photographs from 1947 to 2013 is shown in Drawing 5[2].

Table 5-1. X,Y,Z Creeks Historic Aerial Photographs

Year	Roll	Photo #	Scale	Date
1947	A10908 A11101	110 008	1:40,000	May 11 September 23
1950	AS 167 5101/02	14	1:40,000	September 23
1962	AS 830	50, 51	1:31,680	September 18
1972	AS 1185 Line 67	4	1:21,120	July 8
1984	AS 3085	71, 72	1:20,000	August 22
1997	AS 4824	60, 61	1:15,000	July 19
2008	AS 5450	239	1:30,000	August 18

The air photo review indicates a general lack of obvious debris flow activity on Y and Z Creeks between 1947 and 2013. A swath of a lighter shade of vegetation is apparent on the 1947, 1950 and 1962 air photos on the west edge of both fans (Drawing 5). This vegetation is most obvious on the 1962 air photographs and may represent an older debris flow path that was re-vegetated by deciduous trees. The debris flow path of the 2013 event on X Creek is obvious on the orthophoto (Drawing 5) and the older air photos indicate that debris flows in the last century have also followed this alignment.

These observations support the supposition that small debris flows with decadal frequency occur on X, Y, Z creeks with magnitudes in the hundreds and perhaps low thousand cubic meters. A better specification of frequencies and magnitudes with more extensive records could be achieved through a dendrochronologic study.

6.0 CONCEPTUAL MITIGATION OPTIONS AND RECOMMENDATIONS FOR FUTURE STUDY

Given the lack of damage following the 2013 events, BGC does not propose any short-term recommendations for X, Y and Z Creeks at this time. This result informs the observation that these three creeks appear to have a significantly lower hazard potential than creeks to the

[2] The air photo chronosequence shows orthophotos for the different years of historic air photographs, although there is a moderate degree of error in the spatial positioning. A high degree of accuracy was not considered necessary for this exercise.

west or east that have larger watershed areas, ample debris supply sources and higher potential to produce larger events. Nonetheless the risk to the Grassi Subdivision is not zero.

Long-term mitigation measures will strongly depend on future development plans, although BGC understands through discussions with the Town that there are currently no development plans upslope of Wilson Way or further to the east on the fan of X Creek.

However, as mapped, the distal fan margins of Y and Z Creek do encroach on existing housing. The present study aimed to determine damages of the June 2013 hydroclimatic event and provide some initial commentary on hazard analysis. It does not replace more detailed investigations to support the development of detailed hazard maps and specific mitigation measures for low frequency events. Therefore, BGC recommends that Y and Z Creek channels be traversed individually at least to the respective fan apexes and old debris flow deposits mapped via a GPS unit. Following this traverse, a limited number of shallow (2 m) test trenches should be excavated along existing trails (to avoid excessive ground disturbance) immediately upstream of the existing development to determine if larger (thicker) and thus more destructive flows have occurred in the past and can be identified as the surface units. Should such flows be identified during test trenching, the Town may contemplate a detailed hazard and risk assessment that would include more rigorous test trenching, dendrochronology and numerical debris flow modelling. Field checking of potential drainage paths is also recommended as such channels may approach the resolution of the LiDAR imagery. There may be benefit in installing additional structures such as identified on Drawing 4.

As with other creeks in the Canmore area, the present hazard may change significantly in the case of stand-replacing wildfires or beetle infestation. Wildfires and extensive beetle infestations and associated tree mortality could lead to recruitment of significant sediment volumes and thus larger debris flows as have been experienced in the historic past. Should large wildfires occur in the X-Y-Z watersheds, it is recommended that the hazard be re-assessed.

7.0 CLOSURE

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Yours sincerely,

BGC ENGINEERING INC.
per:

Matthias Jakob, Ph.D., P.Geo.
Senior Geoscientist

Reviewed by Hamish Weatherly, M.Sc., P.Geo.

MJ/HW

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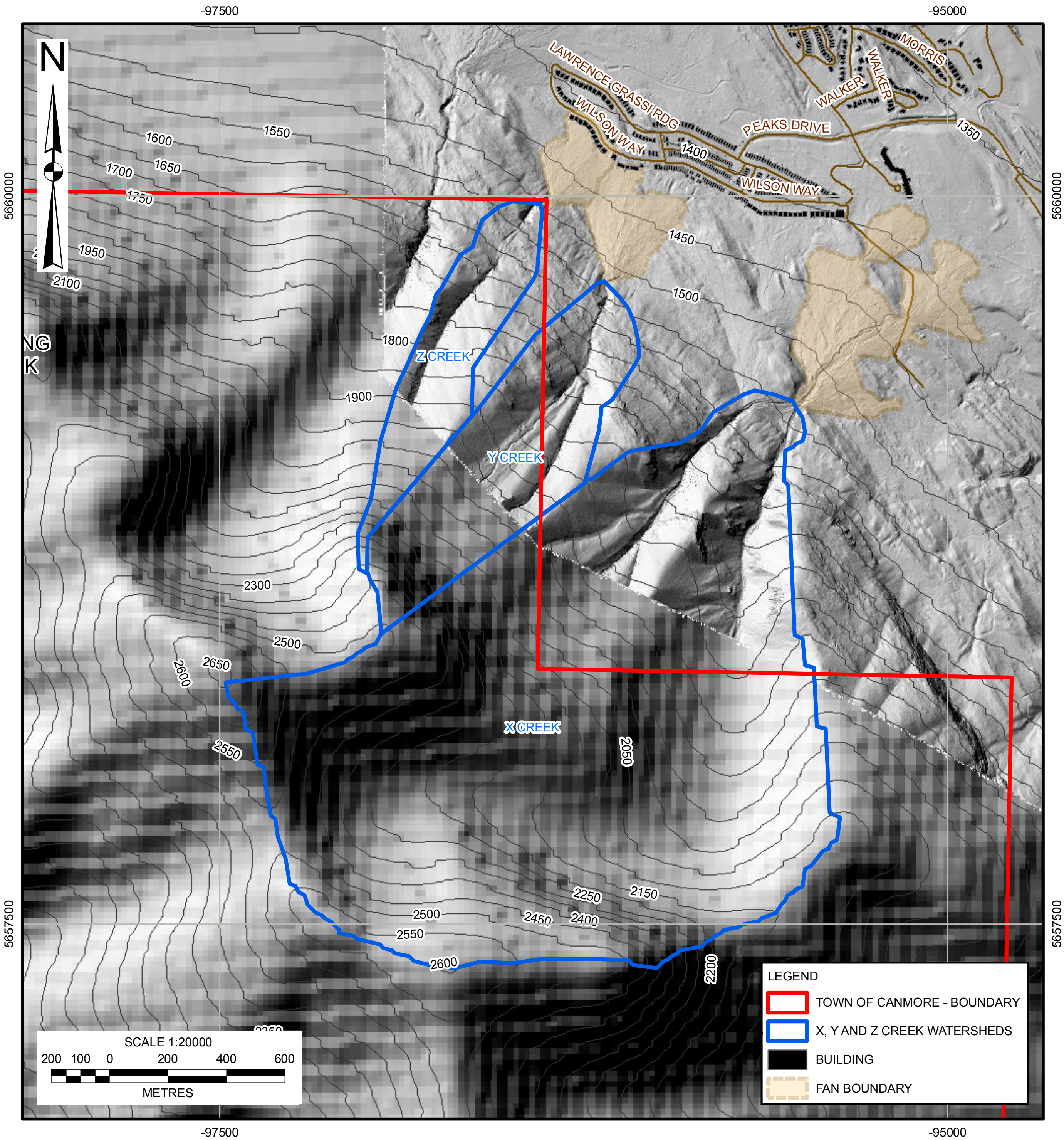
FIGURES



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PROJECT:
X, Y, Z CREEKS, FORENSIC ANALYSIS

TITLE:
X,Y,Z CREEKS
WATERSHEDS

CLIENT: Town of CANMORE

PROJECT No.:	DWG No.:	REV.:
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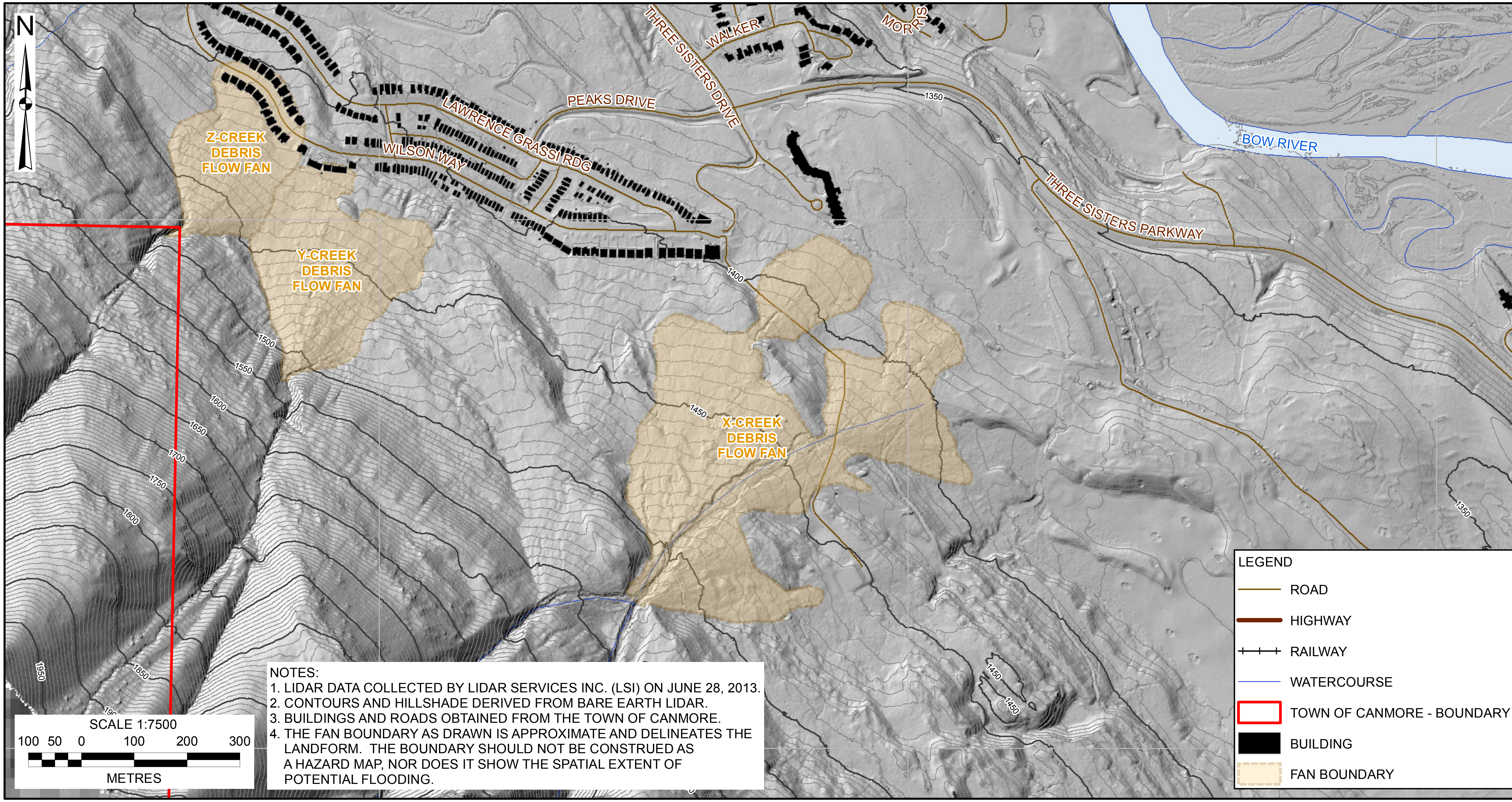

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CLIENT: Town of CANMORE

PROJECT: X, Y, Z CREEKS, FORENSIC ANALYSIS

TITLE: X,Y,Z CREEKS HILLSHADE

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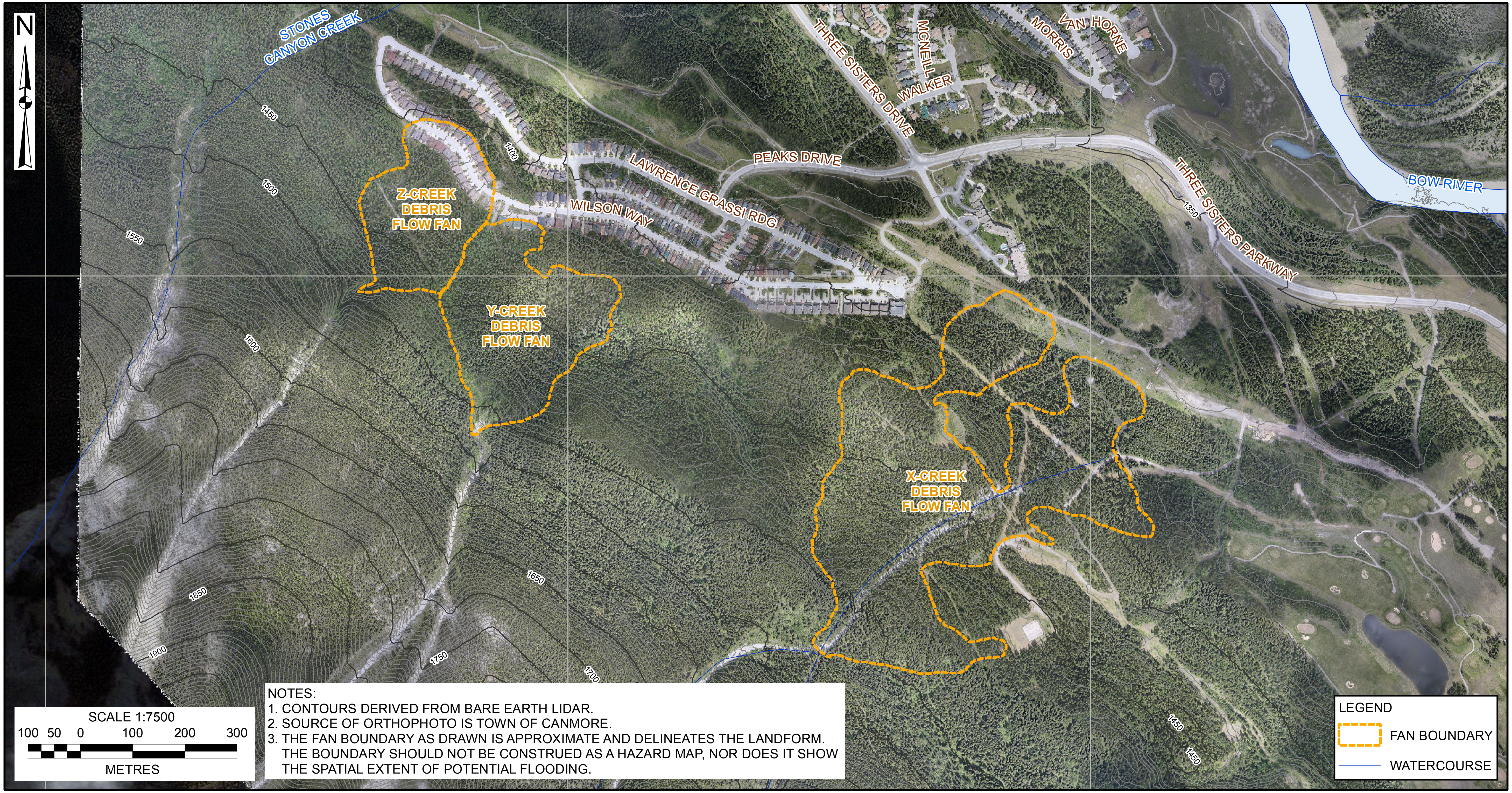

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PROJECT:
X, Y, Z CREEKS, FORENSIC ANALYSIS

TITLE:
X, Y, Z CREEK FANS
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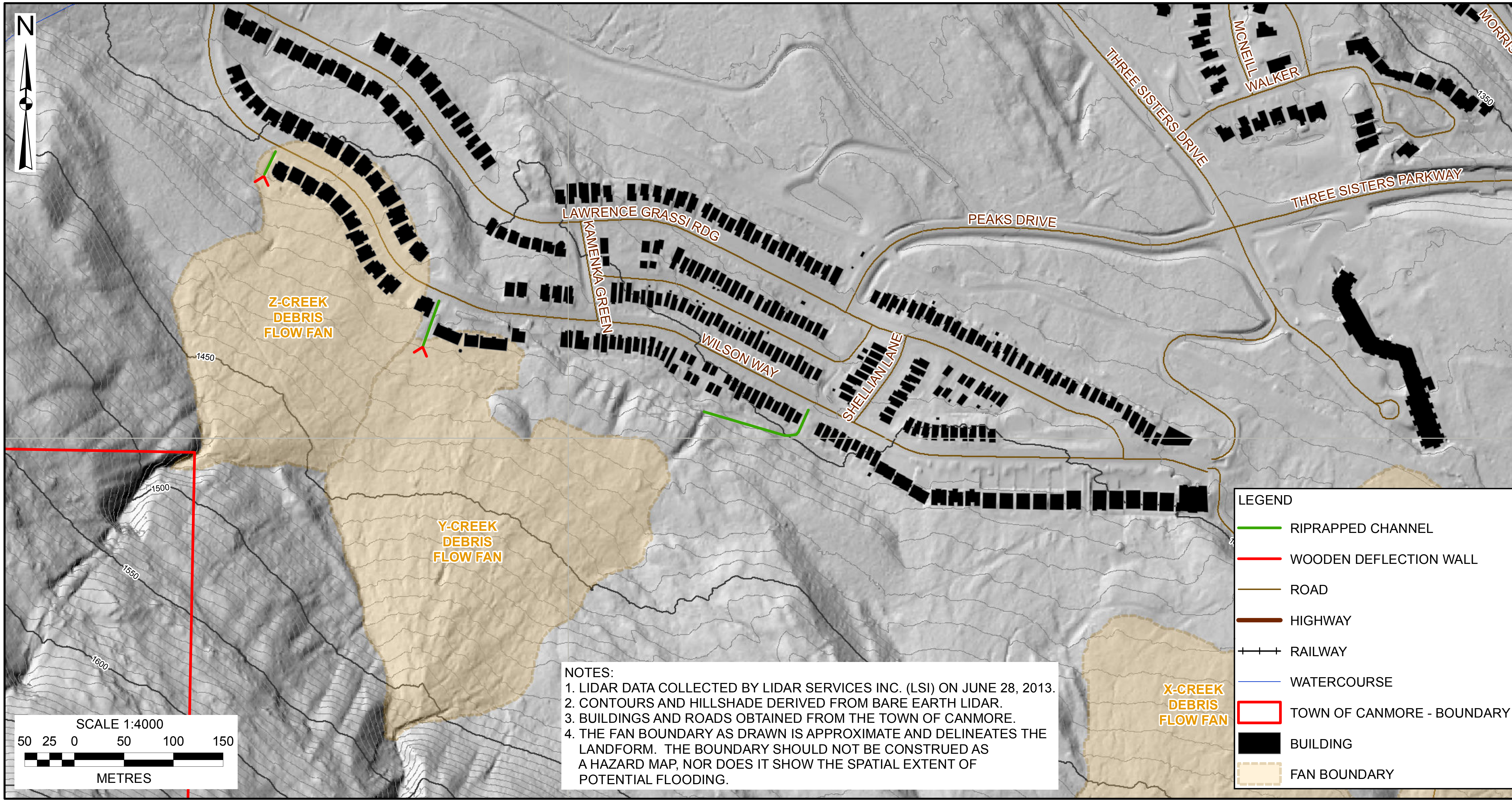

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CLIENT: Town of CANMORE

PROJECT: X, Y, Z CREEKS, FORENSIC ANALYSIS

TITLE: X,Y,Z CREEKS EXISTING DRAINAGE STRUCTURES

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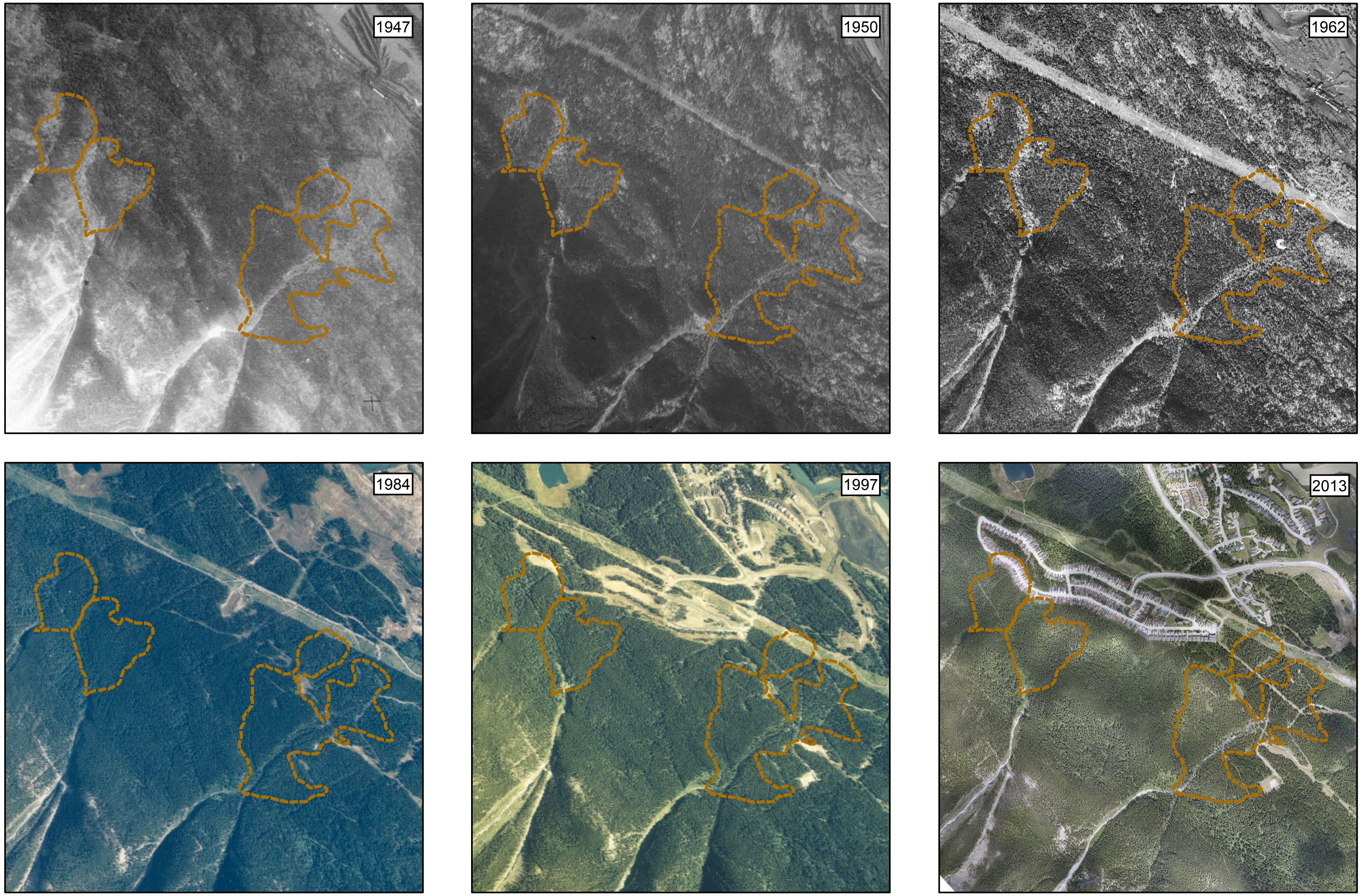

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CLIENT: Town of CANMORE

PROJECT: X, Y, Z CREEKS, FORENSIC ANALYSIS

TITLE: X, Y, Z CREEKS HISTORICAL AIR PHOTO COMPARISON

PROJECT No.:	DWG No.:	REV.:
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