SMITH CREEK ASP

Smith Creek ASP - Conceptual Mitigation Design

FINAL Rev. 2
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Project No.: 1531-006

Prepared by BGC Engineering Inc. for:
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TABLE OF REVISIONS

ISSUE	DATE	REMARKS
DRAFT Rev. A	September 4, 2020	Original issue
DRAFT Rev. B	September 9, 2020	Updated based on QPD comments
FINAL Rev. 0	October 30, 2020	Updated based on ToC comments and findings of BGC Hazard and Risk Assessment
FINAL Rev. 1	December 15, 2020	Updated based on internal review and ToC comments on Smith Creek ASP Risk Assessment and Three Sisters Preliminary Mitigation Design
FINAL Rev. 2	January 4, 2021	Updated based on ToC comments dated Dec 23, 2020

LIMITATIONS

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EXECUTIVE SUMMARY

Three Sisters Mountain Village Properties Ltd. (TSMV) is planning to develop an area located between Stewart Creek and Pigeon Creek in Canmore, Alberta (Drawing 01). The development plan for the area is presented in the Smith Creek Area Structure Plan (ASP). Some of the Smith Creek ASP is located on, or in the vicinity of the Stewart, Smith, Marsh, Cairnes and Pigeon creek fans. These areas are potentially at risk from debris floods and debris flows (Drawing 02, 03, 04). This report provides the basis and conceptual options for protecting the proposed development from the five creeks: Stewart, Smith, Marsh, Cairnes and Pigeon creeks.

The objective of the proposed mitigation is to reduce debris-flow and debris-flood risk in the proposed development area. The mitigation concepts provided are at a conceptual level, and do not include cost estimation or detailed design drawings.

Three mitigation options were identified for Stewart Creek (Drawing 05):

1) Local protection within the proposed development – Stewart Creek would not be directly managed. Instead, berms or re-grading would be used to limit the risk of flows entering the development proposed by the Smith Creek ASP.

2) Realignment of the creek into the wildlife corridor - Stewart Creek would be permanently diverted away from the development by constructing a diversion structure near the fan apex, and setback berms to route flows down the fan, away from the development proposed by the Smith Creek ASP.

3) Partial diversion of flows that exceed the existing channel capacity - Base flows would continue down the existing channel, but flows in excess of the existing channel capacity would be routed down the wildlife corridor, similar to the realignment option (Option 2).

The concepts for Smith, Marsh and Cairnes creek also use the local protection and diversion strategies (Drawing 06), as follows:

- Smith Creek does not currently have a well-defined channel and needs to be directed around the proposed development; it could either be diverted east to join Marsh Creek, or west to join the Stewart Creek wildlife corridor. A combination of berms and re-grading are recommended in and around the development to reduce risk if flow avulses from the re-aligned channel.
- Marsh Creek is generally well channelized within the development, but local protection berms would protect the development from flows that avulse from the channel.
- Cairnes Creek is likely to avulse into a local paleochannel near the upstream edge of the development; this paleochannel could be blocked with a berm, or infilled. Other mitigation on Cairnes Creek would include local protection berms.

On Pigeon Creek, two small portions of the proposed development are on low ground that could flood during higher return period debris floods. QPD on behalf of TSMV has advised that these areas will either be left undeveloped, or will be re-graded and elevated as part of the development construction to reduce the flood risk (Drawing 06).

On all five creeks, appropriately designed crossings would be required for the proposed extension of Three Sisters Parkway. Depending on the crossing types selected, sediment and woody debris management structures may also be required. Given the limited space on some channels within the development, it may be preferable to locate the sediment and woody debris management structures upstream of the development.

The proposed mitigation options should be further assessed during future, more-detailed municipal approval stages.

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1. INTRODUCTION

Three Sisters Mountain Village Properties Ltd. (TSMV) is planning to develop an area located between Stewart Creek and Pigeon Creek in Canmore, Alberta. Some of the areas to be developed are located on, or in the vicinity of the Stewart, Smith, Marsh, Cairnes and Pigeon creek fans (Drawing 01). The development plan for the area is presented in the Smith Creek Area Structure Plan (ASP). Parts of the proposed development area are potentially at risk from future steep creek hazards including debris flows and debris floods.

Previously, BGC delineated a steep creek hazard exposure area for Smith, Marsh, Cairnes and Pigeon creeks to be used in the planning and permitting process with the Town of Canmore (BGC, June 18, 2019). This hazard exposure area was expanded to include Stewart Creek (BGC, December 15, 2020). QPD has used the hazard exposure area for conceptual planning of the Smith Creek ASP. The current development layout intersects the steep creek hazard exposure area in several locations, and therefore mitigation will be beneficial to reduce economic and life loss risk to the proposed development.

QuantumPlace Developments Ltd. (QPD), as agent for TSMV, retained BGC Engineering Inc. (BGC) to develop conceptual mitigation options to reduce risk caused by steep creek hazards from Stewart, Smith, Marsh, Cairnes and Pigeon creeks at proposed development in the Smith Creek ASP. This report documents conceptual mitigation options. This project is being carried out under BGC's standard terms and conditions, signed by both BGC and QPD on April 30, 2020.

1.1. Scope

BGC provided a proposal to QPD on May 13, 2020 that was accepted by QPD on May 25, 2020 and finalized on May 26, 2020. The proposed scope of work included the following tasks:

- Review previous hazard assessments on Stewart, Smith, Marsh and Cairnes creeks, particularly modelling and hazard mapping to confirm that methods are consistent across all creeks.
- Develop conceptual mitigation to reduce the debris flood- and debris-flow risk for the current Smith Creek ASP concept plan, including considering different options for risk reduction. Conceptual mitigation includes approximate layout and sizing of mitigation elements, but does not include material takeoffs or cost estimation.
- Document the conceptual mitigation analysis in a report with schematic illustrations of mitigation options.

In December 2020, BGC suggested modifying the scope to also include Pigeon Creek; this suggestion was accepted by QPD on behalf of TSMV.

The hazard assessment update and review is documented in BGC's report "Smith Creek ASP – Steep Creek Hazard and Risk Assessment", dated December 15, 2020.

This report refers to parcel areas within the conceptual proposed development layout using the codes shown on Drawings 01 through 06 (i.e. SC 14, SM 11, PO 02 etc.). Conceptual parcel areas were provided to BGC by QPD on September 9, 2020 (pers. comm., Ellie Abootorabi).

2. BACKGROUND

The regional and local watershed geology, geomorphology, and hydrology are described in BGC's previous hazard assessments (BGC, August 31, 2015; December 15, 2020). This section provides a brief summary of previous work completed at Stewart, Smith, Marsh, Cairnes and Pigeon creeks relevant to the conceptual mitigation.

2.1. Previous Work

BGC has previously assessed creek hazards on Stewart Creek for the Town of Canmore (BGC, January 3, 2014). Further hazard and risk assessments have been completed for QPD, on TSMV's behalf, by BGC for various stages of the Stewart Creek development (BGC, July 4, 2017; June 19, 2017).

A hazard assessment for the Smith Creek ASP was completed by BGC in 2015 that included analysis of Stewart, Smith, Marsh, and Cairnes Creeks (BGC, August 31, 2015). A steep creek hazard study area boundary was defined for the Smith Creek ASP in 2019 (BGC, June 18, 2019).

Debris floods and debris flows were numerically modelled, using FLO-2D (FLO-2D Software, 2020), for all the creeks relevant to this study in previous scopes of work. However, there were several limitations to the previous work, as follows:

- Previous numerical modelling for Smith, Marsh and Cairnes Creeks had only included the 1000- to 3000-year return period event, and not lower return periods.
- The peak discharges used for Stewart, Smith, Marsh Cairnes and Pigeon Creeks had not been adjusted to account for climate change, a research subject that has advanced significantly over the past few years.
- A risk assessment had not been completed, which was needed to inform the selection of the design event for conceptual mitigation.

These limitations were addressed in BGC's Smith Creek ASP Hazard and Risk Assessment report, which included a hazard assessment update (December 15, 2020). The hazard assessment update and risk assessment results are summarized below.

2.2. Hazard Assessment Update

The hazard assessment update (BGC, December 15, 2020) included the following tasks and analyses:

- Calculations of climate-change-adjusted peak discharge values for Stewart, Smith, Marsh, Cairnes and Pigeon Creeks.
- Numerical modelling of Stewart Creek debris floods for five return periods, including avulsion scenarios for the upper four return periods.
- Numerical modelling of Smith, Marsh and Cairnes creek afterflows for four return periods, including avulsion scenarios on Cairnes Creek for the upper three return period classes.
- Numerical modelling of Pigeon Creek debris floods for the 1000- to 3000-year return period.

Note that, although Smith, Marsh and Cairnes creeks are prone to debris flows, the debris flows are not expected to reach the Smith Creek ASP development boundary because the proposed development is located beyond the distal margin of the debris flow fan. Therefore, the hazard assessment update and conceptual mitigation design focused on the afterflow phase of the debris flow process, which behaves similarly to a debris flood and is likely to runout farther and interact with the proposed development.

Table 2-1 summarizes the results of the hazard assessment update. Note that the debris volumes listed for Smith, Marsh and Cairnes Creeks correspond with the estimated debris flow volumes. Although this material is expected to deposit on the fans upstream of the development, some portion of the debris could be remobilized by the afterflows. Therefore, these sediment volumes represent an upper bound, rather than an estimate of the likely sediment transport to the proposed development.

Table 2-1. Summary of updated peak discharge (Q) and debris volume estimates (BGC, December 15, 2020).

Return period (years)	Stewart Creek		Smith Creek		Marsh Creek		Cairnes Creek		Pigeon Creek	
	Q (m^3/s)	Debris Volume (m^3)	Q (m^3/s)	Debris Volume (m^3)	Q (m^3/s)	Debris Volume (m^3)	Q (m^3/s)	Debris Volume (m^3)	Q (m^3/s)	Debris Volume (m^3)
10 to 30	23	16,000	5	350	5	450	7	500	Not assessed	
30 to 100	42	21,000	9	1,700	8	2,000	11	2,200		
100 to 300	64	26,000	13	3,000	11	3,600	16	3,800		
300 to 1000	96	31,000	18	4,300	16	5,200	24	5,400		
1000 to 3000	129	35,000	25	5,600	21	6,700	32	7,100	317	131,000

Numerical modelling results of Stewart, Smith, Marsh and Cairnes Creeks for the 300- to 1000-year return period without avulsion scenarios are shown on Drawing 02, while Drawing 03 shows the 300- to 1000-year return period avulsion scenarios. Pigeon Creek modelling results for the 1000- to 3000-year debris flood with culvert blockage and no avulsions are shown on Drawing 04.

The hazard assessment and numerical modelling demonstrated that:

- Peak discharges on all creeks could increase substantially (+30%) in the future (years 2050 to 2100) compared to current values, due to the effects of climate change.
- Deep (> 1 m) and high velocity (>1 m/s) flows are predicted to occur on Stewart, Marsh and Cairnes creeks within designated green space/creek corridors that are immediately adjacent to the proposed development.
- At higher return periods, flows may exceed the channel capacity, resulting in shallow flooding (<0.25 m) within portions of SC 15, SC 13, SM 11, SM 12, SM 10, SM 08, SM 09a, SM 09b, SM 07 and SM 04 (west to east) under unmitigated conditions.
- Deep (>1 m) and high velocity (>1 m/s) flows may affect local areas of SC 13, SM 11, SM12, SM 08 and SM 07 under unmitigated conditions with current pre-development topography.

- Pigeon Creek debris floods could result in 1 to 2 m of flooding on the northwestern corner of SM 04, and on the eastern edge of TL 01 and 02.

2.3. Risk Assessment

A detailed risk assessment was completed for Stewart, Smith, Marsh and Cairnes creeks, based on the hazard assessment update (BGC, December 15, 2020). The risk assessment demonstrated that:

- Group life loss risk is tolerable for all four creeks
- Individual life loss risk is intolerable for Stewart, Smith and Cairnes creeks, and tolerable for Marsh Creek.
    - On Stewart and Cairnes creeks, the areas with intolerable risk are located on the development boundary.
    - On Smith Creek, the areas with intolerable risk are located along inactive channels within the proposed development.
- Mitigation of the 300- to 1000-year return period event would reduce individual risk on all three creeks to tolerable levels.

A risk assessment was not completed for Pigeon Creek, because TSMV intends to re-grade or avoid development in the areas affected by Pigeon Creek.

The results of this risk assessment informed the conceptual design of steep creek mitigation measures, as described in the following sections.

3. CONCEPTUAL MITIGATION CONSIDERATIONS

This section describes the basis, constraints, and assumptions considered as part of the conceptual mitigation development.

3.1. Design Objectives

The design objectives are:

1. Reduce the risk posed by steep creeks to the proposed Smith Creek ASP development.
2. Avoid risk transfer to existing development.
3. Maximize design life and limit maintenance requirements, as possible.

3.2. Hazard Characterization

The mitigation is intended to reduce the likelihood of steep creek processes affecting the development. This includes debris floods at Stewart Creek and Pigeon Creek, and the watery afterflows, which are similar to a debris flood, that continue beyond the Smith, Marsh, and Cairnes Creek fans during debris flows.

Debris floods are floods that mobilize most grains during a high discharge flood, cause extensive bank erosion, and convey large volumes of sediment and large woody debris (Church & Jakob, 2020). The 2013 event on Stewart Creek was a debris flood. This study considers the updated peak discharges that include climate change adjustments and sediment bulking (BGC, December 15, 2020).

Debris flows are very rapid channelized flows of saturated debris in a steep channel that often cause extensive impact and sedimentation damage on fans (Hungr, Leroueil & Picarelli, 2014). While Smith, Marsh, and Cairnes creeks are debris flow-prone, mapped fan extents and modelling in previous reports show that debris-flow runout does not reach the proposed development. Instead, the hazard to the proposed development is overland flows with fine sedimentation (BGC, August 31, 2015). The conceptual mitigation is based on the updated modelling presented in BGC (December 15, 2020).

3.3. Risk Reduction and Design Event

The mitigation design event informs the sizing and layout of the mitigation system. Since Town of Canmore has adopted life loss risk tolerance thresholds (Town of Canmore, 2016), reduction of life loss risk to tolerable levels was a primary consideration for design event selection.

Economic risk reduction, sustainability and resiliency were also considered qualitatively. As a result, design elements such as berms were added to the mitigation system to provide additional risk reduction (e.g. economic risk) beyond the life loss tolerance thresholds.

3.3.1. Stewart, Smith, Marsh and Cairnes Creeks

BGC's Smith Creek ASP Hazard and Risk Assessment (December 15, 2020) was used to inform the selection of the design event for each creek. BGC reviewed the risk posed by each hazard scenario to identify the scenarios that need to be mitigated for the total risk to be reduced to below the risk tolerance threshold. BGC notes that group risk from each creek was tolerable, and therefore the mitigation focused on reducing individual and economic risk.

Figure 3-1 shows the risk posed by events of each return period for Stewart, Smith and Cairnes creeks in the locations where individual risk is considered intolerable. For reference, in the Town of Canmore, the annualized individual life loss risk tolerance threshold is 1:100,000 or 10 micromorts[1] (Town of Canmore, 2016) for people within buildings that are impacted by steep creek hazards. Marsh Creek is not shown because life loss risk is tolerable for all assessed return periods, given the proposed development plan.

In Figure 3-1, the only return period that results in life loss risk that is below 10 micromorts is the 1000- to 3000-year return period event. This suggests that the risk posed by that event is tolerable for proposed development, but the risk from more frequent events (< 1000-year return period) needs to be mitigated. Therefore, the 300- to 1000-year return period event was selected as the design event for conceptual mitigation for Stewart, Smith and Cairnes creeks.

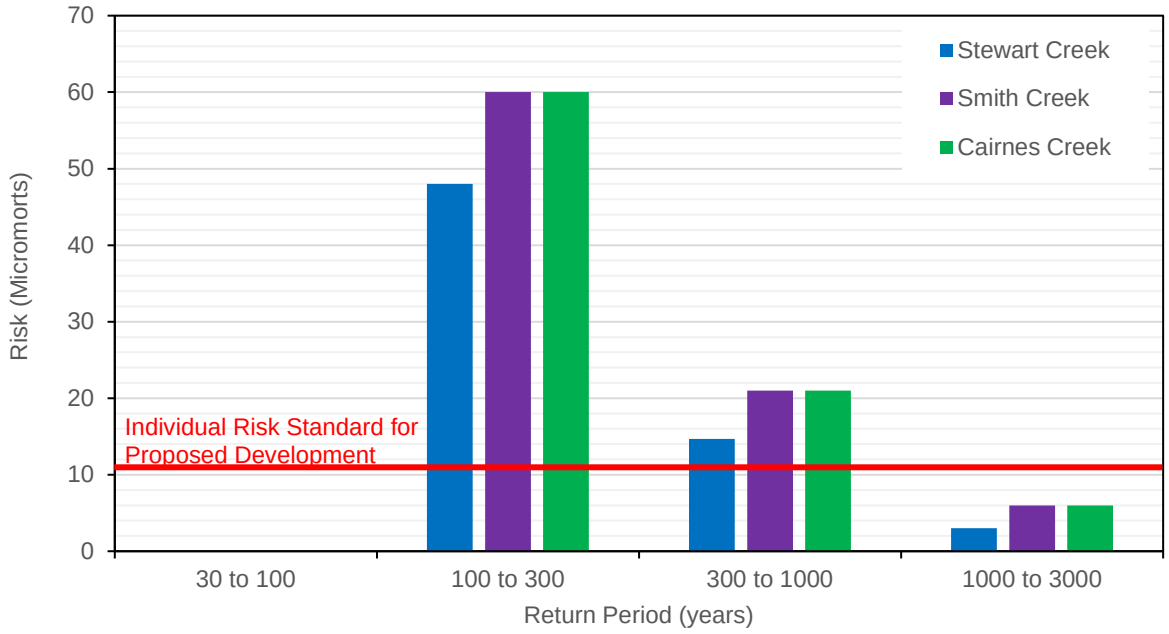

Figure 3-1. Individual risk posed by events of each return period on Stewart, Smith and Cairnes Creeks. Marsh Creek not shown because life loss risk is tolerable for all return periods, given the proposed development plans.

Table 3-1 summarizes the selected design discharges and sediment volumes for each creek. The discharge values correspond with the expected discharge of the 300- to 1000-year return period event on each creek in the year 2100, under changed climate conditions. For Smith, Marsh, and

[1] One micromort is equal to a 1 in 1 million (1E-6) risk of death.

Cairnes creeks, the sediment volume corresponds with the estimated debris volume of a 300- to 1000-year return period debris flow. Although this material is expected to deposit on the fans upstream of the development, some portion of the debris could be remobilized by the afterflows. Therefore, these sediment volumes represent an upper bound, rather than an estimate of the likely sediment transported to the proposed development by the creeks.

Table 3-1. Design event discharges for each creek at the fan apex.

Creek	Design Discharge (m^3/s)	Sediment Volume (m^3)
Stewart	96	31,000
Smith	18	4,300
Marsh	16	5,200
Cairnes	24	5,400

3.3.2. Pigeon Creek

Re-grading of parcels potentially affected by Pigeon Creek flows has been informed by the numerical modelling results for the 1000- to 3000-year return period debris flood. This event was selected so that the hazard that Pigeon Creek poses to the proposed development is reduced for all events up to the maximum assessed magnitude.

A residual hazard assessment will be required once the final development grade has been established, in order to confirm that the final development is not affected by Pigeon Creek flows.

3.4. Design Level

All design options are at a conceptual level. Design options have been developed to a stage that allows the technical merit of the mitigation to be discussed. Details of the design, including final dimensions and layout of design elements and budgetary level cost estimates, are beyond the scope of the conceptual design.

3.5. Maintenance and Post-Event Restoration

Although specific maintenance requirements and restoration plans have not been defined at this stage, all mitigation requires periodic inspection, maintenance, and restoration, particularly following steep creek hazard events. Restoration of the mitigation structures following debris floods or debris flows may include disposal of large woody debris and sediment retained by structures or deposited in channels, and repair to structures and/or erosion protection, as needed. Permanent access roads to the structures would be required to facilitate maintenance.

3.6. Land Ownership, Access and Environment

The conceptual designs assume that all land is available for construction and access to mitigation structures. Potential for challenges related to permitting and land use are considered by presenting options within and outside of the wildlife corridor.

3.7. Geotechnical and Topographic Design Parameters

Geotechnical design parameters are assumed based on terrain interpretation from lidar-derived topography, aerial photographs, and test pits in this region completed as a separate scope of work. Subsurface conditions have not been investigated for the mitigation designs as part of this scope of work.

BGC has conducted a test pitting program at Three Sisters Creek in 2014, which is west of Stewart Creek (BGC, October 31, 2014). As this test pitting is near the study area and in a similar depositional setting, BGC has assumed for the conceptual mitigation development that the surficial soils are similar among the fans. Based on the findings from test pitting at Three Sisters Creek, the conceptual mitigation design assumes that soils on site are granular, including sand, gravel, cobbles, with some boulders, and that the water table is typically below the deepest portion of all proposed channel options. Bedrock and groundwater are assumed to have no bearing on the proposed designs at this stage. BGC has not investigated the extent of underground coal mining adits and shafts and assumes that these workings (if present) will not interact with the proposed designs. QPD on TSMV's behalf has advised BGC that there are very limited mining works in the developable area at Smith Creek ASP. Position coordinates, areas, alignments, and volumes are estimated based on the currently available lidar topography provided by Lidar Services International Inc., flown June 2013. Further site investigations and surveying will be required to complete final designs.

3.8. Risk Transfer

Risk transfer occurs when mitigation measures designed to reduce risk at one site increase risk at another location. Berms that prevent creek avulsion at one location transfer risk downstream along the channel because they increase the peak discharge and sediment volume that remains within the channel. Mitigation options that transfer risk have been identified and transferred risk has been addressed by additional downstream mitigation.

3.9. Elements at Risk

Elements at risk in the vicinity of Stewart, Smith, Marsh, Cairnes and Pigeon creeks include:

- The proposed Smith Creek ASP development
- Stewart Creek Golf and Country Club
- Existing development north of the Stewart Creek Golf and Country Club
- The TransCanada Highway
- Linear infrastructure adjacent to the highway, include ATCO powerlines
- Existing development in Dead Man's Flats within the Municipal District of Bighorn

The conceptual mitigation design focuses on reducing risk to the proposed Smith Creek ASP development. The design avoids or manages risk transfer to existing development, but is not specifically intended to reduce risk to these elements.

4. STEWART CREEK MITIGATION

4.1. Overview and Mitigation Objective

Stewart Creek enters at the fan apex into a confined, forested fan-reach that has been artificially re-directed to the west through the Stewart Creek Golf and Country Club for approximately 1 km. After flowing northwest between several golf course holes, the creek turns sharply to the east, re-enters the historical fan, and flows towards and under the TransCanada Highway to the Bow River. During the June 2013 storm, a debris flood occurred on Stewart Creek that caused damage to the golf course.

Updated numerical modelling completed for conceptual mitigation development (BGC, December 15, 2020; Drawings 02 and 03) shows that flow avulses to the northeast down the historical channel, upstream of the golf course. There are also avulsions out of the channel along the golf course reach and downstream of the golf course into the proposed development area.

The mitigation objective at Stewart Creek is to prevent impact from debris floods to the proposed development including parcels SC 13, SC 14, SC 15 and SM 12.

4.2. Mitigation Options

Three different mitigation options considered at Stewart Creek are described in this section:

1. Local protection of proposed development, using berms or site regrading, and channel armouring of the reach within the development where individual risk is intolerable.
2. Diversion berm near the fan apex, to re-align Stewart Creek down the wildlife corridor, away from proposed development.
3. Overflow channel near the fan apex, where flows in excess of a certain discharge are routed down the wildlife corridor, similar to Option 2.

4.2.1. Option 1 – Local Protection and Channel Armouring

“Local protection” refers to the strategy of constructing mitigation locally at the element at risk. At Stewart Creek, local protection could consist of berms within the development, or regrading of the development to increase the elevation and reduce the risk of flow entry. The berms would be located around SC 13, SC 14, SC 15 and SM 12.

To BGC’s knowledge, the post-development topography for the Smith Creek ASP is not finalized, so this section describes local protection using berms rather than regrading. If local protection is a preferred option, regrading options could be explored further.

Local protection setback berms would be intended to reduce the risk of avulsions impacting the proposed development. This mitigation would allow the creek to continue in its current configuration through the golf course and proposed development. A culvert or underpass would be required to allow flows to pass under Three Sisters Parkway where it crosses Stewart Creek. In addition, avulsed flows could affect the small area of proposed development that overlaps the northeast corner of the Stewart Creek fan (SM 12). The hazard to this area could be managed by constructing a berm or by re-grading and placing fill within the development area to reduce the flood risk.

Conceptual Design

The following describes the conceptual design, which is also shown on Drawing 05:

- Setback berms or re-grading to reduce the risk of avulsion into SC 13, SC 14, SC 15 and SM 12.
    - Possible berm alignments are shown on Drawing 05 and are described from west to east, as follows:
        - One berm around the south and west side of SC 15. This structure is intended to manage high flows within the existing Stewart Creek channel, and would also be designed to direct flows towards PO 03.
        - Four berms within SC 13, as follows: 1) on the west side, to direct flows towards PO 03; 2) and 3) within the parcel, on the north side of the existing Stewart Creek, to manage avulsions; and 4) on the southwest edge of SC 13, to manage flows if Stewart Creek avulses from the fan apex down the wildlife corridor.
        - One berm on the southwest edge of SC 14 to protect development from Stewart Creek flow avulsion in the wildlife corridor.
        - One berm on the east edge of SM 12 to protect development from Stewart Creek flow avulsion in the wildlife corridor.
    - 1.5 m high berms with 2H:1V side slopes and a 2.5 m crest width are proposed. Berm heights were estimated using the maximum flow depth at each avulsion location from the numerical model results, plus 1 m of freeboard as an estimate for conceptual design. These dimensions and locations would need to be refined in later design stages.
    - Berm side slopes facing the creek would be armoured with stone pitching and the outside side slopes vegetated.
    - Depending on the cut/fill balance for the proposed construction, re-grading and infill of the low areas may be preferable to berms, for safety and because berms would occupy significant space within the development. Fill that is placed to avoid flood inundation would be armoured with stone pitching, or possibly riprap, depending on the design discharges, proximity to the creek, and likelihood of future flows.
- Channel upgrades within the development boundary, are as follows:
    - Construction of a grade control structure at an existing knickpoint[2] located within the proposed development. The grade control structure would be designed to protect against erosion and sediment recruitment from the knickpoint.
    - Channel armouring or setback berms to achieve a channel capacity of 12 m^3/s, which is the expected discharge in this reach for the design event
- Culverts or bridges on Three Sisters Parkway and local residential streets would need to be sized to pass the local peak discharge of the 300 to 1000-year return period flow (12 m^3/s).

[2] Over-steepened section of channel, which can be prone to erosion.

  - The crossings would also need to be designed to account for sedimentation and erosion and should include a woody debris and sediment management structure to limit the risk of blockage. It may be preferable to locate the debris management structure at the upstream edge of the development, rather than immediately upstream of the crossing.
  - The crossing at the corner of SC 13 and SC 15 could allow excess discharge to flow into PO 03, through the designated recreation space between these parcels.
- The Three Sisters Parkway road design should consider that Stewart Creek flows that avulse near the fan apex will arrive at the upstream road ditch. The road design needs to pass this flow under or across the road, and not convey it along the road to SC13 or SM12. Flow diversion by the road is not captured by the numerical models, but could be a significant risk transfer mechanism unless it is explicitly considered in the road design. The design options presented here assume that the proposed wildlife underpass will serve a secondary purpose to pass debris floods beneath Three Sisters Parkway.

Advantages and Disadvantages

The primary advantage of this option is allowing the creek to stay in its current configuration while reducing risk to the proposed development. This option is also contained within the development footprint and does not require construction within the provincial park boundary.

Disadvantages of this option include:

- The creek is maintained within a constructed channel, rather than restoring the creek to its historical channel and fan. In the long-term, this may require more maintenance, especially as the creek may naturally avulse down the wildlife corridor in the future.
- Risk to the golf course is not reduced. The 12 m^3/s discharge estimate for the lower channel assumes that flows are not channelized within the golf course, and that substantial sedimentation, avulsion and attenuation occur within the golf course area.
- The design assumes the channel within the community retains its conveyance capacity and is not blocked with sediment, large woody debris, or debris introduced by residents. There is some uncertainty around this assumption, and high probability that flows intersect houses if the channel becomes blocked within the community.

4.2.2. Option 2 - Creek Diversion

A diversion berm upstream of the development and downstream of the fan apex is proposed to re-direct flows down the Stewart Creek fan rather than through the golf course. The realigned creek would flow under proposed wildlife underpasses on Three Sisters Parkway and the TransCanada Highway.

Conceptual Mitigation

The following describes the conceptual design, from upstream to downstream:

- Diversion of the creek near the fan apex, using a combination of excavation and berm construction to create a new preferential flow path.

  - The technically preferable location for the diversion structure is at the existing channel bend, as shown on Drawing 05; however, this alignment is within the provincial park boundary.
  - An alternate location downstream of the provincial park could also be considered, if it is not possible to construct the diversion within the park.
  - The berm geometry would depend on the diversion location selected, but a substantial structure would be required to limit the risk of future avulsion. Numerical modelling suggests that flow depths in the area could be up to 3 m, so a berm height of approximately 4 m would likely be required to provide sufficient freeboard.
  - The upstream side slope of the berm would be armoured with stone pitching and the outside side slope would be vegetated.

- Downstream of the diversion structure, given the wide corridor available for the creek, the main objective would be to control the location where the creek crosses Three Sisters Parkway and the TransCanada Highway.
  - This could be achieved by excavating a seed or starter channel, to guide the creek from the diversion structure to the Three Sisters Parkway underpass, and then to the TransCanada Highway underpass. The starter channel capacity would be determined during detailed design.
  - A combination of diversion berms, setback berms, local re-grading and an appropriately designed road ditch on Three Sisters Parkway could be used to capture and divert flows towards the underpasses. A possible setback berm alignment upstream of Three Sisters Parkway is shown on Drawing 05, and alignments would be refined during detailed design.
  - Otherwise, the channel construction should seek to minimize requirements for long-term maintenance by creating a wide, natural floodplain.
- At Three Sisters Parkway and the TransCanada Highway, the current proposal involves routing the creek through the proposed wildlife underpasses shown on Drawing 05.
  - BGC understands from QPD on TSMV's behalf that the underpasses can be sized to accommodate the creek and wildlife, and that the crossing would be at least 4 m tall and 12 m wide (Federal Highway Administration, 2011).
  - The proposed underpass locations do not align with existing Stewart Creek paleochannels, so setback berms or other flow management structures would be required, as described above. Future design stages should explore whether the underpass locations can be optimized for steep creeks and wildlife.
- Culverts should be installed on Three Sisters Parkway to align with the paleochannel locations.
  - The culverts would be sized to pass local flows that collect within the paleochannels but would not be sized for the full Stewart Creek discharge.
  - Depending on the catchment that reports to each minor culvert, upstream debris management structures may be advisable to avoid culvert blockage.
- A sediment management area upstream of the TransCanada Highway may be needed in the short-term to capture the increased sediment load, while the re-directed channel establishes itself. Sedimentation management would need to be explored in further detail

in later stages of design, depending on what type of work is chosen to establish the new Stewart Creek channel.

Advantages and Disadvantages

The primary advantage of this option is to redirect the flow down the wildlife corridor and away from the proposed development. This option may require less maintenance in the long-term once a channel is established, as the channel would pass through less infrastructure. This mitigation would also reduce risk to the golf course from inundation during high flows.

Disadvantages of this options include:

- Increased berm fill and erosion protection volume required compared to the localized setback berms (Option 1).
- The proposed berm alignment is partially within the provincial park, although it may be possible to select a different berm alignment further downstream.
- Loss of the creek as part of the landscaping features within the golf course.

4.2.3. Option 3 – Overflow Channel

This option combines aspects of Option 1 and Option 2. In this option, an assessment would be completed to identify a target discharge that can be managed by the existing Stewart Creek channel without avulsion or damage. Then, a diversion structure at the fan apex would be constructed such that flows in excess of the target discharge would be routed down the wildlife corridor. The Municipal District of Bighorn No. 8 is in the process of constructing a conceptually similar system on Heart Creek, where flows in excess of 10 m^3/s are diverted away from proposed development (BGC, August 6, 2019).

Conceptual Mitigation

The design elements of Option 3 would be identical to the elements described for Option 2, with the exception of the diversion structure. While the Option 2 diversion structure was intended to divert all of the flow towards the wildlife corridor and inactivate the existing channel, the Option 3 diversion structure would result in conditional diversion. The structure would allow a baseline discharge into the existing channel, and only larger discharges would be diverted towards the wildlife corridor. Option 3 is not shown on Drawing 05, but would be similar to Option 2.

Advantages and Disadvantages

The primary advantage of this option is likely aesthetic, since it would maintain the flows in the existing channel through the golf course and proposed development but would control the life loss risk.

The primary disadvantages of this option are the cost, maintenance and design complexity. The cost of Option 3 would be comparable or greater than the cost of Option 2, but Option 3 would require the maintenance and review of two channels, rather than one. There is also increased uncertainty about the performance of a conditional diversion structure during a debris flood, compared to a channel-blocking structure.

4.3. TransCanada Highway Culvert

Neither of the design concepts include an upgrade of the existing Stewart Creek culvert under the TransCanada Highway, which has a capacity of about 4 m^3/s. The existing culvert did not block in the 2013 event, but may block during higher return period events (greater than ~ 200-year return period), especially under climate change conditions.

For Option 1, if the Stewart Creek culvert gets blocked, overflow to the west would pass through an existing wildlife underpass under the highway. If the overflow went east, it could drain through an additional proposed wildlife underpass. This way, the wildlife underpasses provide a secondary release valve, which limits the risk of ponding and overtopping of the highway.

Option 2 and 3 routes the creek through a proposed wildlife underpass, as shown on Drawing 05. In this case, only local flows from the development area would be routed through the existing Stewart Creek culvert, and it would therefore be less likely to block.

5. SMITH, MARSH, AND CAIRNES CREEKS MITIGATION

5.1. Mitigation Objective

The mitigation objective at Smith, Marsh, and Cairnes creeks is to limit the likelihood of impacts from debris-flow afterflows, debris floods and clearwater floods to the proposed development. Although the Smith, Marsh, and Cairnes watersheds are more typical of debris-flow processes, impacts from afterflows and floods are considered here because debris flows are not expected to reach the proposed development. Based on numerical modelling of 1000 to 3000-year return period debris flows (BGC June 18, 2019) and preliminary field investigations, debris will likely deposit on the upper fans of each creek. However, the afterflows or floods could impact the proposed development, as shown by numerical modelling in BGC (June 18, 2019; December 15, 2020; Drawing 02 and 03).

5.2. Smith Creek Mitigation

The proposed Smith Creek mitigation consists of diverting the creek to provide a clear flow path in the event of higher discharge flows. The following options have been identified, as shown on Drawing 06:

- Option 1: Smith Creek could be diverted west, into the proposed wildlife corridor between SM 11/12 and SC 13/14. This option would involve:
    - Berms and excavation to divert the creek west, either within or downstream of the provincial park.
    - Depending on the channel alignment, berms or re-grading of the upstream development interface, to avoid flow through SM 11. Debris flows that deposit on the fan may fill in the constructed channel, which would cause flow avulsion from the channel.
    - If Stewart Creek is also diverted to the wildlife corridor, Smith Creek would join the new Stewart Creek channel upstream of Three Sisters Parkway. The Stewart Creek channel infrastructure would need to be sized to accommodate the additional discharge.
    - If Stewart Creek is not diverted to the wildlife corridor, Smith Creek would require similar infrastructure as described in Stewart Creek Option 2 to manage the flows.
- Option 2: Smith Creek could be diverted to the east, through the greenspace south of SM 10, to join Marsh Creek. This option would involve:
    - Berms or excavation to divert the creek east, either within or downstream of the provincial park.
    - Depending on the channel alignment, berms or re-grading of the upstream development interface, to avoid flow through SM 11. Debris flows that deposit on the fan may fill in the constructed channel, which would cause flow avulsion from the channel.
    - Addition of an appropriately sized and designed box culvert under Three Sisters Parkway near SM 10
    - Upgrades and channel armouring of the Marsh Creek channel downstream of the confluence to accommodate the additional discharge.

The preferable diversion for Smith Creek may depend on the mitigation selected for Stewart Creek. Overall, Option 1 is likely preferable, because it involves routing flows towards the undeveloped wildlife corridor.

In both cases, the diversions should be as minimal as possible, with the intention of guiding the creek without creating a confined channel or extensive maintenance requirements. The diversions shown on Drawing 06 are approximate and subject to refinement during further stages of design.

5.3. Marsh Creek Mitigation

The Marsh Creek channel is proposed to flow through an open space and recreation area between SM 10 to the west and SM 08, 09a and 09b to the east. Although the life loss risk posed by Marsh Creek is considered tolerable, mitigation works are recommended to avoid avulsion, shallow flooding and erosion of the creek corridor into the development.

Only one mitigation concept has been developed for Marsh Creek, as shown on Drawing 06. Given the wide corridor available, Marsh Creek flows should be left unconfined and natural, with the following exceptions:

- A low berm (<1.5 m) or re-grading to prevent avulsion of the creek into SM 08.
    - The berm should be setback from the creek channel to allow for channel migration, erosion, and sedimentation, and limit maintenance requirements.
- Installation of an appropriately sized and designed culvert system or bridge to convey Marsh Creek under Three Sisters Parkway.
    - The crossing would need to be designed to account for sedimentation and erosion, and should include a woody debris and sediment management structure upstream to limit the risk of blockage. It may be preferable to locate the debris management structure at the upstream edge of the development, rather than immediately upstream of the crossing.
    - The crossing would be sized to accommodate the design event.
- Berms or re-grading upstream of the Three Sisters Parkway culvert, to ensure that flows are directed towards the culvert. The Three Sisters Parkway road design should consider where flows that exceed the culvert capacity will be directed. Ideally these flows would be directed across the road as opposed to along the highway ditch to developed areas.
- Depending on the final site layout and grading, a low berm may also be recommended on the eastern boundary of SM 10. This berm is not shown on Drawing 06.

Note that the existing culvert under the TransCanada highway at a Marsh Creek has a diameter of 1.2 m and a capacity of about 4 m^3/s. The existing culvert did not block in the 2013 event, but the capacity may be exceeded during higher return period events, especially under climate change conditions. If the culvert capacity is exceeded, water may pond upstream of the highway, including against the regraded SM 04.

5.4. Cairnes Creek Mitigation

Cairnes Creek is the most channelized of the three creeks, consisting of an upper and lower fan separated by a channel reach incised up to 17 m into a glacial fluvial terrace. Numerical modelling shows impacts to the development from:

- A shallow avulsion into SM 08 on the upper fan (< 0.25 m flow depths)
- A deeper, higher velocity avulsion (0.5 to 1 m flow depth, 1 to 3 m/s velocity) into a paleochannel on the southwest corner of SM 07
- Shallow flow spreading on the lower fan into SM 04 (< 0.5 m flow depths)

The paleochannel avulsion into SM 07 was shown to result in intolerable life loss risk to people within buildings (BGC, December 15, 2020). Two mitigation concepts have been developed for the SM 07 paleochannel, as follows:

- Option 1: Construction of a berm to block flows from avulsing into the paleochannel in SM 07.
    - Due to the berm location on the boundary of the mapped debris flow fan (Drawing 06), the berm should be designed to withstand potential debris flow impact and sized to accommodate debris flow runup.
    - The upstream side of the berm should be constructed of stone pitching for durability.
    - The berm would be about 20 m long and 3 to 4 m high.
- Option 2: Infill or re-grading of the SM 07 paleochannel during development.
    - Alteration of the topography to remove the paleochannel as a potential flow path for Cairnes Creek.
    - The required infill depth would vary from 2 to 5 m, depend on the location within the paleochannel and the grading plan for the surrounding lots.
    - The upstream side of the infill should be constructed of stone pitching for durability.

Option 2 is preferable for long-term risk reduction, because it does not require maintenance, and does not involve the construction of houses immediately downstream of a potential debris retention structure.

Additional steep creek management at Cairnes Creek could include:

- Low berms (<1.5 m) or re-grading to prevent avulsion of the creek into SM 08.
    - The berms should be setback from the creek channel to limit maintenance requirements.
    - Berm armouring should consist of stone pitching, if armouring is required depending on the berm alignment.
- Installation of an appropriately sized and designed culvert system or bridge to convey Cairnes Creek under Three Sisters Parkway.
    - The crossings would need to be designed to account for sedimentation and erosion, and should include a woody debris and sediment management structure upstream, to limit the risk of blockage. It may be preferable to locate the debris management structure at the upstream edge of the development, rather than immediately upstream of the crossing.

- The crossing would be sized to accommodate the design event
- Three Sisters Parkway should be designed to limit the potential for flow that exceed the culvert capacity from being diverted by the road ditch to developed areas.

Flooding in SM 04 will be managed through re-grading, as described in Section 6 below.

Modifications to the naturally channelized portion of Cairnes Creek within the development are not recommended; structures in this area would require regular maintenance but would not result in appreciable risk reduction.

Note that the existing culvert under the TransCanada highway at a Cairnes Creek has a diameter of 1.2 m and a capacity of about 4 m^3/s. The existing culvert did not block in the 2013 event, but the capacity may be exceeded during higher return period events, especially under climate change conditions. If the culvert capacity is exceeded, water may pond upstream of the highway, including against the regraded SM 04.

6. PIGEON CREEK MITIGATION

6.1. Mitigation Objective

The following areas are potentially subject to flooding from Pigeon Creek debris floods, according to the results of numerical modelling of the 1000- to 3000-year return period debris flood:

- SM 04: up to 2 m of flooding in the lower elevation areas on the northwest corner of the parcel
- TL 02: up to 1.2 m of flooding in a small area on the eastern edge
- TL 01: unknown flow depths in a small area on the eastern edge

The objective of the Pigeon Creek mitigation is to reduce flood risk in these areas, either by increasing the grade in the inundated area, or by sterilizing (not developing) the inundated area.

6.2. Conceptual Mitigation

The conceptual mitigation design for Pigeon Creek is shown on Drawing 06 and summarized below:

- Increase the grade in the lowest areas of SM 04 by at least 3.0 m (2.0 m flooding + 1.0 m freeboard). Regrade the surrounding areas accordingly, to account for drainage both within and around the development. The edges of the fill should be armoured to prevent erosion from Pigeon Creek and Cairnes Creek.
- Increase the grade in the low area of TL 02 by at least 2.2 m (1.2 m flooding + 1.0 m freeboard. The edges of the fill should be armoured with stone pitching to prevent erosion from Pigeon Creek. Alternately, adjust the layout of TL 02 so that development does not occur within the area that may be inundated.
- Adjust the layout of TL 01 so that development does not occur within the area that may be inundated. BGC understands that TSMV may have already completed this change.

In addition, there are two proposed roads which cross Pigeon Creek and provide access to the development. These access points will be managed by installing multiple large capacity culverts or clearspan bridges. The bridge or culvert capacity would be determined in consultation with the Town of Canmore and other stakeholders, and should be designed to manage or allow passage of sediment and large woody debris.

7. CONCLUSIONS AND OPTION COMPARISON

This report provides a steep creek mitigation basis and conceptual mitigation options for Stewart, Smith, Marsh, Cairnes and Pigeon creeks.

On Stewart Creek, Option 2 (creek diversion) may be preferable because it involves restoring the creek to its alluvial fan. In addition, the long-term maintenance costs may be lower, once the new channel is established.

On Smith Creek, diversion towards the Stewart Creek wildlife corridor (Option 1) may be preferable, especially if Stewart Creek is also diverted, and the setback berms and channel infrastructure are already in place. Diversion towards Marsh Creek may increase the risk of avulsion upstream of or within the proposed development, and may be associated with higher maintenance costs.

For the Cairnes Creek paleochannel where individual risk is intolerable, the preferred option will likely depend on the final development grading and layout.

For Marsh and Cairnes creeks, the preferred option is to install crossings at Three Sisters Parkway that are designed to pass the design event and avoid flow diversion if the culvert is blocked or the capacity is exceeded. Berms are proposed at the upstream edge of development to protect development from avulsions and to direct avulsed flows back to the channels that pass through the development.

QPD on behalf of TSMV has advised that the hazard posed by Pigeon Creek will be reduced by regrading portions of SM 04, and by either regrading or not developing portions of TL 02 and TL 01.

The proposed mitigation options should be further assessed during future more detailed municipal approval stages.

8. CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

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Junior Geological Engineer

Reviewed by:

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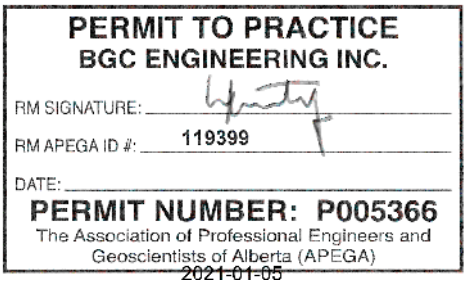
Principal Hydrologist

APEGA Permit to Practice No.: P5366

BCP/HW/mj



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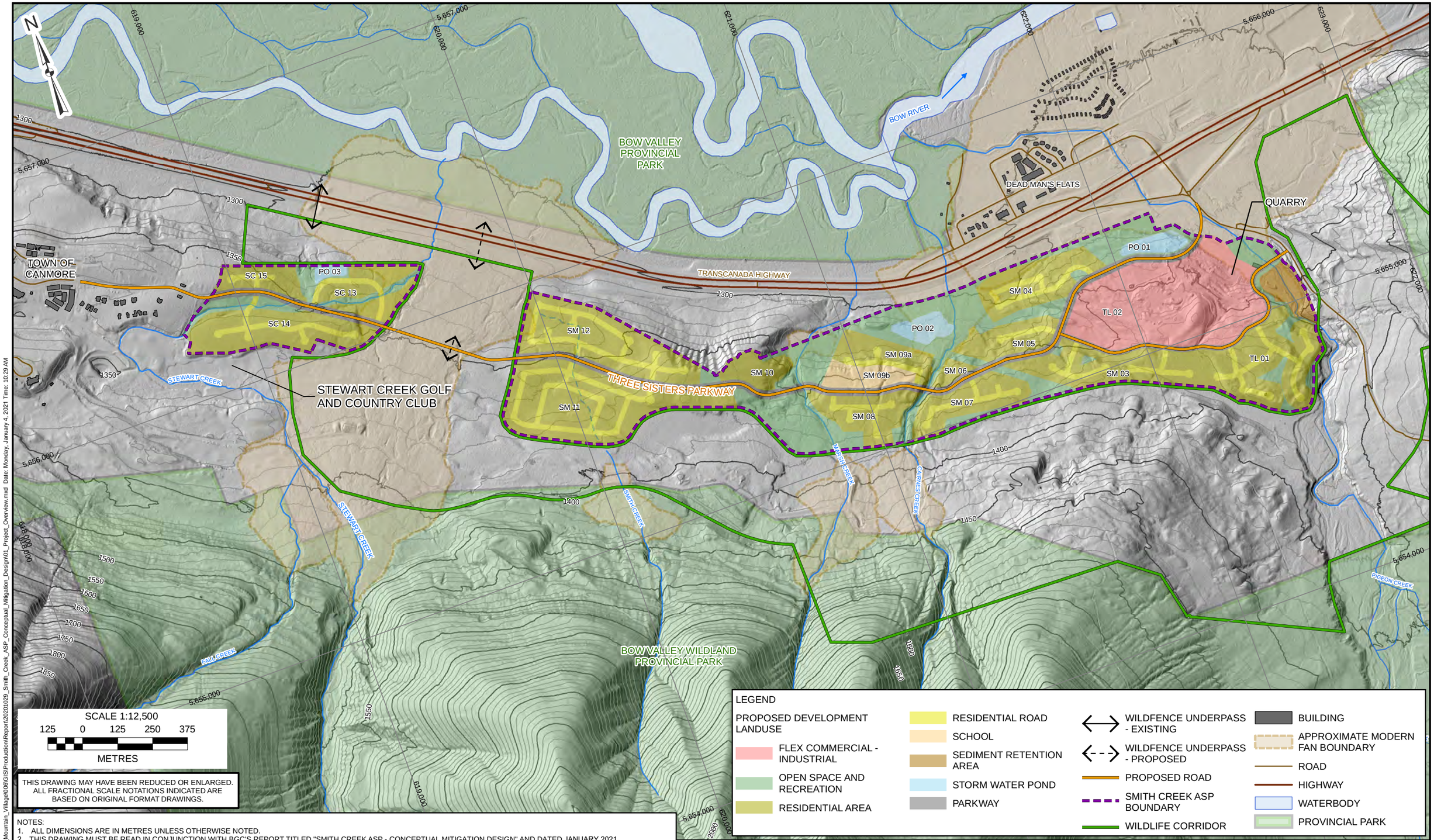
DRAWINGS



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METRES

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LEGEND

PROPOSED DEVELOPMENT LANDUSE
- FLEX COMMERCIAL - INDUSTRIAL
- OPEN SPACE AND RECREATION
- RESIDENTIAL AREA
- RESIDENTIAL ROAD
- SCHOOL
- SEDIMENT RETENTION AREA
- STORM WATER POND
- PARKWAY
- WILDFENCE UNDERPASS - EXISTING
- WILDFENCE UNDERPASS - PROPOSED
- PROPOSED ROAD
- SMITH CREEK ASP BOUNDARY
- WILDLIFE CORRIDOR
- BUILDING
- APPROXIMATE MODERN FAN BOUNDARY
- ROAD
- HIGHWAY
- WATERBODY
- PROVINCIAL PARK

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN" AND DATED JANUARY 2021.
3. SMITH CREEK ASP LAYOUT OBTAINED FROM THREE SISTERS MOUNTAIN VILLAGE, DATED SEPTEMBER 9, 2020.
4. EXISTING BUILDINGS AND ROADS IN DEAD MAN'S FLATS OBTAINED FROM THE MUNICIPAL DISTRICT OF BIGHORN.
5. EXISTING BUILDINGS IN CANMORE OBTAINED FROM TOWN OF CANMORES OPEN DATA PORTAL ON OCTOBER 26, 2020.
6. CREEK ALIGNMENT IS APPROXIMATE FOR SMITH CREEK.
7. THE FAN BOUNDARIES ARE APPROXIMATE AND ARE INTENDED TO DELINEATE THE LANDFORM. THE BOUNDARIES SHOULD NOT BE CONSTRUED AS A HAZARD MAP, NOR DO THEY SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
8. PROJECTION IS NAD 83 UTM ZONE 11N. VERTICAL DATUM UNKNOWN.
9. BASE TOPOGRAPHIC DATA BASED ON LIDAR, RECEIVED FROM MCELHANNEY, 2013. CONTOUR INTERVAL IS 10 m.
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APPROVED:	MJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN

TITLE: PROJECT OVERVIEW

PROJECT No.: 1531006

DWG No.: 01

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PIGEON CREEK MODELLING WAS ONLY COMPLETED FOR THE 1000- TO 3000-YEAR RETURN PERIOD DEBRIS FLOOD, AS DESCRIBED IN THE REPORT. REFER TO DRAWING 04 FOR MODELLING RESULTS.

BOW VALLEY PROVINCIAL PARK

BOW RIVER

DEAD MAN'S FLATS

QUARRY

TOWN OF CANMORE

TRANSCANADA HIGHWAY

THREE SISTERS PARKWAY

STEWART CREEK GOLF AND COUNTRY CLUB

STEWART CREEK

SMITH CREEK

MARSH CREEK

CAIRNES CREEK

PIGEON CREEK

FALL CREEK

BOW VALLEY WILDLAND PROVINCIAL PARK

PO 01
PO 02
PO 03
SC 13
SC 14
SC 15
SM 03
SM 04
SM 05
SM 06
SM 07
SM 08
SM 09a
SM 09b
SM 10
SM 11
SM 12
TL 01
TL 02

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- RESIDENTIAL AREA
- RESIDENTIAL ROAD
- SCHOOL
- SEDIMENT RETENTION AREA
- STORM WATER POND
- PARKWAY

MAXIMUM FLOW DEPTH
- 0 - 0.25 m
- 0.25 - 0.5 m
- 0.5 - 1 m
- 1 - 2 m
- > 2 m
- WILDFENCE UNDERPASS - EXISTING
- WILDFENCE UNDERPASS - PROPOSED
- PROPOSED ROAD

- SMITH CREEK ASP BOUNDARY
- WILDLIFE CORRIDOR
- BUILDING
- APPROXIMATE MODERN FAN BOUNDARY
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CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN

TITLE: BASE CASE 300- TO 1000-YEAR RETURN PERIOD FLOW DEPTHS FROM NUMERICAL MODELLING

PROJECT No.: 1531006

DWG No.: 02

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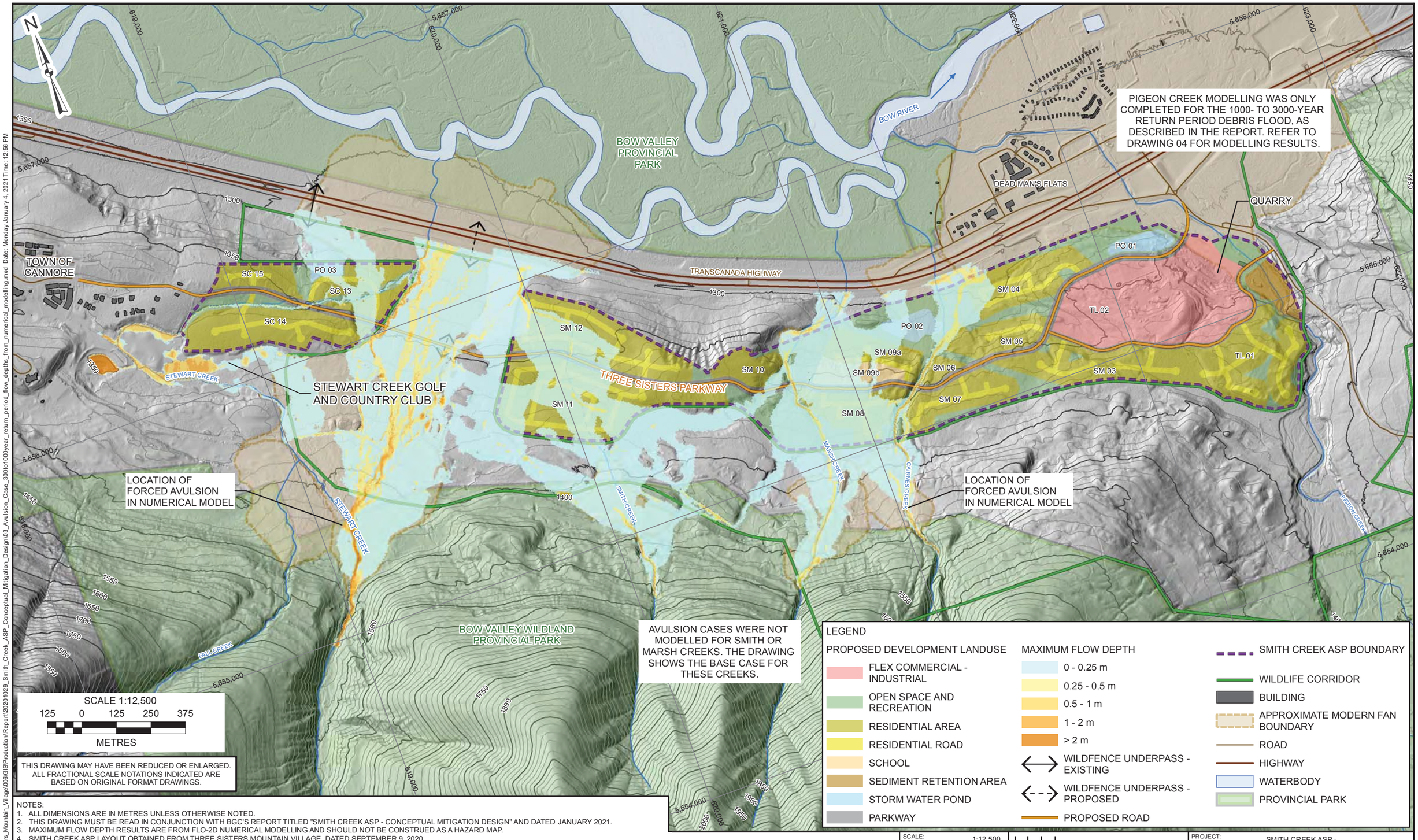

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PROJECT: SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN

TITLE: AVULSION CASE 300- TO 1000-YEAR RETURN PERIOD FLOW DEPTHS FROM NUMERICAL MODELLING

PROJECT No.: 1531006

DWG No.: 03

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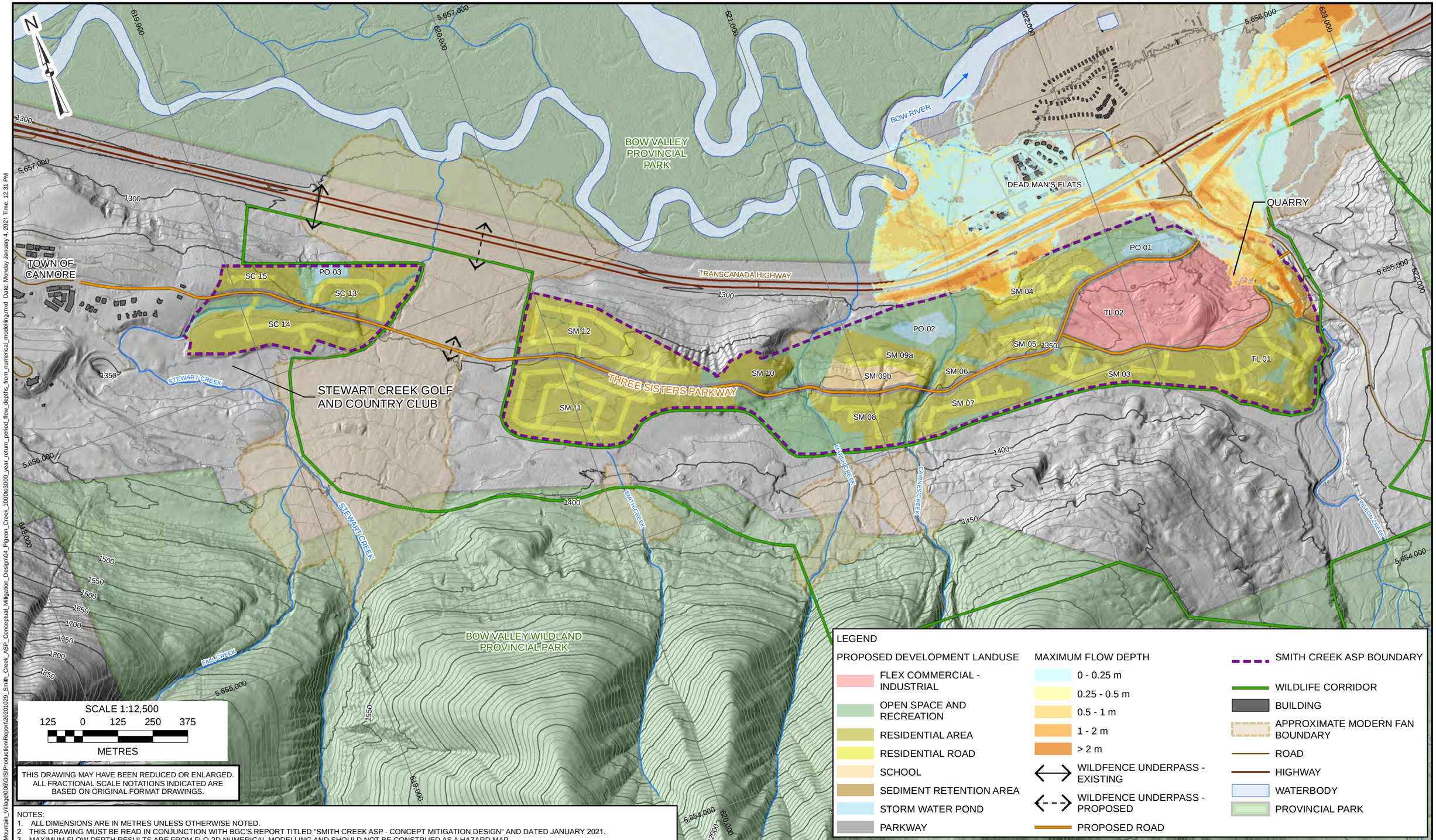

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8. THE FAN BOUNDARIES ARE APPROXIMATE AND ARE INTENDED TO DELINEATE THE LANDFORM. THE BOUNDARIES SHOULD NOT BE CONSTRUED AS A HAZARD MAP, NOR DO THEY SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
9. PROJECTION IS NAD 83 UTM ZONE 11N. VERTICAL DATUM UNKNOWN.
10. BASE TOPOGRAPHIC DATA BASED ON LIDAR, RECEIVED FROM MCELHANNEY, 2013. CONTOUR INTERVAL IS 10 m.
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SCALE:	1:12,500
DATE:	JAN 2021
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APPROVED:	MJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK ASP - CONCEPT MITIGATION DESIGN

TITLE: PIGEON CREEK 1000- TO 3000-YEAR RETURN PERIOD FLOW DEPTHS FROM NUMERICAL MODELLING

PROJECT No.:	DWG No.:
1531006	04

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OPTION 1 - LOCAL PROTECTION AND CHANNEL ARMOURING

CHANNEL UPGRADES TO ACCOMODATE DESIGN EVENT INCLUDING APPROPRIATE ROAD CROSSINGS

INTEGRATION OF PARKWAY AND LOCAL ROADS WITH SC 13 BERMS

KNICKPOINT FROM 2013 EVENT (IMMEDIATELY DOWNSTREAM OF PROPOSED CULVERT)

WOODY DEBRIS AND SEDIMENT MANAGEMENT STRUCTURE ON UPSTREAM EDGE OF DEVELOPMENT, IF NEEDED

CROSSING DESIGN COULD ALLOW EXCESS DISCHARGE TO FLOW INTO PO 03

BERMS OR REGRADING TO LIMIT DAMAGE IF STEWART CREEK AVULSES DOWN THE WILDLIFE CORRIDOR

DEBRIS FLOODS ARE EXPECTED TO ATTENUATE SIGNIFICANTLY AS THEY PASS THROUGH THE GOLF COURSE. ESTIMATED DISCHARGE IN THE LOWER CHANNEL IS 12 m^3/s.

OPTION 2 - CREEK DIVERSION

SETBACK BERM NOT NEEDED DUE TO NATURAL GRADE

CROSSINGS TO ACCOMODATE LOCAL DRAINAGE

REALIGNED CREEK FLOWS THROUGH WILDLIFE UNDERPASSES WHICH HAVE A HIGH CAPACITY TO CONVEY SEDIMENT AND WATER

SETBACK BERM TO DIRECT FLOWS TO UNDERPASS. OTHER ALTERNATIVES COULD BE CONSIDERED, INCLUDING REGRADING

SETBACK BERM NOT NEEDED DUE TO NATURAL GRADE

CREEK DIVERTED NEAR FAN APEX

TRANSCANADA HIGHWAY

TOWN OF CANMORE

STEWART CREEK GOLF AND COUNTRY CLUB

STEWART CREEK

FALL CREEK

BOW VALLEY WILDLAND PROVINCIAL PARK

SC 15

PO 03

SC 13

SC 14

SM 12

SM 11

SCALE 1:10,000

100 50 0 100 200 300

METRES

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

PROPOSED MITIGATION

- PROPOSED CROSSING
- PROPOSED DIVERSION STRUCTURE
- PROPOSED CHANNEL REALIGNMENT

PROPOSED BERMS

- SETBACK AND DIVERSION BERMS
- SC 13 BERMS
- SC 14 BERM
- SC 15 BERM
- SM 12 BERM

LEGEND

- EXISTING CULVERT
- WILDFENCE UNDERPASS - EXISTING
- WILDFENCE UNDERPASS - PROPOSED
- PROPOSED ROAD
- SMITH CREEK ASP BOUNDARY
- WILDLIFE CORRIDOR
- BUILDING
- APPROXIMATE MODERN FAN BOUNDARY
- ROAD
- HIGHWAY
- PROVINCIAL PARK

PROPOSED DEVELOPMENT LANDUSE

- OPEN SPACE AND RECREATION
- RESIDENTIAL AREA
- RESIDENTIAL ROAD
- STORM WATER POND
- PARKWAY

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN" AND DATED JANUARY 2021
3. MITIGATION LOCATIONS ARE APPROXIMATE AND SUBJECT TO CHANGE DURING FUTURE DESIGN STAGES. MITIGATION STRUCTURES WILL REQUIRE PERMANENT ACCESS FOR MAINTENANCE AND INSPECTION.
4. SMITH CREEK ASP LAYOUT OBTAINED FROM THREE SISTERS MOUNTAIN VILLAGE, DATED SEPTEMBER 9, 2020.
5. EXISTING BUILDINGS AND ROADS IN DEAD MAN'S FLATS OBTAINED FROM THE MUNICIPAL DISTRICT OF BIGHORN.
6. EXISTING BUILDINGS IN CANMORE OBTAINED FROM TOWN OF CANMORES OPEN DATA PORTAL ON OCTOBER 26, 2020.
7. THE FAN BOUNDARIES ARE APPROXIMATE AND ARE INTENDED TO DELINEATE THE LANDFORM. THE BOUNDARIES SHOULD NOT BE CONSTRUED AS A HAZARD MAP, NOR DO THEY SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN

TITLE: STEWART CREEK CONCEPTUAL MITIGATION OPTIONS

PROJECT No.: 1531006

DWG No.: 05

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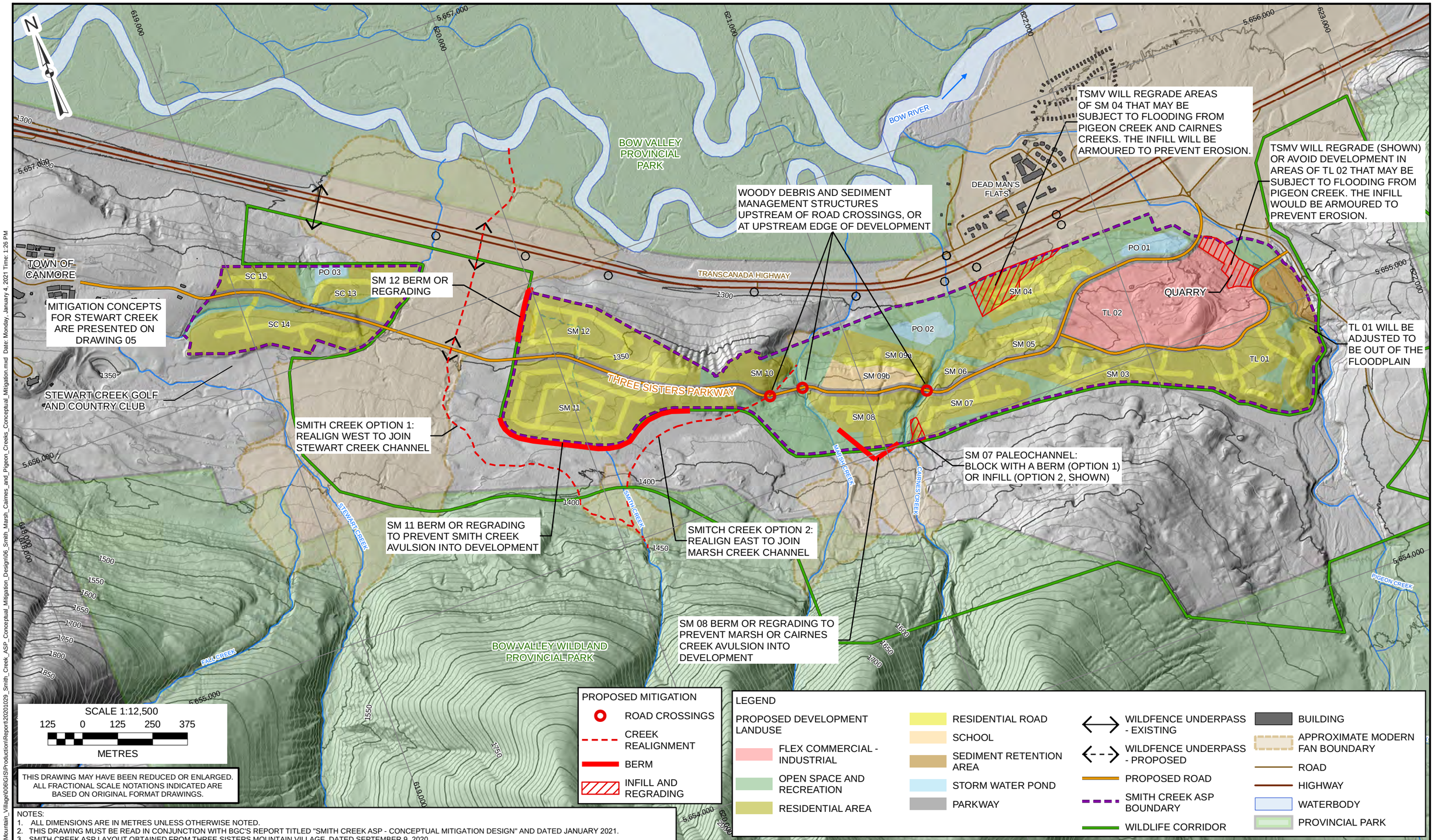

SCALE 1:12,500

125 0 125 250 375

METRES

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PROPOSED MITIGATION

- ROAD CROSSINGS
- CREEK REALIGNMENT
- BERM
- INFILL AND REGRADING

LEGEND

PROPOSED DEVELOPMENT LANDUSE

- FLEX COMMERCIAL - INDUSTRIAL
- OPEN SPACE AND RECREATION
- RESIDENTIAL AREA
- RESIDENTIAL ROAD
- SCHOOL
- SEDIMENT RETENTION AREA
- STORM WATER POND
- PARKWAY
- WILDFENCE UNDERPASS - EXISTING
- WILDFENCE UNDERPASS - PROPOSED
- PROPOSED ROAD
- SMITH CREEK ASP BOUNDARY
- WILDLIFE CORRIDOR
- BUILDING
- APPROXIMATE MODERN FAN BOUNDARY
- ROAD
- HIGHWAY
- WATERBODY
- PROVINCIAL PARK

NOTES:

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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK ASP - CONCEPTUAL MITIGATION DESIGN

TITLE: SMITH, MARSH, CAIRNES AND PIGEON CREEK CONCEPTUAL MITIGATION

PROJECT No.: 1531006

DWG No.: 06

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