MASTER DRAINAGE PLAN

SMITH CREEK

JULY 2020

THREE SISTERS mountain village

QUANTUM PLACE

wsp

REVISION HISTORY

FIRST ISSUE				
June 8, 2020	1st SUBMISSION			
Prepared by	Reviewed by	Approved By		
Michael Nishiyama, M.A.Sc., P.Eng.	Joshua Maxwell, M.Sc., P.Eng., PMP	Chris Conner, P.Eng., PMP		
Second Issue				
July 31, 2020	2nd SUBMISSION			
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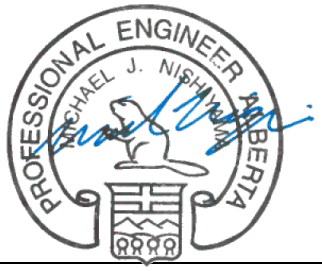
SIGNATURES

PREPARED BY



30 July 2020

Michael Nishiyama, M.A.Sc., P.Eng.
Water Resources Engineer

APPROVED[1] BY

PERMIT TO PRACTICE

Jul. 30 2020

Joshua Maxwell, M.Sc., P.Eng., PMP
Team Lead Water Resources

[1] Approval of this document is an administrative function indicating readiness for release and does not impart legal liability on to the Approver for any technical content contained herein. Technical accuracy and fit-for-purpose of this content is obtained through the review process. The Approver shall ensure the applicable review process has occurred prior to signing the document.

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1 INTRODUCTION

1.1 GENERAL

WSP Canada group Limited was retained by QuantumPlace Developments Ltd. on behalf of Three Sisters Mountain Villages (Client) to conduct a Master Drainage Plan (MDP) study for the proposed Smith Creek Development (SCD). The Smith Creek Development lands are located south of the Trans-Canada Highway (TCH) from the existing Stewart Creek development to Deadman's Flats at the eastern edge of Three Sisters Lands, in the Town of Canmore, Alberta (**Figure 1.0**). Five prominent creeks flow through the proposed development, Stewart Creek, Smith Creek, Marsh Creek, Cairns Creek and Pigeon Creek. The creeks originate from mountainous terrain and generally flow from southwest to northeast, all eventually draining into the Bow River. The watershed areas are forested up to the treeline and consist of exposed rock surfaces above the treeline. The project area is part of the third reach of the Bow River basin which extends from Banff National Park to upstream of the Bearspaw Dam. The Bow River basin is the most populated river basin in Alberta and supplies water to more than a million people.

1.2 STUDY OBJECTIVES

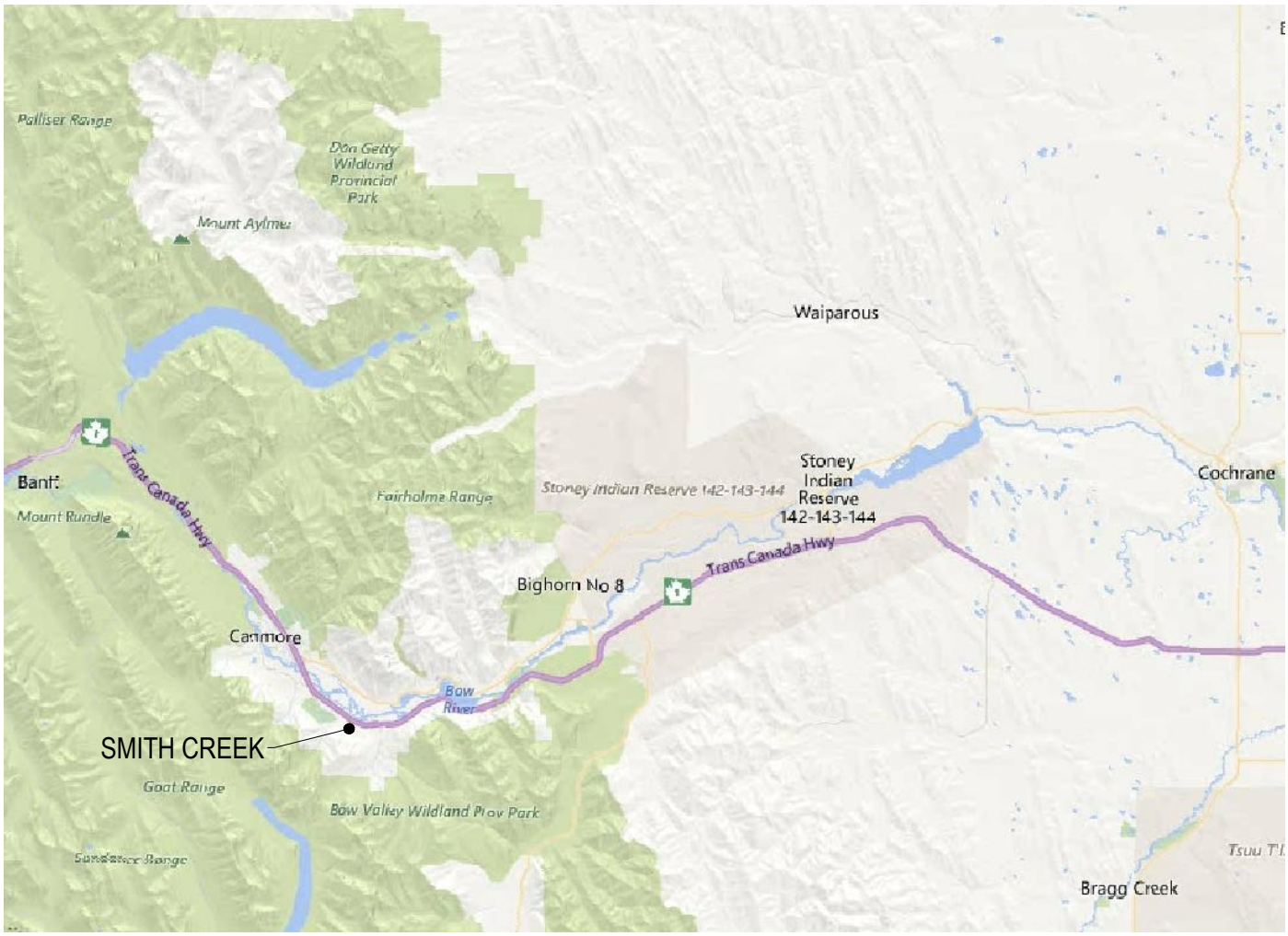
The purpose of this study is to present the stormwater management strategies for the proposed layout of the SCD in support of the Area Structure Plan (ASP). The main objectives are to provide a hydrological and hydraulic assessment to estimate the on-site stormwater storage requirements.

The SCD will include specific hydrological site considerations. These include the requirement to consider wetlands, ensure downstream infrastructure has sufficient capacity, and safeguard the development from drainage from the upstream basin.

1.3 DESIGN CRITERIA

The Town of Canmore design criteria for stormwater management have several guiding documents, which include the following:

- Canmore Engineering Design & Construction Guidelines 2010
- Canmore Stormwater Master Plan 2005
- Central Canmore Stormwater Study Mountain Engineering
- Mountainous Terrain Guidelines – June 2006
- Engineering DCG Part 2.5 – Extra Reference, SWM Ref#1-Ref#7



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PROJECT:
SMITH CREEK
MASTER DRAINAGE PLAN

TITLE:
LOCATION PLAN

SCALE: NA
DATE: 2020-07-28
PROJECT NO: 16M-02148-02
DRAWING NO: FIGURE 1.0

2 BACKGROUND

2.1 OVERALL SITE DETAILS

The SCD study area is 332 ha. Approximately 175 ha of the existing study area is reserved for protected wildlife corridors. The surrounding area is mostly dense forest, with some residential and commercial developments north of the study area in the Hamlet of Dead Mans Flats. The topography consists of rolling terrain and a series of defined ridges and plateaus of mountain slope regions with five creeks (Stewart Creek, Smith Creek, Marsh Creek, Cairns Creek and Pigeon Creek) flowing through the site. Two of these creeks are permanent (Stewart and Pigeon Creek) while the remaining three creeks primarily flow during spring runoff. Within the study area there are three natural wetlands which comprise of a total area of approximately 2 ha. Ultimately the creeks and runoff from the site discharge into the Bow River. The proposed development is proposed to be residential, mixed-use, commercial land, park sites, schools and environmental reserve. The existing topography and proposed land use plan have been included as **Figures 2.0** and **2.1**.

2.2 PREVIOUS STUDIES

The following studies and guidelines have been reviewed and utilized in preparation of this report:

- Stantec Consulting Ltd. (May 2004, Calgary Alberta): DC sites 1 to 6 Stormwater Master Drainage Plan. Prepared for Three Sisters Mountain Village Ltd
- Westhoff Engineering Resources, Inc., (February 2004, Calgary Alberta): Master Drainage Plan prepared for Three Sisters Mountain Village
- Westhoff Engineering Resources, Inc., (February 2013, Calgary Alberta): Master Drainage Plan for Three Sisters Mountain Village, prepared for Three Sisters Mountain Village
- BGC Engineering Inc., (January 2014): Stewart Creek, Forensic Analysis and Conceptual Debris Flood Mitigation
- BGC Engineering Inc., (August 2015): Smith Creek ASP Preliminary Hazard Assessment.
- BGC Engineering Inc., (September 2016): Pigeon Creek Debris-Flood Risk Assessment
- MMM Group Limited, (October 2016, Calgary, Alberta): Three Sisters Mountain Village Stormwater Management Strategies, prepared for Three Sisters Mountain Village Properties Ltd. and QuantumPlace Developments Ltd
- Tetra Tech EBA Inc., (November 2016): Pigeon Creek Hazard Assessment
- BGC Engineering Inc., (July 2017): Stewart Creek Hazard and Risk Assessment
- BGC Engineering Inc., (June 2019): Smith Creek ASP Study Area Boundary.

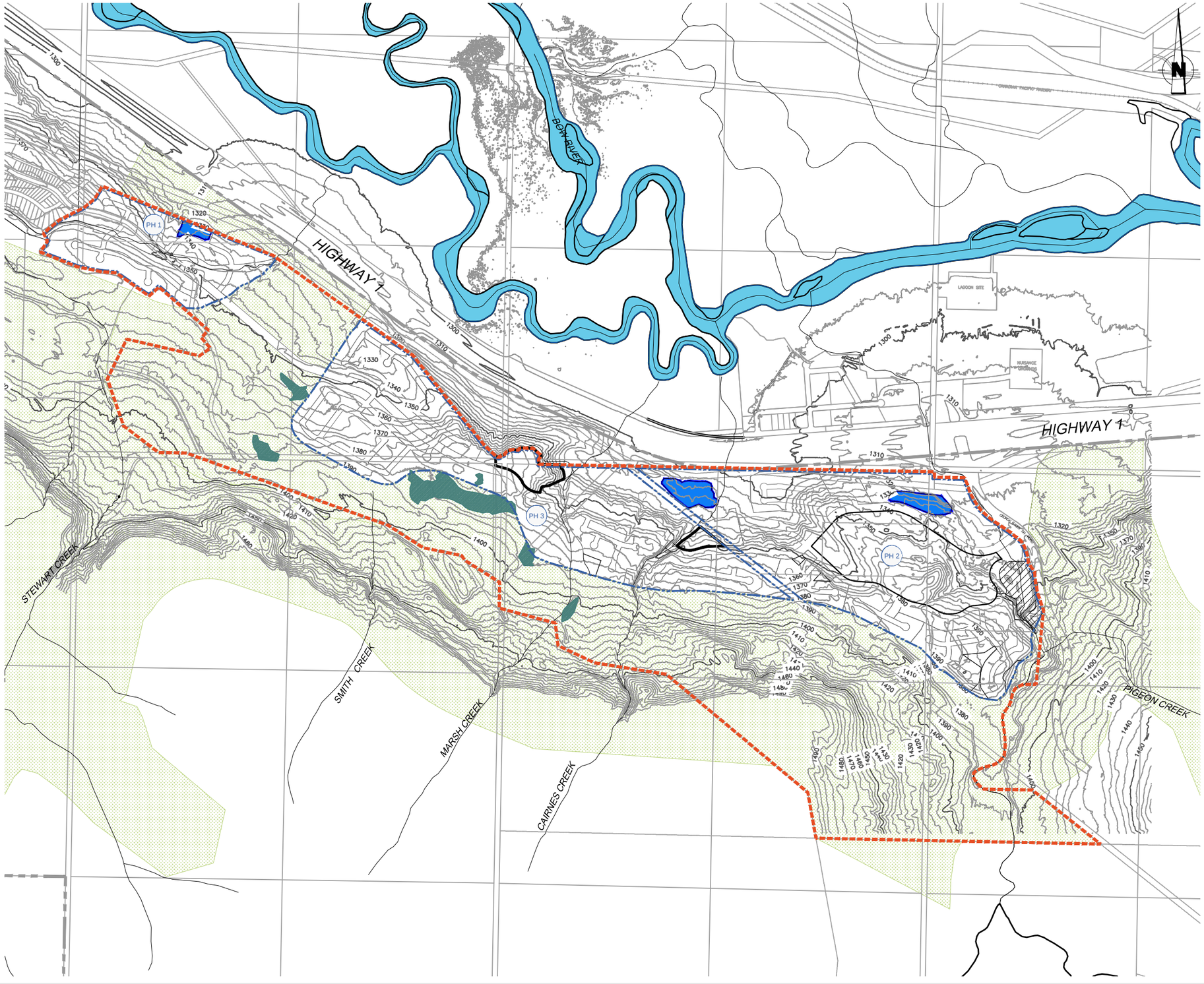
2.3 RELEASE RATE

Previous work has been conducted to estimate a release rate for the area. The Three Sisters Mountain Village Stormwater Master Drainage Plan (Stantec, 2004) determined a pre-development discharge rate of approximately 4.5 L/s/ha to nearby creeks, based on a hydrological study using stream flow and rainfall data. The authors created a SWMHYMO model of the Three Sisters Creek watershed to generate a unit discharge rate. It is important to note that the authors determined that this rate was applicable to the nearby creeks, and not the Bow River. Subsequently, the authors of the Three Sisters Mountain Village Stormwater Management Strategies (MMM Group Limited, 2016) performed a regional flood frequency analysis (FFA) and calculated pre-development release rates ranging from 4.2 to 4.5 L/s/ha for the creeks in the study area, for a 1:100 year return event. The report recommended using a release rate of 4.3 L/s/ha across the site.

Since the publication of these reports BGC has conducted a detailed review of local creeks as a part of an ongoing study of creek hazard assessment. The BGC 2017 Stewart Creek Hazard and Risk Assessment report indicates that previous estimates of release rates and the applied methodology of regional FFA may not be an appropriate approach. BGC has conducted multiple creek hazard reports for the 2013 flood events and has applied HEC-HMS, a rainfall-runoff model developed by the US Army Corps of Engineers. BGC's models have generated significantly higher peak rates compared to previous regional FFA's. For context, the estimated release rates by the previous FFA's was near 4.5 L/s/ha, while the estimated release rate from the 2017 HEC-HMS model for Stewart Creek for the 100-year return event was approximately 40 L/s/ha. Comparing the previously conducted models of release rate analysis with BGC's, the BGC analysis is considered to represent a more accurate rate than previously determined.

Presently there is no specific limitation on the allowable rate of discharge to the Bow River. This report proposes that the Smith Creek development be subject to a release rate of 35 L/s/ha. This rate was selected as it allows for effective water quality and quantity control, while maintaining a release rate below that of the estimated pre-development rate by BGC. The rate is also in agreement with the curve numbers, and hydrological parameters outlined in Section 3.3. This report will outline the preliminary infrastructure required to meet the proposed release rate.

Review of the proposed release rate will be evaluated as further information becomes available for both the development lands and the regional hydrology. The proposed rate of 35L/s/Ha may be increased or decreased should further supporting information become available.



LEGEND:

PROJECT AREA

CONTOURS 1400

WILDLIFE CORRIDOR

EXISTING WETLAND

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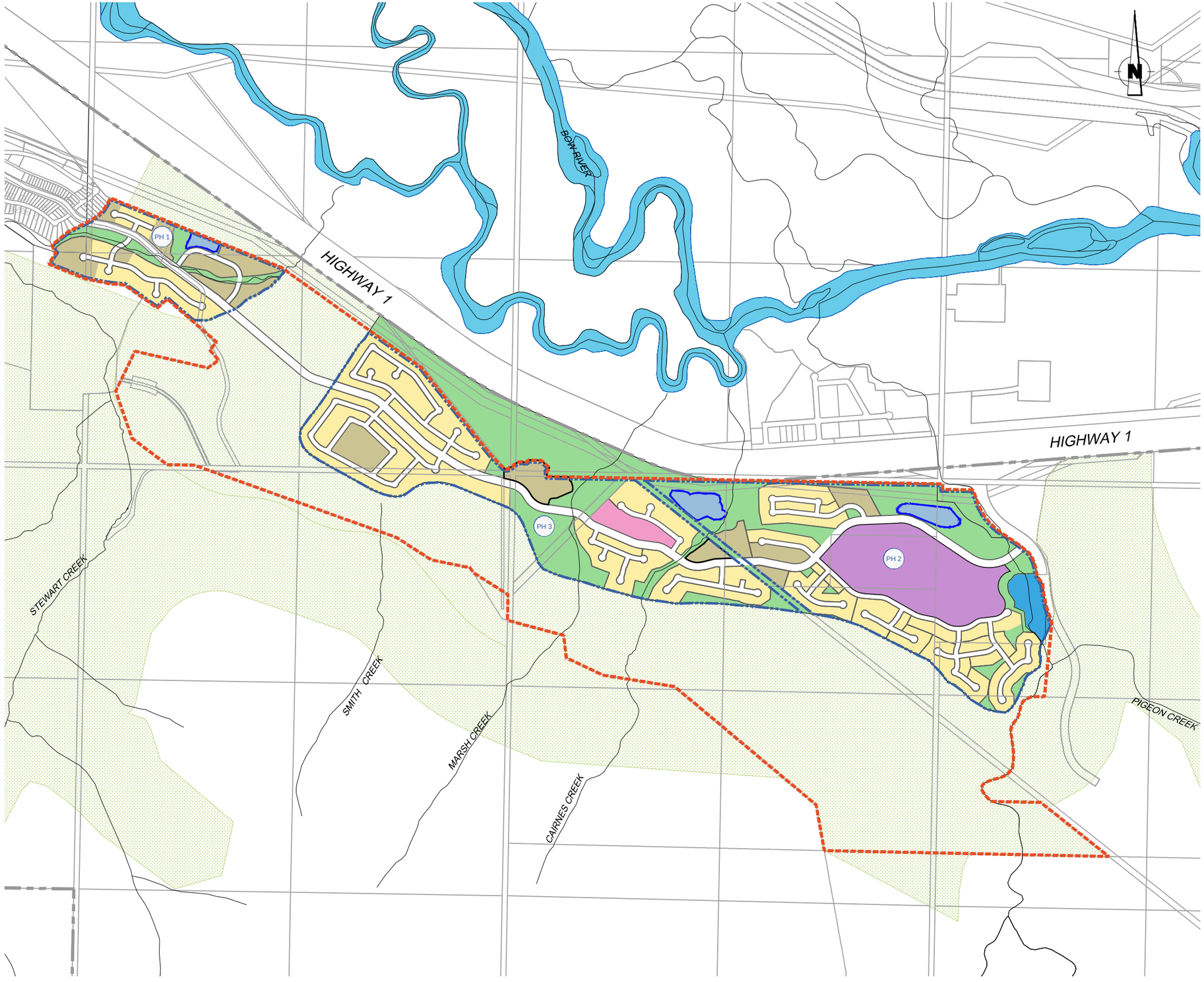
SMITH CREEK
MASTER DRAINAGE PLAN

TITLE:

TOPOGRAPHY PLAN
FIGURE 2.0



LEGEND:

- PROJECT AREA
- PHASE BOUNDARIES
- RESIDENTIAL (LOW DENSITY)
- RESIDENTIAL (MEDIUM DENSITY)
- COMMERCIAL AREA
- WATER
- NATURAL HEAVY VEGETATION
- SCHOOL SITE
- WILDLIFE CORRIDOR

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MASTER DRAINAGE PLAN

TITLE:

LAND USE PLAN
FIGURE 2.1

3 DRAINAGE ANALYSIS

3.1 MODEL DEVELOPMENT

A stormwater drainage model was developed using PCSWMM (Version: 2019 Professional 2D) software. This software is a Windows-based stormwater management modeling system that is capable of evaluating hydrologic and hydraulic performance. The model has a hydrological component that computes runoff from sub-catchments, which is then routed through the hydraulic components which consist of various hydraulic structures and storage elements. The model is used to evaluate the performance of the stormwater infrastructure and assist in the development of solutions for managing runoff.

3.2 METHODOLOGY

The model was developed following the Canmore Engineering Design & Construction Guidelines 2010 and considers the guidance of the current draft engineering guide lines as provided by the Town in early 2020. The following primary sources of information were utilized to construct the model:

- CAD drawings of existing and proposed utilities
- Previous drawings of record plans
- LiDAR data, 2015
- NRCAN Geo Spatial Data DEM
- Aerial imagery to evaluate land use, 2019
- Surficial Geology of Alberta, Alberta Energy Regulator, 2016
- Environment Canada Intensity-Duration-Frequency Data

The Intensity-Duration-Frequency (IDF) data and storm distributions from the City of Calgary stormwater management and design manual was utilized to determine the applicable rainfall amount for the site. The City of Calgary design events have been applied as prescribed in the Canmore Design Guidelines. The design events selected were the 5, 25, and 100 return year events over a 24 hour duration with a Chicago distribution. The 24 hour events simulate long duration events, highlighting issues associated with volume concerns, and release rates, while the Chicago distribution of the event assists in assessing peak flow conditions.

The varying design events were analyzed in conjunction with the proposed development plan, using PCSWMM software, to determine an effective stormwater management strategy. Three stormwater management facilities (SWMFs) were proposed to manage the runoff to an appropriate release rate, and to provide water quality treatment.

3.3 HYDROLOGY

The hydrologic section of the model was used to compute runoff hydrographs from the basins. These runoff hydrographs are then routed through the conveyance system by the model. The computation of the runoff hydrographs is based on the catchment characteristics and the methodology applied for the hydrological calculations was the runoff curve number (CN) method. This methodology was applied as it is a common and recognized procedure and also follows previously conducted analysis in the area by BGC (2017). This curve number analysis applies a value (curve number) that ranges from 0 to 100, which determines the amount of rainfall that is infiltrated and stored as soil moisture. Runoff curves numbers that are larger will generate more runoff and smaller numbers will result in the opposite. Values for the runoff curve numbers are evaluated based on the type of surface and soil type. The applied values were referenced from the National Engineering Handbook (NEH) Part 630 Hydrology Chapter 9 Hydrologic Soil-Cover Complexes, as well as compared to the previously analyzed values by BGC. The general surficial geology of the study area is a mix of moraine and fluvial deposits, as indicated by the map Surficial Geology of Alberta, Alberta Energy Regulator, 2013. The following table presents the catchment parameters and infiltration parameters. **Figures 3.0** and **3.1** illustrate the delineated offsite and onsite major stormwater basins for the site respectively.

Table 3.1 Applied Hydrological Parameters for PCSWMM Model

Subcatchment Hydrological Parameters	
Pervious Area Manning's Coefficient	0.250
Impervious Area Manning's Coefficient	0.018
Pervious Area Depression Storage (mm)	2.5
Impervious Area Depression Storage (mm)	1.3
Densely Vegetated Areas Curve Number	60
Natural Area Curve Number	70
Post Development Curve Number	77

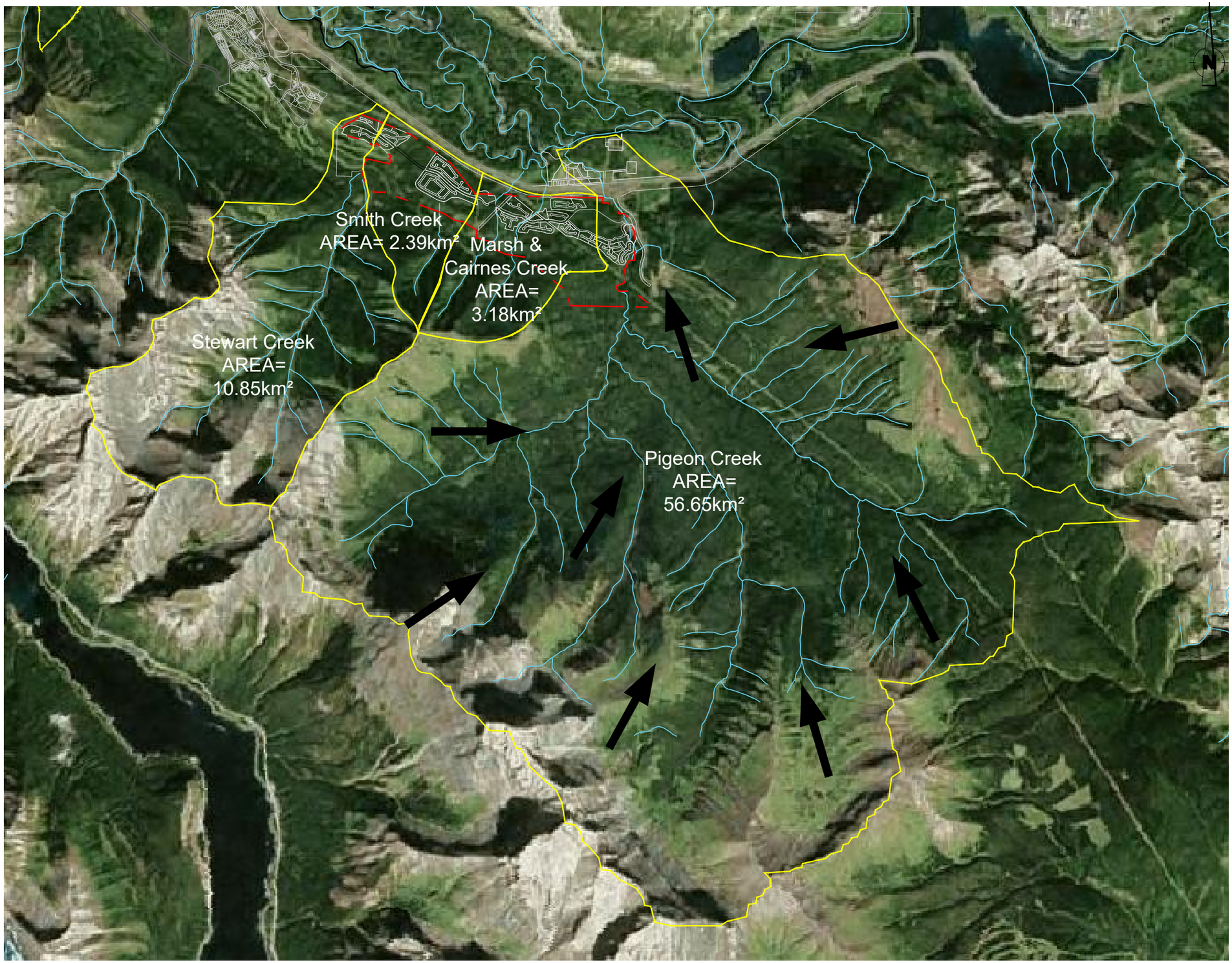
BGC had previously determined a curve number range of 60 to 79 for the varying natural cover watersheds in the area. A value of 60 was applied by WSP as a composite curve number value for all of the predevelopment and heavily tree or vegetated natural watersheds, while a number of 70 represents green space that is not heavily vegetated, such as parks. The post development portion of the site had a lump sum value of 77 applied, as it was estimate to represent a mix of residential, commercial, mixed use, and natural zoning.

The natural and upstream catchment areas were delineated using PCSWMM's watershed delineation tool, and were assessed using available terrain data, aerial imagery, street level view imagery and previous report information. The proposed development catchment areas were evaluated based upon the layout and functional grading of the site. These basins were then connected to the hydraulic network. The impervious percentage values for the contributing catchments were estimated using the proposed land use in

conjunction with the design standards. A detailed stormwater design will be required at a later stage to analyze the finalized plan and land use types.

3.4 HYDRAULICS

The hydraulic analysis consists of a one-dimensional (1D) system that conveys flow along delineated flow paths. A conveyance system was implemented in the model to represent drainage infrastructure such as ditches, pipes, culverts, and overland major drainage. The conveyance system was developed with the available plan, but as the development plan is still being designed some assumptions regarding the characteristics of the drainage infrastructure had to be made. It was assumed that flows conveyed by the drainage infrastructure were done so by an oversized conveyance system, as to ensure all runoff reached its respective SWMF, and to provide the most efficient routing method for the flows. The minor system was assumed to have a Manning's 'n' value of 0.013, as for concrete pipes. The storage capacities of the SWMFs were determined through an iterative process of analyzing the volume of flow and adjusting the SWMF to perform optimally.



LEGEND:

PROJECT AREA

OFFSITE WATERSHEDS

MAJOR DRAINAGE DIRECTION

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SMITH CREEK
MASTER DRAINAGE PLAN

TITLE:

OFFSITE WATERSHEDS
FIGURE 3.0

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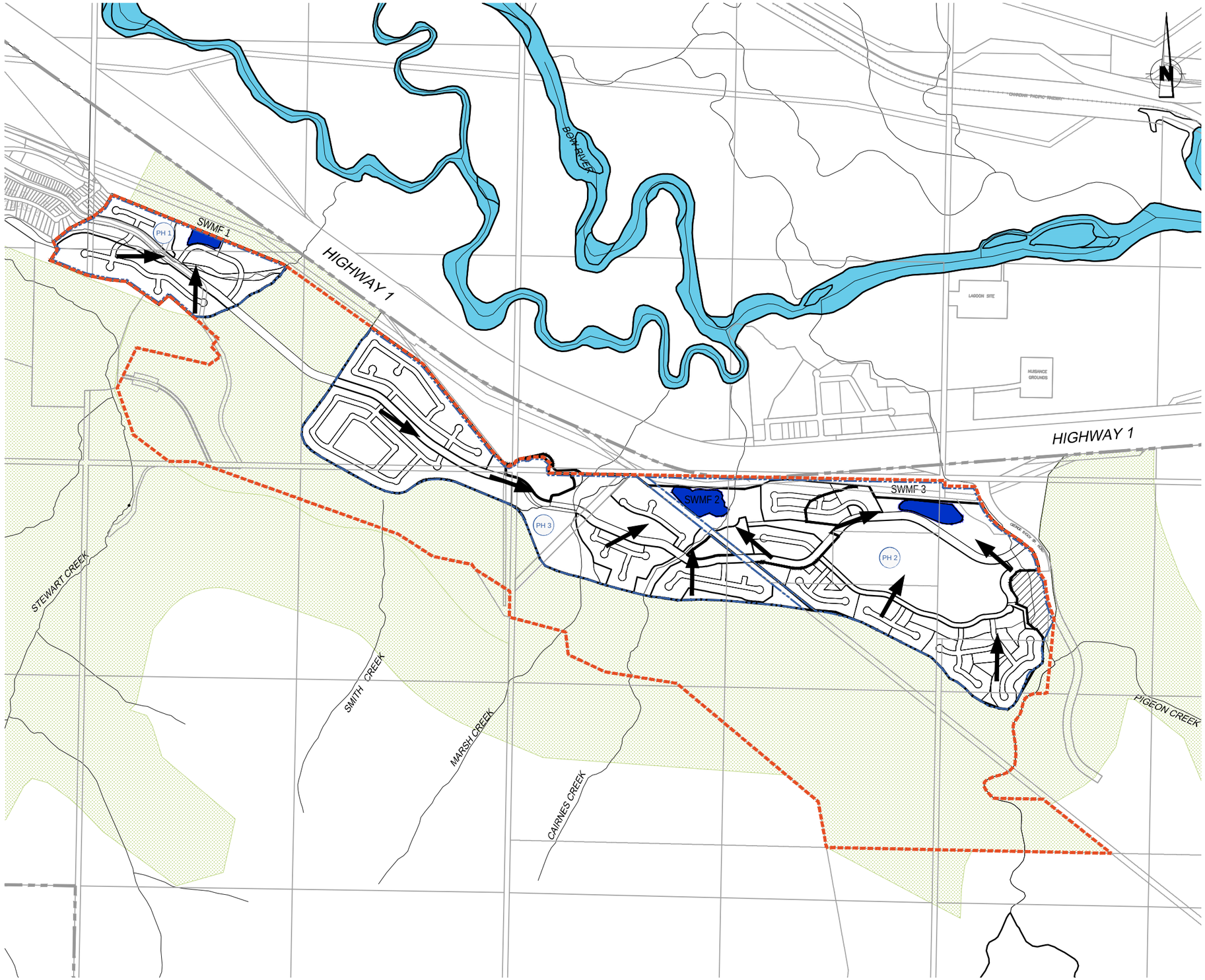

LEGEND:

PROJECT AREA

MAJOR STORM BASINS

SWMF

MAJOR DRAINAGE DIRECTION

WILDLIFE CORRIDOR

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MASTER DRAINAGE PLAN

TITLE:

PROPOSED MAJOR BASIN
FIGURE 3.1

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4 RESULTS AND RECOMMENDATIONS

4.1 GENERAL

The proposed stormwater system will be designed following the major/minor methodology. The minor storm system will be designed to convey the 1 in 5-year storm runoff. The streets and gutters will be used to convey flows exceeding the 1 in 5-year storm (i.e. major) to the proposed SWMFs. The minor system will be designed in detail at a later phase, but the methodology to be applied is the unit area release rate approach, applying a minimum rate of 70 L/s/ha, and a maximum of 120 L/s/ha. The roads throughout the development will be built conforming to Canmore's design guidelines. The SWMFs will be contained within a Stormwater Facility and will be designed to detain excess run-off from the most critical storm event. The SWMFs will have a piped outlet to discharge the controlled flows to the nearest creek that ultimately conveys flows to the Bow River. **Figure 4.0** indicates the proposed stormwater infrastructure. The illustrated sizing, and location of the stormwater infrastructure is preliminary and subject to modification upon future detailed analysis.

The master drainage plan proposes three SWMFs across the site; in general, the site is graded eastward and towards Highway 1. The ponds are located: in the north central portion of Phase 1 (SWMF 1), at the north-west corner of phase 2 (SMWF 2) and at the north east corner of Phase 2 (SWMF 3). SWMF 2 while being located within Phase 2 largely services Phase 3. It has been identified that due to the natural topography, grading challenges exist within the Phase 3 basin. The basin's detailed grading plan is still being evaluated, but will ensure effective stormwater runoff routing for the site. The SWMF's are subject to change as to accommodate basin area modifications for the next phase of design. Portions of the site that are highly constricted due to existing topography can be serviced by various options such as routing major flows via pipes, incorporating LID features to reduce runoff rates, or providing supplementary storage via an underground tank or an additional SWMF. The current plan ensures sufficient SWMF capacity has been allocated at this phase to provide adequate stormwater management.

4.2 STORMWATER MANAGEMENT FACILITIES

The purpose of this report is to outline the preliminary stormwater management infrastructure, and to estimate the required volume to provide adequate servicing. Three SWMFs are proposed for the site to provide water quality and quantity control. The performance of the facilities was modelled utilizing PCSWMM, and was applied to calculate the preliminary runoff volumes, pond water levels, and peak flows. The finalized volumes will depend upon the overall plan, allowable release rate, and overall efficiency of the design of the facility. At this phase it is undetermined if the SWMF's will be a wet pond or a dry pond, and will be evaluated at the subdivision phase. Either type of facility will have the same storage requirements, and provide sufficient water quality control. This pond design optioning has been discussed with the Town, and they are in agreement reviewing this at a later phase supports flexibility in the design process, and allows the Town to further evaluate its design preference, as pertaining to maintenance and performance.

Table 4.1: SWMF 1 Modelling Results

SUMMARY OF MODELING RESULTS SWMF 1			
Contributing Areas	21.59 ha		
Allowable Peak Discharge (m^3/s)	0.76		
Available Storage (m^3)	4000		
Rainfall Event	Rainfall (mm)	Runoff (mm)	Estimated Volume (m^3)
5 Year - 24 Hour Chicago	51.2	30.5	1100
25 Year - 24 Hour Chicago	72.1	47.9	2000
100 Year - 24 Hour Chicago	89.4	62.9	3100

Table 4.2 SWMF 2 Modelling Results

SUMMARY OF MODELING RESULTS SWMF 2			
Contributing Areas	76.34 ha		
Allowable Peak Discharge (m^3/s)	2.67		
Available Storage (m^3)	11000		
Rainfall Event	Rainfall (mm)	Runoff (mm)	Estimated Volume (m^3)
5 Year - 24 Hour Chicago	51.2	30.5	4300
25 Year - 24 Hour Chicago	72.1	47.9	7400
100 Year - 24 Hour Chicago	89.4	62.9	10700

Table 4.3 SWMF 3 Modelling Results

SUMMARY OF MODELING RESULTS SWMF 3			
Contributing Areas	48.99 ha		
Allowable Peak Discharge (m^3/s)	1.71		
Available Storage (m^3)	10000		
Rainfall Event	Rainfall (mm)	Runoff (mm)	Estimated Volume (m^3)
5 Year - 24 Hour Chicago	51.2	30.5	3900
25 Year - 24 Hour Chicago	72.1	47.9	6600
100 Year - 24 Hour Chicago	89.4	62.9	9100

4.2.1 WATER QUALITY

Table 4.4: Water Quality Analysis for SWMF's Sediment Settling Capacity

Settling Capacity for Smith Creek SWMF's			
SWMF	1	2	3
Permanent Storage Depth (m)	2.0	2.0	2.0
Maximum Settling Depth (m)	2.0	2.0	2.0
Storage Volume (m^3)	5000	12000	11000
Approximate Drawdown Time (hrs)	2.1	1.5	2.3
Particle Diameter (μm)	75	75	75
Density of Sediments (kg/m^3)	2650	2650	2650
Density of Water (kg/m^3)	1000	1000	1000
Dynamic Viscosity of Water (kg/m.s)	0.00131	0.00131	0.00131
Theoretical Settling Velocity Analysis (Stokes Law)			
Settling Velocity (m/s)	0.00438	0.00438	0.00438
Settling Time (s)	457	457	457
Settling Time (hrs)	**0.13**	**0.13**	**0.13**

4.2.2 BEST MANAGEMENT PRACTICES

Canmore guidelines indicate that the Town is in support of the application of Low Impact Development (LID) and Best Management Practices (BMP) for stormwater treatment. BMPs are methods of managing stormwater for adequate conveyance and control, and are economically acceptable to the community. The Town outlines several best management practices, and the overall site will be evaluated in the implementation of these features. LID focuses on maintaining and restoring the natural hydrological processes of a site, which in turn reduces runoff volumes and peaks, and provides enhanced water quality. The key elements of LID can include the utilization of natural site features, small scale local stormwater control features, prolonging runoff flow paths and times, and creating multi-functional landscapes. These principles promote the hydrological cycle by improving absorption, infiltration, evaporation, evapotranspiration, filtration, pollutant uptake, and biodegradation of pollutants.

LID-BMP features that could potentially be implemented on site include bioretention (rain gardens), and naturalized drainage ways. These features make use of greenspace along drainage routes, and can be outlined as a part of the detailed servicing phase of the design.

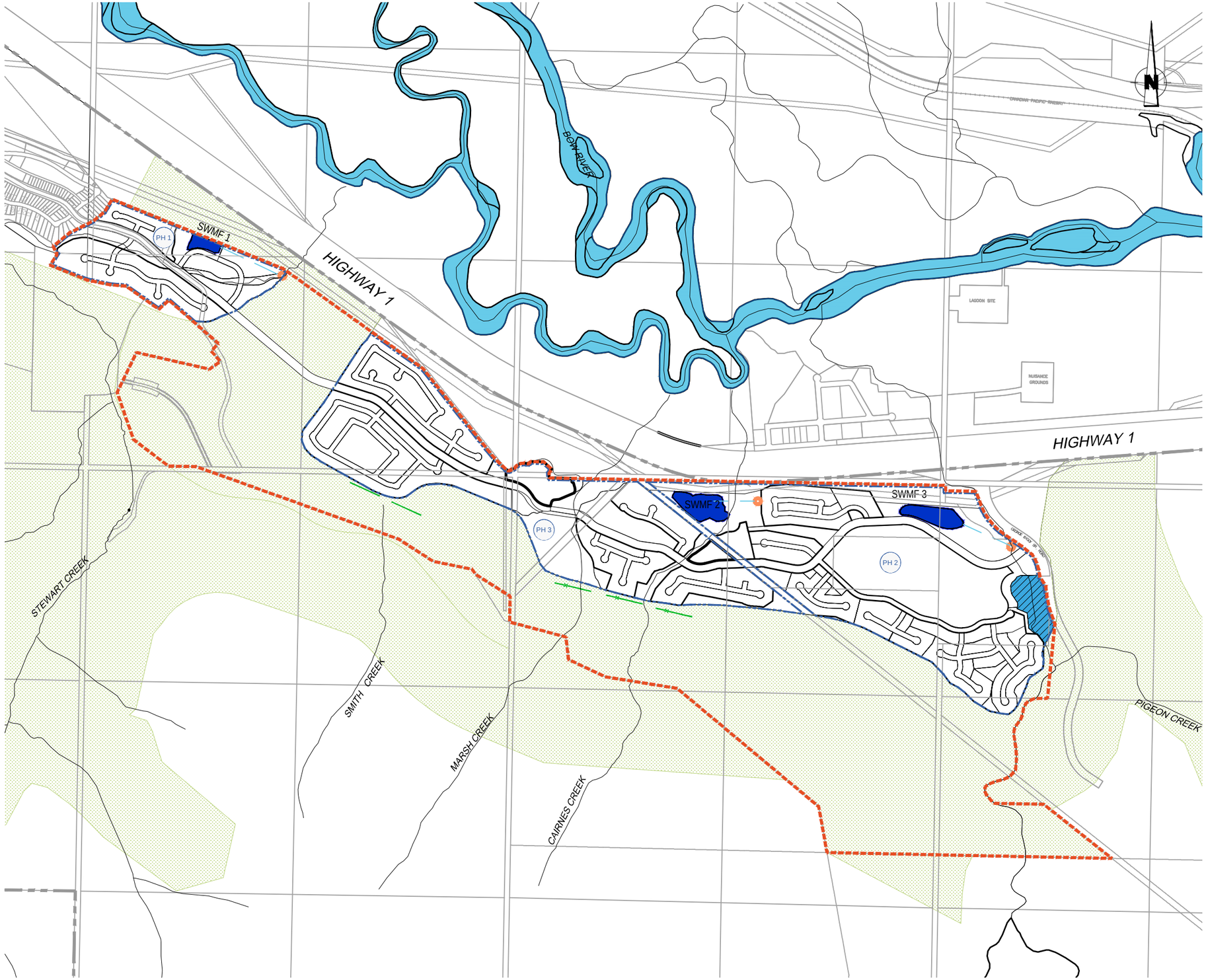
4.3 CONTROL STRUCTURE AND OUTFALLS

The three proposed SWMFs will each include a control structure that will outlet to a nearby creek. SWMF 1 is proposed to outlet to Stewart Creek, while SWMF 2 is proposed to outlet to Cairns Creek, and SWMF 3 to Pigeon Creek. Each of these Creeks ultimately discharge to the Bow River. The control structures will be designed to limit discharge from the critical design storm event to a maximum of 35 L/s/ha. These structures

will be designed to achieve the drawdown performance required by the Town, while maintaining acceptable discharge rates. An outfall site investigation is proposed to be conducted for each of the outfall locations. The purpose of the outfall site investigation is to assess the feasibility of the outfall location, examine the creeks capacity to receive water, and to evaluate a preliminary design. It is anticipated that the creeks and downstream infrastructure will have capacity to receive water, as the facilities are discharging at a predevelopment rate.

4.4 UPSTREAM BASIN AND CREEK DIVERSION

The proposed development site sits below a large area of mountainous terrain and drainage from this area naturally runs through the site. Flows from the upstream basins will have to be managed by stormwater infrastructure at the interface of the upstream basin and the development. Typically, this includes a series of walls, berms, and/ or drainage channels to attenuate and direct flows into the stormwater minor and major system. The ultimate design of the diversion infrastructure will be dependent upon the finalized plan, and will require a detailed hydraulic analysis to ensure its effectiveness. The creek's on site present some concerns due to potential risks associated with flooding. As indicated in the BGC, 2016, 2017, and 2019 reports portions of the development is within the hazard zones of the on-site creeks. The ongoing assessment and mitigation of hazards is being completed by BGC for the area. It is recommended that the ongoing mitigation of the creek hazards be continually reviewed as development proceeds.



LEGEND:

PROJECT AREA

SWMF

OUTFALL

DIVERSION INFRASTRUCTURE

WILDLIFE CORRIDOR

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SMITH CREEK
MASTER DRAINAGE PLAN

TITLE:

STORMWATER MANAGEMENT PLAN
FIGURE 4.0

P:\5215046-000 Quantum-Smith Creek ASP\Civil\5000 - Professional Services\5410 - Design-Technical\5414 - Sketches-Figures\Storm Master Drainage Plan 2020\16M\02148\02-CF4.0.dwg Jul 29, 2020-1:23pm BY:(KennedyE)

5 CONCLUSION

Based upon the analysis, the following conclusions are presented:

- There is no established allowable rate of discharge to the Bow River. Previously completed regional flood frequency analysis are not consistent with measured rates from BGC reports. A predevelopment rate of 35 L/s/ha has been proposed, which is substantiated by the BGC reports and predevelopment analysis. This will continue to be evaluated as further information about the regional hydrology and development lands become available.
- A PCSWMM model was generated to analyze the preliminary performance of the proposed stormwater infrastructure.
- Three stormwater storage facilities locations were proposed to serve the proposed development, providing an approximate 4000 m^3 11000 m^3 and 10000 m^3 of capacity. These are preliminary required storage volumes, and will be subject to the finalized development site plan and approved release rate. The SWMFs can function as either wet ponds or dry ponds.
- The study area sits below a large area of mountainous terrain. Drainage from this natural catchment is a key consideration for the development
- The proposed storm servicing concepts shown in **Figures 3.1** and **4.0** should be adopted as the basis for future storm design for the Smith Creek development. Detailed engineering should be undertaken at each stage of development, along with a review of the concept and overall conformity.
- Implementation of Low Impact Development and Best Management Practices for stormwater management will be considered in later design stages.

APPENDIX A STEEP CREEK HAZARD MAPS

N

HAZARD ZONE CHARACTERISTICS (2013 MODELLED EVENT)

I_{DF} RANGE

> 100	VERY FAST FLOWING AND DEEP WATER AND DEBRIS. HIGH LIKELIHOOD OF SEVERE BUILDING STRUCTURE DAMAGE AND SEVERE SEDIMENT AND WATER DAMAGE. EXTREMELY DANGEROUS TO PEOPLE IN BUILDINGS, ON
10 to 100	FAST FLOWING AND DEEP WATER AND DEBRIS. HIGH LIKELIHOOD OF MODERATE TO MAJOR BUILDING STRUCTURE DAMAGE AND SEVERE SEDIMENT AND WATER DAMAGE. VERY DANGEROUS TO PEOPLE IN
1 to 10	POTENTIALLY FAST FLOWING BUT MOSTLY SHALLOW WATER WITH DEBRIS. MODERATE LIKELIHOOD OF BUILDING STRUCTURE DAMAGE AND HIGH LIKELIHOOD OF MAJOR SEDIMENT AND/OR WATER DAMAGE. POTENTIALLY DANGEROUS TO PEOPLE ON THE FIRST FLOOR OR IN THE BASEMENT OF
< 1	SLOW FLOWING SHALLOW AND DEEP WATER WITH LITTLE OR NO DEBRIS. HIGH LIKELIHOOD OF WATER DAMAGE. POTENTIALLY DANGEROUS TO

618,000 618,500 619,000

5,656,500 5,656,000

TRIO SUBDIVISION

STEWART CREEK PHASE 3 SUBDIVISION

LOT 5, BLOCK 15, PLAN 0610834

STORM WATER POND

TRANS CANADA HIGHWAY

STEWART CREEK

END OF MODEL DOMAIN

KAME TERRACE

CONCRETE CULVERT

FORMER MINING PIT/LANDFILL

GOLF COURSE POND

STEWART CREEK FAN

FALL CREEK FAN

SCALE 1:5,000

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.

LEGEND

- 2013 DEBRIS FLOOD EXTENT
- PROPOSED BUILDING
- BUILDING
- 14 LOT NUMBER
- ROAD
- TRANS-CANADA HIGHWAY
- MUNICIPAL DISTRICT OF BIGHORN - BOUNDARY
- APPROXIMATE MODERN FAN BOUNDARY

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "STEWART CREEK HAZARD AND RISK ASSESSMENT - FINAL", DATED JULY 2017.
3. WATERCOURSE, WATER BODY, ROAD AND RAILWAY OBTAINED FROM CANVEC.
4. ORTHOIMAGERY PROVIDED BY TOWN OF CANMORE, DATED 2013.
5. THE FAN BOUNDARIES AS DRAWN ARE APPROXIMATE AND DELINEATE THE LANDFORMS. THE BOUNDARIES SHOULD NOT BE CONSTRUED AS HAZARD ZONES, NOR DO THEY SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
6. LIMITS OF DISTURBANCE DIGITIZED FROM STEWART CREEK PHASE 3 BUILDING GRADE PLAN SHEET NO. C3.1 PROVIDED BY QPD MARCH 27, 2017.
7. PROJECTION IS NAD 83 UTM ZONE 11N.
8. PARCEL BOUNDARIES AND BULDING OUTLINES PROVIDED BY THE TOWN OF CANMORE AND QUANTUM PLACE DEVELOPMENTS DATED FEBRUARY 14, 2017.
9. THIS MAP REPRESENTS A SNAPSHOT IN TIME. FUTURE CHANGES (DEVELOPMENT, DEBRIS-FLOOD MITIGATION, GEOHAZARD EVENTS) MAY WARRANT THE RE-DRAWING OF CERTAIN AREAS.
10. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

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CHECKED:	SK
APPROVED:	MJ

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CLIENT: THREE SISTERS MOUNTAIN VILLAGE PROPERTIES LTD.

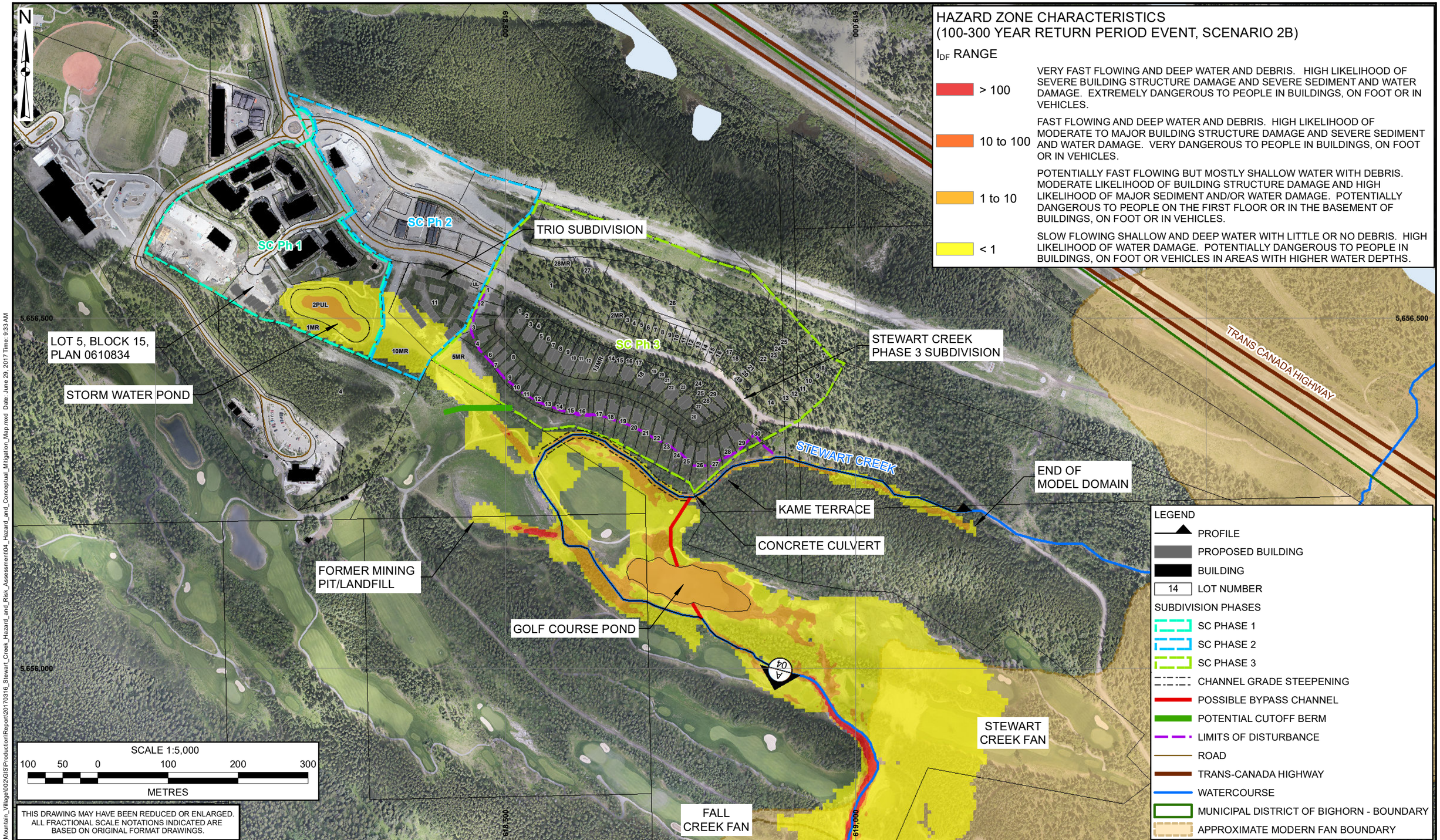
PROJECT: STEWART CREEK HAZARD AND RISK ASSESSMENT - FINAL

TITLE: 2013 EVENT MAP AND MODEL CALIBRATION

PROJECT No.: 1531002

DWG No.: 02

X:\Projects\1531_Three_Sisters_Mountain_Village\002\GIS\Production\Report\20170316_Stewart_Creek_Hazard_and_Risk_Assessment\02_2013_Event_Map_and_Model_Calibration.mxd Date: June 29, 2017 Time: 9:38 AM



HAZARD ZONE CHARACTERISTICS
(100-300 YEAR RETURN PERIOD EVENT, SCENARIO 2B)

I_{DF} RANGE

> 100	VERY FAST FLOWING AND DEEP WATER AND DEBRIS. HIGH LIKELIHOOD OF SEVERE BUILDING STRUCTURE DAMAGE AND SEVERE SEDIMENT AND WATER DAMAGE. EXTREMELY DANGEROUS TO PEOPLE IN BUILDINGS, ON FOOT OR IN VEHICLES.
10 to 100	FAST FLOWING AND DEEP WATER AND DEBRIS. HIGH LIKELIHOOD OF MODERATE TO MAJOR BUILDING STRUCTURE DAMAGE AND SEVERE SEDIMENT AND WATER DAMAGE. VERY DANGEROUS TO PEOPLE IN BUILDINGS, ON FOOT OR IN VEHICLES.
1 to 10	POTENTIALLY FAST FLOWING BUT MOSTLY SHALLOW WATER WITH DEBRIS. MODERATE LIKELIHOOD OF BUILDING STRUCTURE DAMAGE AND HIGH LIKELIHOOD OF MAJOR SEDIMENT AND/OR WATER DAMAGE. POTENTIALLY DANGEROUS TO PEOPLE ON THE FIRST FLOOR OR IN THE BASEMENT OF BUILDINGS, ON FOOT OR IN VEHICLES.
< 1	SLOW FLOWING SHALLOW AND DEEP WATER WITH LITTLE OR NO DEBRIS. HIGH LIKELIHOOD OF WATER DAMAGE. POTENTIALLY DANGEROUS TO PEOPLE IN BUILDINGS, ON FOOT OR VEHICLES IN AREAS WITH HIGHER WATER DEPTHS.

LEGEND

- PROFILE
- PROPOSED BUILDING
- BUILDING
- 14 LOT NUMBER

SUBDIVISION PHASES

- SC PHASE 1
- SC PHASE 2
- SC PHASE 3
- CHANNEL GRADE STEEPENING
- POSSIBLE BYPASS CHANNEL
- POTENTIAL CUTOFF BERM
- LIMITS OF DISTURBANCE
- ROAD
- TRANS-CANADA HIGHWAY
- WATERCOURSE
- MUNICIPAL DISTRICT OF BIGHORN - BOUNDARY
- APPROXIMATE MODERN FAN BOUNDARY

SCALE 1:5,000

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.

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "STEWART CREEK HAZARD AND RISK ASSESSMENT - FINAL", DATED JULY 2017.
3. WATERCOURSE, WATER BODY, ROAD AND RAILWAY OBTAINED FROM CANVEC.
4. ORTHOIMAGERY PROVIDED BY TOWN OF CANMORE, DATED 2013.
5. THE FAN BOUNDARIES AS DRAWN ARE APPROXIMATE AND DELINEATE THE LANDFORMS. THE BOUNDARIES SHOULD NOT BE CONSTRUED AS HAZARD ZONES, NOR DO THEY SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
6. LIMITS OF DISTURBANCE DIGITIZED FROM STEWART CREEK PHASE 3 BUILDING GRADE PLAN SHEET NO. C3.1 PROVIDED BY QPD MARCH 27, 2017.
7. PROJECTION IS NAD 83 UTM ZONE 11N.
8. PARCEL BOUNDARIES AND BULDING OUTLINES PROVIDED BY THE TOWN OF CANMORE AND QUANTUM PLACE DEVELOPMENTS DATED FEBRUARY 14, 2017.
9. THIS MAP REPRESENTS A SNAPSHOT IN TIME. FUTURE CHANGES (DEVELOPMENT, DEBRIS-FLOOD MITIGATION, GEOHAZARD EVENTS) MAY WARRANT THE RE-DRAWING OF CERTAIN AREAS.
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APPROVED:	MJ

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CLIENT: THREE SISTERS MOUNTAIN VILLAGE PROPERTIES LTD.

PROJECT: STEWART CREEK HAZARD AND RISK ASSESSMENT - FINAL

TITLE: HAZARD AND CONCEPTUAL MITIGATION MAP

PROJECT No.: 1531002

DWG No.: 04

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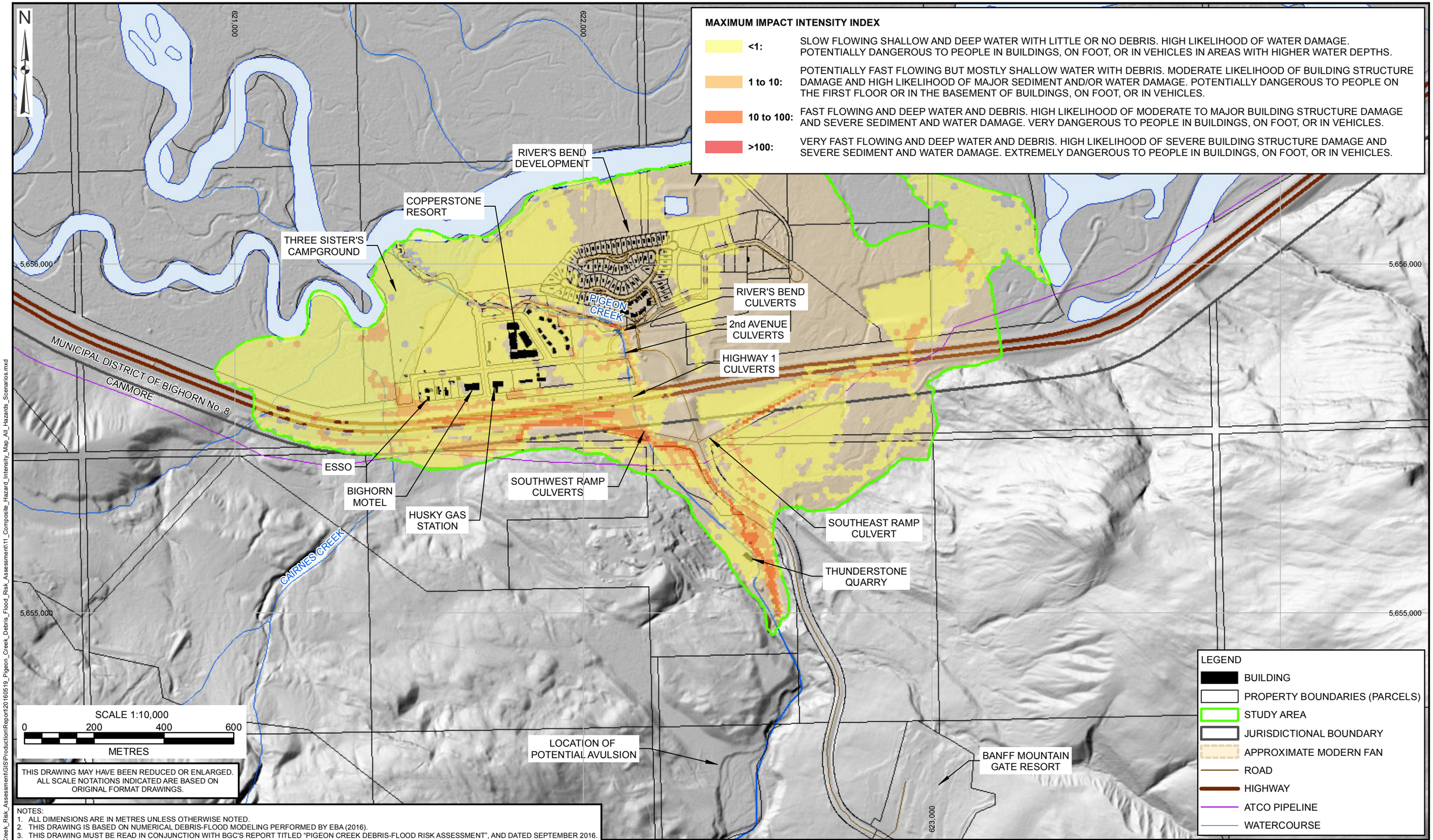

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NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING IS BASED ON NUMERICAL DEBRIS-FLOOD MODELING PERFORMED BY EBA (2016).
3. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "PIGEON CREEK DEBRIS-FLOOD RISK ASSESSMENT", AND DATED SEPTEMBER 2016.
4. FOOTPRINT OF EXISTING BUILDINGS OBTAINED FROM CANMORE. FOOTPRINT OF RIVER'S BEND DEVELOPMENT FROM MD BIGHORN VIA CANMORE.
5. THIS MAP DISPLAYS THE COMBINED HAZARD EXTENT AND INTENSITY OF ALL HAZARD SCENARIOS. AS SUCH, IT DOES NOT REPRESENT ANY PARTICULAR SCENARIO RETURN PERIOD. WHERE DIFFERENT HAZARD SCENARIOS OVERLAP, THE MAXIMUM HAZARD INTENSITY VALUE IS SHOWN ON THIS MAP.
6. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY McELHANNEY, DATED AUGUST AND OCTOBER 2013.
7. PROJECTION IS NAD83 UTM ZONE 11N.
8. THE STUDY AREA BOUNDARY EXTENDS BEYOND THE GEOMORPHIC EXTENT OF THE FAN TO INCLUDE AREAS IMPACTED BY MODELLED DEBRIS-FLOODS.
9. THE FAN BOUNDARY AS DRAWN IS APPROXIMATE AND DELINEATES THE LANDFORM. THE BOUNDARY SHOULD NOT BE CONSTRUED AS A HAZARD MAP, NOR DOES IT SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
10. THIS MAP ASSUMES THAT EXISTING AND FUTURE EROSION PROTECTION WORKS PERFORM AS INTENDED.
11. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

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CLIENT: Town of CANMORE

PROJECT: PIGEON CREEK DEBRIS-FLOOD RISK ASSESSMENT

TITLE: COMPOSITE HAZARD INTENSITY MAP: ALL HAZARD SCENARIOS

PROJECT No.:	DWG No.:
1261-014	11

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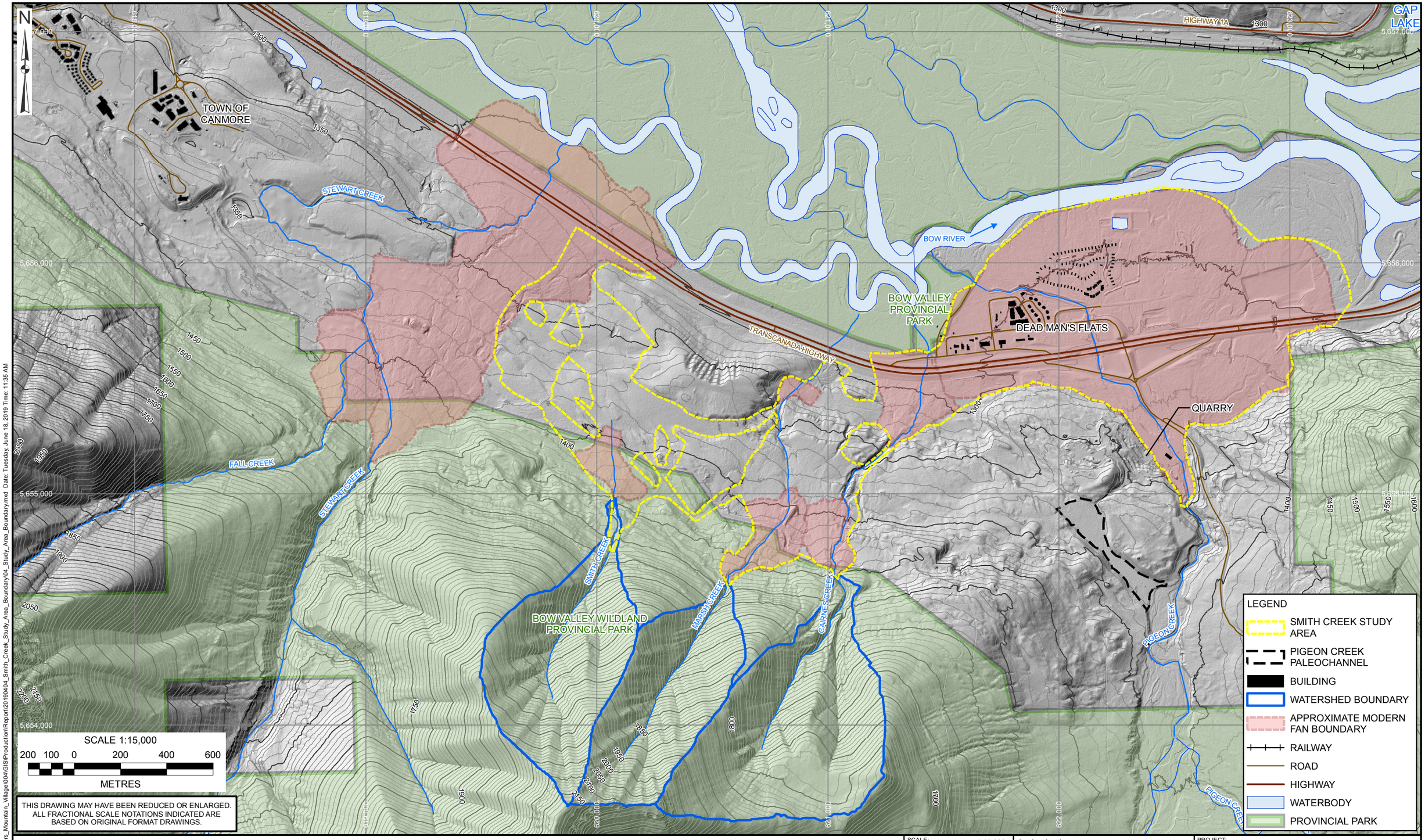

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NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "SMITH CREEK STUDY AREA BOUNDARY" AND DATED JUNE 2019.
3. BUILDINGS AND ROADS OBTAINED FROM THE MUNICIPAL DISTRICT OF BIGHORN.
4. THE FAN BOUNDARY AS DRAWN IS APPROXIMATE AND DELINEATES THE LANDFORM. THE BOUNDARY SHOULD NOT BE CONSTRUED AS A HAZARD MAP, NOR DOES IT SHOW THE SPATIAL EXTENT OF POTENTIAL FLOODING.
5. PROJECTION IS NAD 83 UTM ZONE 11N. VERTICAL DATUM UNKNOWN.
6. BASE TOPOGRAPHIC DATA BASED ON LIDAR, RECEIVED FROM MCELHANNEY, 2013. CONTOUR INTERVAL IS 10 m.
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BGC ENGINEERING INC.
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CLIENT: THREE SISTERS mountain village

PROJECT: SMITH CREEK STUDY AREA BOUNDARY

TITLE: STUDY AREA BOUNDARY

PROJECT No.:	DWG No.:
1531004	04