Appendix 12-A

Fluvial Geomorphology Assessment of Alexander Creek

Clarke Geoscience Ltd.

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

CROWN MOUNTAIN COKING COAL PROJECT

Drone Photo of Confluence of West Alexander Creek and Alexander Creek (by Lotic Environmental, in July 2020)

October 21, 2021

Prepared for: NWP Coal Ltd.

Attention: Mr. Mike Allen, Project Manager

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1.0 Introduction

Clarke Geoscience Ltd. (CGL) was retained by NWP Coal Ltd. to complete a fluvial geomorphology assessment of Alexander Creek for the Crown Mountain Coking Coal Mine Project, located in the East Kootenays, BC (Figure 1.1). The scope of work was defined in a letter proposal to Lotic Environmental (dated May 3, 2021).

1.1 Project Background and Study Objectives

The Crown Mountain Coking Coal Project (the Project) is a proposed open pit metallurgical coal mine situated within the Rocky Mountains north of Sparwood, BC. The Project will produce 2 million tonnes of product per year for 16 years (not including site decommissioning).

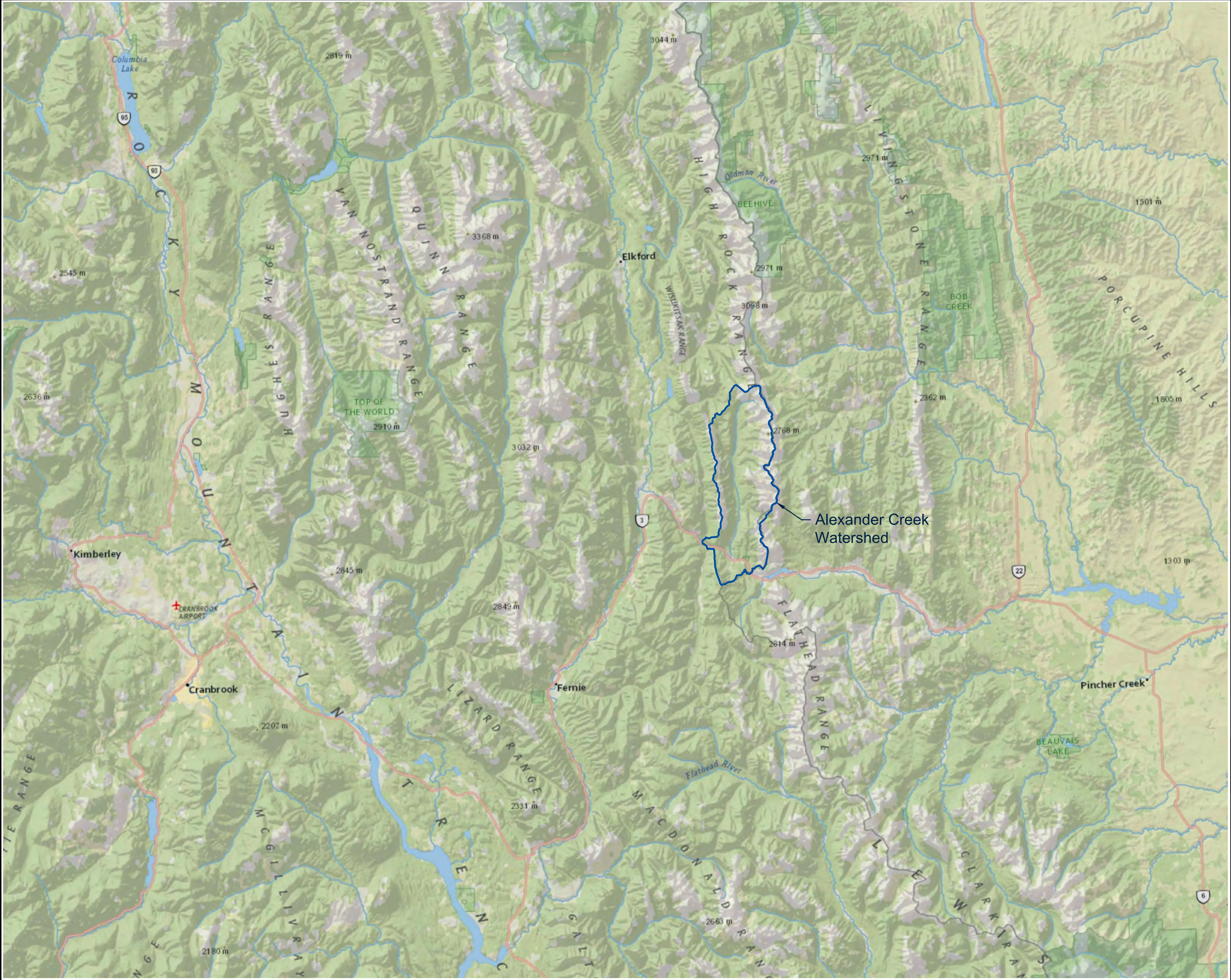
We have prepared the following work plan to assess the potential changes the Project may have on the aquatic environment downstream of the project footprint within the Local Study Area (LSA). This assessment focusses on the characterization of downstream fluvial geomorphology and the potential response to Project-related changes.

The overall study objective of the fluvial geomorphology assessment is to complete a high-level overview assessment of the potential effects the Project could have on the fluvial geomorphology of lower West Alexander Creek and Alexander Creek between the confluence with West Alexander Creek and Michel Creek (near Highway 3) The Grave Creek watershed is not within the study area of the fluvial geomorphology assessment.

Fluvial geomorphology is an evolving physical environment, which influences the character of in-stream habitat.

Specific objectives of the fluvial geomorphology assessment are to:

- Characterize the geomorphological context of the assessment study area shown in Figure 1.2, including the watershed processes and natural geomorphic disturbances impinging the channel.
- Characterize the sediment supply and transport regime above and below the Project footprint (see Figure 1.2).
- Review historic channel response to past flood events and land use activity.
- Characterize the fluvial geomorphic environment and the capacity for channel adjustment, including incision, widening, and textural changes.
- Comment on the resiliency of the reaches downstream of the Project to potential future changes in hydrology and sediment load.
- Identify sites (or reaches) requiring further, more detailed field assessment or future monitoring.



Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

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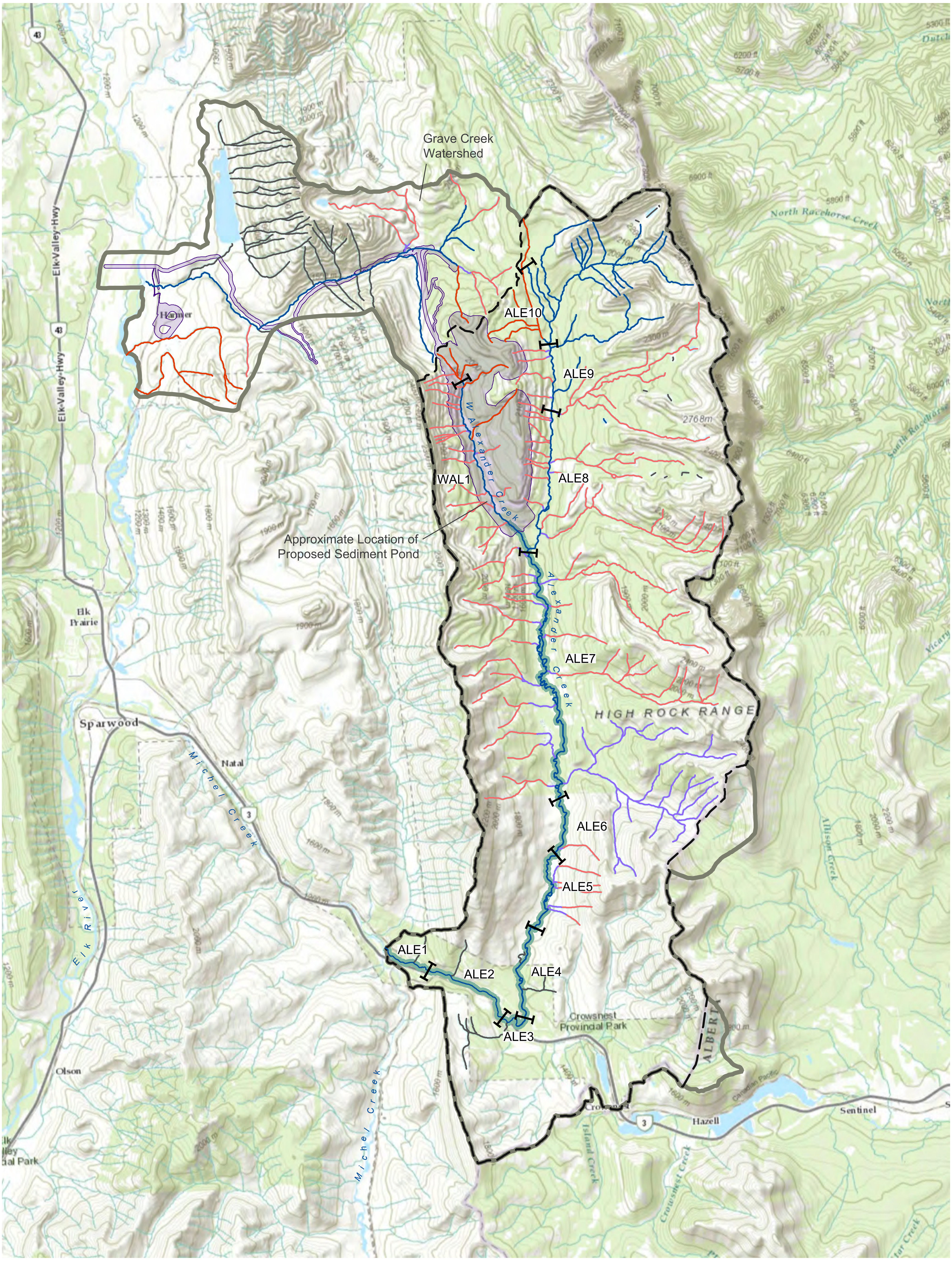
CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

LOCATION OF STUDY AREA

Scale: 1:500,000	NAD 1983 UTM Zone 11 U	Figure No. 1.1
Project No: 21-0104	Date: September 30, 2021	

Clarke Geoscience Ltd.



LEGEND:

- LOCAL STUDY AREA (LSA) BOUNDARY*
- ALEXANDER CREEK WATERSHED BOUNDARY
- CROWN MOUNTAIN MINE PROJECT FOOTPRINT
- FLUVIAL GEOMORPHOLOGY ASSESSMENT STUDY REACHES
- ALE1 — REACH BREAK AND NUMBER* (ALE - ALEXANDER CREEK, WAL1 - WEST ALEXANDER CREEK)

WATERCOURSE - FISH-BEARING STATUS*

- FISH-BEARING
- DEFAULTS TO FISH-BEARING
- NON FISH-BEARING
- DEFAULTS TO NON FISH-BEARING
- NO STATUS

* GIS data source: Lotic Environmental (2020)

Basemap sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, and the GIS User Community

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CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

ALEXANDER CREEK WATERSHED STUDY AREA

Scale: 1:100,000	NAD 1983 UTM Zone 11 U	Figure No. 1.2
Project No: 21-0104	Date: September 30, 2021	

Clarke Geoscience Ltd.

1.2 Crown Mountain Coal Project Components Affecting Fluvial Geomorphology

The project footprint, shown in the Conceptual Project Layout and Infrastructure within the Application Information Requirements (AIR) document, is located entirely within the West Alexander Creek sub-basin. It is understood that the Project footprint, including areas identified for surface extraction and for mine waste management, will encompass all but the lower ~700 m of West Alexander Creek. Infrastructure, including water supply, power/natural gas and mine product hauling will occur within the Grave Creek watershed, which lies outside the West Alexander Creek sub-basin to the north (see Figure 1.2).

Project activities that are expected to interact with surface water quantity and sediment transport within West Alexander Creek will also potentially affect downstream channel geomorphology in Alexander Creek. These activities are identified in the Surface Water Quantity Effects Assessment, which will form part of the Environmental Assessment application. Those activities within Alexander Creek watershed with a potential to have significant effects on hydrology and sediment transport are considered further with respect to this fluvial geomorphology assessment.

Table 1.1: Project Activities with Potential for Effects on Fluvial Geomorphology

Project Activities
Forest harvesting, land clearing and grubbing vegetation within the development footprint
Site water management and discharge including construction, operation and eventual decommissioning of the Interim and Main Sediment Ponds. Pond will discharge via a controlled outlet structure (spillway) to West Alexander Creek.

2.0 Study Approach and Assessment Methods

To achieve the study objectives listed above, and to provide a high-level qualitative assessment of potential effects on fluvial geomorphology, the assessment approach relies upon air photo/image interpretation and professional judgement.

Specific study tasks are described as follows:

- *Task 1: Review project information, previous reports and scientific literature*

  Project information pertaining to the Project was reviewed, including a description of various project phases to be considered (i.e., construction, operation, and closure). Previously completed baseline reports were also reviewed, including:

  - Fish and Fish Habitat Baseline Assessment (Lotic Environmental, 2020);
  - Hydrology Baseline Report (Dillon Consulting, 2020).

  A review of scientific literature pertaining to river sensitivity and effects on fluvial geomorphology was also completed. This is not intended to be a comprehensive review.

However, there are publications on the downstream effects of dams that are relevant due to the proposed development of a sediment detention pond on West Alexander Creek.

Preliminary information regarding Surface Water Quantity Effects of the Project was obtained from the NWP Coal Ltd. Environmental Assessment Application (Chapter 10) (NWP Coal Ltd., 2021).

- *Task 2: Compile and Review Existing Field Data*

Field data collected during the fish and fish habitat baseline assessment that is relevant to this assessment was reviewed. This included reach-specific channel measurements, such as substrate characterizations, and photos. Details on reach classification are provided in Section 4.1.

- *Task 3: Historical Air Photo and Imagery Review*

Historical air photo imagery covering the study area was obtained on loan from the UBC Vancouver Geographic Information Centre. Air photos for eleven (11) different years[1] spanning a 57-year period of record (1948-2005) were reviewed. More recent orthoimagery was obtained from Google Earth (1962, 1972, and 2000) and ESRI (2017). A complete list of imagery reviewed is provided in Appendix A.

- *Task 4: Reporting*

A draft report is prepared for distribution and review by Lotic Environmental and by NWP Coal Ltd. Comments and feedback will be incorporated into a final report.

3.0 Geomorphological Context of Study Area

The geomorphological assessment was conducted within the Aquatic Local Study Area, for the purposes of making the assessment applicable to other disciplines including the Fish and Fish Habitat Effects Assessment. Grave Creek was not assessed as the hydrological impact from the Project was found to be negligible. To this end, the assessment made use of the same reaches (within the West Alexander and Alexander Creeks) that were identified and assessed by Lotic Environmental (2020).

3.1 Alexander Creek Watershed

The Alexander Creek watershed has an area of ~185 km^2. The watershed has a total relief of 1304 m, from a high point of 2656m at Mount Secord (part of the mountain ridge forming the western boundary) to its mouth at 1352 m where it joins Michel Creek (see Figure 1.2). The watershed is predominantly oriented in a north-south direction, and the valley side slopes have a predominantly east-west aspect. Alexander Creek flows south from its headwaters along a total length of ~25 km to its confluence with Michel Creek, a tributary to the Elk River, located southeast of Sparwood, BC.

[1] Air photos from 1948, 1952, 1962, 1969, 1972, 1977, 1981, 1984, 1994, 2000 and 2005.

Alexander Creek is a 4th-order stream, with several small steep mountain tributary catchments. The largest tributary is West Alexander Creek, with a catchment area of ~15km^2 (8% of total watershed). The Crown Mountain Project footprint is located entirely within the West Alexander Creek subbasin (and it extends outside the watershed to the northwest).

3.2 Alexander Creek Hydrology

The hydrologic regime of a watershed, which is characterized by runoff, influences the transport of sediment and stream channel evolution in-channel processes. Streamflow is the result of hydrologic processes that derive from the complex interaction between weather and the biophysical environment (Winkler, et al. 2010). Baseline hydrologic conditions in the Alexander Creek watershed are summarized in a report by Dillon Consulting (2020). The report is prepared to inform the environmental assessment process to determine potential impact of the Project on hydrology. This report, together with other readily available data is used to summarize the following characteristics of the hydrologic regime considered relevant to the fluvial geomorphology assessment.

- The mean annual discharge of Alexander Creek is 2.9 m^3/s and for West Alexander Creek is 0.2 m^3/s (approx. 7% of the total) (Dillon Consulting, 2020).
- Most runoff occurs between April and July. The timing of peak runoff is coincident with the annual spring freshet, which is driven by snowmelt. Low runoff conditions occur in September-October due to lack of snowmelt and rain, and in the winter months (Jan-Feb) due to below freezing temperatures.
- Peak (maximum) flows occur in May-June and are attributed to snow melt and/or rain-on-snow conditions. Previous analysis did not include a flood frequency analysis.

3.2.1 Past Flood Events in the Area

Floodplain mapping and an accompanying design brief has been completed for the lower reaches of Michel Creek, downstream of Alexander Creek, near Sparwood, BC (SRK-Robinson Inc., 1995). The design brief includes anecdotal reports of historic flood events within the region. Annual extremes (maximum daily flows) over the period of record are reported for several active hydrometric stations in the region, but not for Alexander Creek specifically. Based on the record for these other hydrometric stations in the area and from recorded flood events in the Southern Interior (Septer, 2007), significant past flood events in the local region have occurred during the following years:

- 1948 (year of historic flooding throughout southern BC)
- 1951 or 1952 (anecdotal only)
- 1974 (high flows recorded, but no reported flood issues in Sparwood area at the time)
- 1995 (early June heavy rain (60mm) on a late snowpack)

- 2013 (spring rain on a late snowpack caused extreme flooding throughout the east Kootenays and Rocky Mountains with many documented impacts through the region).

3.2.2 Climate Change Effects on Hydrology

Future climate projections for the Columbia River Basin, developed by PCIC (2014) predict increases in average annual temperatures and more frequent extreme warm temperatures. With some degree of uncertainty, the models project increases in total annual precipitation, with a greater proportion falling in the winter months (as rain), as well as more frequent, and larger, precipitation extremes.

Predicted changes in climate are expected to result in higher average annual stream flows. The primary increases are predicted to occur in the late fall and winter, while decreases in streamflow are projected for the late summer and early fall.

Climate change effects on hydrology will have a corresponding effect on fluvial geomorphology. Of greatest relevance to the evolution of the channel are predicted changes in the frequency of extreme floods. Floods, such as those that occurred in 1995 and 2013, are associated with spring rains on a late snowpack and may accelerate the rates of channel development, particularly where reaches are sensitive to change.

3.3 Sediment Sources

Alexander Creek lies within a large glacially-scoured (u-shaped) valley, characterized by a relatively broad, flat valley bottom and steep valley side slopes that extend upwards into mountainous headwaters. Sediment is generated from steep, bedrock and colluvium-mantled slopes and transferred downslope to the valley bottom. Where there is direct connection with tributary creeks, or the mainstem channel, there is potential for sediment delivery. Sediment sources influence the composition of the stream bed (i.e., substrate), influence the nature of channel bedload (i.e., sediment that is entrained in flow) and influence the character of stream channel morphology.

Reconnaissance-level terrain stability mapping is available for the Alexander Creek watershed (iMAPBC, 2006). The mapping indicates that the valley bottom hillslopes above the stream channel are predominantly “stable”. There are limited areas of steep valley side slopes that are classified as “potentially unstable” and that are directly connected to the creek.

Large-scale natural sediment sources to Alexander Creek, and to the lower reach of West Alexander Creek (downstream of the Project area), are identified and mapped on the most recent (2017) orthophotos (see Figures B1 to B4; in Appendix B). Detailed site-level sediment sources are not identified due to the photo scale and resolution and the fact that this stage of the study is a desktop assessment and does not include field assessments and ground-truthing.

Notable sediment sources summarized by reach based on the desktop analysis are shown in Appendix C and detailed below:

- A colluvial fan on the west slope above West Alexander Creek (Reach WAL1) just upstream of the confluence with Alexander Creek, with evidence of snow avalanche and active sediment transport reaching the valley bottom. Although less active than historically, the small steep tributary has the potential to deliver sediment and disrupt channel pattern within the first reach of West Alexander Creek and at the confluence (Figure B1).
- Reach ALE7 of Alexander Creek lies within a relatively wide valley bottom but the channel is, at times, partially connected to adjacent valley side slopes that exhibit some gully erosion and landslide activity. These provide sources of sediment to the channel and may have contributed to some historic channel avulsions (i.e., rapid abandonment of a channel and formation of a new channel) (Figure B1).
- There are several steep, unstable tributary sub-basins with relatively well-developed colluvial fans that occupy the valley bottom of Alexander Creek (Reach ALE7). Some of the fans have been truncated by downcutting of Alexander Creek, which indicates that the fans are no longer active contributors to the valley. There is, however, potential for less-frequent larger-scale geomorphic activity from the tributaries into Alexander Creek (Figure B1).
- Two large landslides are identified on the left bank (see Figure B2 – Reach ALE7). The slides appear to be large-scale rotational slumps that may have been triggered by loss of toe support by undercutting. The largest of the two slides was visible on the 1948 air photos and the second slide, located immediately upstream was first noted on the 1962 air photos. Both landslides remain active in appearance on subsequent air photos and have contributed to a split in flow and a shift in channel pattern at the upstream end of a wide floodplain area.
- Reaches ALE5 and ALE6 are largely decoupled from the adjacent valley side slopes, and there are no major tributaries entering the Alexander Creek mainstem through these reaches.
- Alexander Creek Reach ALE4 (see Figure B4) is incised within a glaciofluvial terrace with steep unconsolidated banks and numerous sediment sources characterized as high, unstable banks located on the outside meander bends.
- Reach ALE3 is at the mouth of the Alexander Creek valley where the terraced side slopes open up. The reach loses confinement and there are few identified large-scale sediment sources.
- Alexander Creek Reach ALE2 (Figure B4) and Reach ALE1 (Figure B5) are tightly constrained within the valley bottom and are confined by the Highway 3 embankment, a railway embankment, and adjacent valley slopes. These slopes have sites of instability and provide a source of sediment to the creek.

3.4 Fish Distribution, Use, and Habitat Quality

A baseline conditions assessment of fish and fish habitat was prepared for Alexander Creek and the West Alexander Creek tributary by Lotic Environmental (2020). The study determined fish distribution and habitat condition. The results of the assessment provide a foundation upon which an environmental effects assessment will be conducted.

The distribution of fish-bearing status as determined by Lotic Environmental is illustrated in Figure 1.2.

Fish use varies by reach but for two primary fish species, including species of Special Concern in BC (blue-listed) native Westslope cutthroat trout (WCT) and bull trout (BT), are characterized as follows:

- Fish are able to access all study area reaches of Alexander Creek and the first reach of West Alexander Creek (WAL1), downstream of the Project site;
- There is good juvenile rearing potential for most reaches providing access to diverse habitat;
- There is good adult rearing potential for low gradient reaches with deeper pools and abundant overhead cover; and,
- There is good spawning potential for most reaches downstream of the confluence with West Alexander Creek. Bull trout spawning potential is more limited.

The fish habitat assessment results, as they pertain to the stream channel geomorphology, are summarized as follows:

- Watershed geomorphology as a whole, provides a diverse and varied environment that provides suitable habitat for all life stages of fish utilizing the system;
- Because fluvial environments vary on a reach by reach basis, connectivity between the environments is important;
- For reaches downstream of the Crown Mountain Project site (Figure 2), instream fish habitat quality was generally considered good quality in a relatively unimpacted condition.

4.0 Fluvial Geomorphology Characteristics of West Alexander Creek and Alexander Creek

4.1 Reach Break Analysis

Stream channel reach breaks were identified and delineated for the Fish and Fish Habitat Baseline Assessment (Lotic Environmental, 2020). The reaches defined by Lotic (2020) are shown on Figure 2 and on other accompanying figures in this report. The stream reaches define length of stream having similar hydrologic and physical characteristics including, but not limited to, confinement, gradient, sinuosity, aggradation, single-channel vs multiple-channel, riparian vegetation, and other characteristics. Reach breaks define a change in characteristics between reaches.

Table 4.1 provides a summary table of reach characteristics, as determined from GIS and supplemented by field data collected in Lotic Environmental (2020). Reach WAL1 d/s is the 700m long section downstream of the Project footprint.

Table 4.1: List of Study Area Reaches

Reach No.	Length (km)	Avg. Gradient (%)
ALE1	1.55	1.8
ALE2	2.81	1.9
ALE3	1.12	0.9
ALE4	3.24	1.2
ALE5	2.83	1.3
ALE6	1.98	1.9
ALE7	10.11	1.0
WAL1 d/s	0.7	1.6

4.2 Fluvial Geomorphological Characteristics of Study Reaches

Based on a review of air photos and imagery, the fluvial geomorphology characteristics for each reach were distinguished. All study reaches, downstream of the proposed Project, are relatively low gradient (<2%) as shown in Table 4.1 and have a predominantly riffle-pool channel morphology, with short sections with a slightly steeper cascade-pool morphology. Study reaches vary in confinement and channel pattern, as summarized in Table 4.2, below and shown in Figure 4.1.

Table 4.2: Fluvial Geomorphological Characteristics of Study Reaches

Reach No.	Confinement	Channel Pattern
West Alexander Creek		
WAL1 d/s	Channel is partially connected to the adjacent steep valley side slopes. There is potential for channel movement across the lower gradient areas approaching the confluence with Alexander Creek.	West Alexander Creek is a narrow channel that is obscured from view due to mature forest cover. It appears to have some sinuosity and possible side channels where the gradient remains low.
Alexander Creek		
ALE7	Channel is relatively unconfined within a wide valley bottom. Alignment is influenced and, at times, redirected along short sections due to tributary fans, valley side slopes, or large landslides.	The channel is highly sinuous and often braided, with numerous side channels. When partially confined, the channel is steeper and less sinuous. Where unconfined, the channel pattern is irregular. This is attributed to movement around large-woody debris jams and accumulated sediment.

Reach No.	Confinement	Channel Pattern
ALE6	Channel is tightly confined within banks that are likely bedrock-controlled. There is a lack of valley bottom sediment sources.	The channel is single and sinuous, lacking visible channel instability or braiding. There is little visible within-channel sediment storage. It is a steeper reach that is characterized as a transport reach.
ALE5	Channel is not well-confined but the valley bottom is narrowed due to colluvial fans or aprons of colluvial material along the valley side slopes.	The valley bottom floodplain opens up, but the channel remains predominantly single channel with occasional side channels. Mature riparian forest makes it difficult to observe channel changes, but the historical sequence indicates some evidence of past channel instability through this reach.
ALE4	Channel has downcut through valley-bottom glaciofluvial terrace deposits and has become fairly well-confined between steep, unconsolidated scarp slopes.	A narrow valley bottom limits ability for lateral channel movement. Bank erosion on the outside meander bends often leads to bank or scarp slope instability. There are numerous large sediment sources along this reach.
ALE3	Partial confinement at the confluence with a valley tributary at the mouth of the Alexander Creek valley.	Singular channel with noted valley bottom wetland areas that are likely inundated during high flows. The wider valley bottom allows for greater sinuosity and reduced flow velocities.
ALE2	Tightly confined within a narrow valley that is shared with Highway 3.	Singular channel, lacking sinuosity due to confinement. Relatively stable morphology, although subject to high flow velocity due to confinement, and localized bank erosion.
ALE1	Confined between steep hillslopes and Highway 3. Short sections become less confined.	Single channel with slightly sinuous pattern. Short sections with a wider floodplain allow for some channel movement. Localized bank erosion and hillslope sediment sources.

4.3 Relative Importance of Natural Sediment Sources

Determining the relative importance of natural sediment sources in comparison to the potential Project-related effects on sediment load is an important part of characterizing channel sensitivity to disturbance. If natural sediment sources are significant and dominate the sediment regime, the Project-related effects may not be detected.

Natural sediment sources, attributed to valley side slope landslides, gullies and mountainous tributary catchments, dominate the sediment regime on Alexander Creek, downstream of the Project site. The sediment regime on West Alexander Creek will be dominated by changes in flow and sediment detention attributed to the Construction and Operation of the Sediment Pond.

4.4 Comparative Image Analysis of the Stream Channel

A review of historical air photos over a 57-year period of record was completed. Interpretation of reach-based stream channel changes was completed for Alexander Creek downstream of the West Alexander Creek confluence, and for the lower part of the first reach of West Alexander Creek (WAL1 d/s). A detailed assessment of site-level changes for the ~25-kilometer-long section of mainstem channel within the study area is outside the scope of work for this assessment.

Major watershed-scale events and historical land use activities that have the potential to affect stream channel geomorphology include:

- Large-scale wildfire affecting the south-western half of the watershed in the early-1900s. The loss of forest cover over a large proportion of the watershed would have affected watershed hydrology by increasing flow yield and increasing peak flows at least for the period until the forest recovered.
- Other land use activities that may have affected watershed hydrology and/or stream channel geomorphology includes: forest harvesting and road building, clearing and riparian vegetation disturbance attributed to livestock range activities, and other localized disturbances attributed to landslides, stream bank erosion, snow avalanche or tributary stream inputs (flooding, debris flood and/or debris flow).

The channel centreline was digitized and mapped on the 2017 orthophoto (see Figures B1 to B5, in Appendix B) and the stream channel centreline was digitized and mapped on the 1962 air photos (rectified and georeferenced) (see Figures C1 to C4; in Appendix C). Where the stream channel splits or becomes braided, the primary channel (or channel thalweg) was traced. Due to scale and resolution, the level of accuracy is in the order of approximately 20m. For this reason, site-level changes and detailed measurements of channel migration are not possible. Rather, general observations regarding channel pattern, sinuosity and general character are provided.

A comparative analysis of stream channel changes over the 55-year period between 1962 and 2017 is made possible by overlaying the two centrelines. Due to resolution, scale, and image distortion mapping inaccuracy (+/- ~20m) allows only for high-level comparisons.

Over the 55-year period between 1962 and 2017, Alexander Creek likely experienced several large flood events (1974, 1995, 2013 events on nearby creeks), forest harvesting, mineral resource exploration activity, and range use – all of which may have led to changes in channel geomorphology. The lower reaches of Alexander Creek (Reaches ALE1 to ALE3) have been highly modified and disturbed by highway, rail and other linear infrastructure development, so a comparison is not provided for these reaches. A summary of notable channel changes over the period is provided in Table 4.3.

Table 4.3: Notable Channel Changes Between 1962 and 2017

Reach	Notable Channel Changes
WAL1 d/s (Figure B1)	Due to small channel size and riparian forest cover, the channel is not easily distinguished. The lower parts of the reach do have some side channels and there appears to be some instability approaching the confluence with Alexander Creek. There are also historic roads and stream crossings near the confluence, which become difficult to distinguish on the air photos.

Reach	Notable Channel Changes
ALE7 (Figures B1, B2 and B3)	There are several areas of significant channel change (see Section 4.2.1). Overall, the channel narrowed, became considerably (30%) less sinuous[2], with possible meander cut offs and abandonment of side channels. There is less visible substrate (mid- and side-channel bars) on the 2017 imagery. However, this may be attributed to increased riparian forest cover and just not as visible. This would require field confirmation.
ALE6 (Figure B3)	Relatively unchanged between 1962 and 2017.
ALE5 (Figures B3 and B4)	Minor changes in channel alignment through a section of low-gradient meadow (mid-Reach). There are no obvious sources of sediment but there are avalanche paths upslope of the left bank of the channel. The channel is, however, relatively uncoupled to the valley side slopes. Small-scale changes in channel alignment may be attributed to a natural meander progression, changing function of large woody debris (debris jams, for example) and/or localized channel disturbance.
ALE4 (Figure B4)	Very little channel change noted except for one location (~50m diversion), which may be a split in flow. Increased vegetation cover along valley side slopes indicating increased stability. Isolated landslide sites on outside meanders noted in both 1962 and 2017.

4.4.1 Focused Areas of Interest

Several areas of significant channel change noted along Reach 7 of Alexander Creek, downstream of the confluence with West Alexander Creek were identified. These focused areas of interest are examined in more detail and 2017 imagery are provided in Figures 4.2 to 4.4.

Although detailed measurements are difficult to obtain from the imagery, some general reach-based observations of channel change were noted. A summary of these observations is provided in Table 4.4.

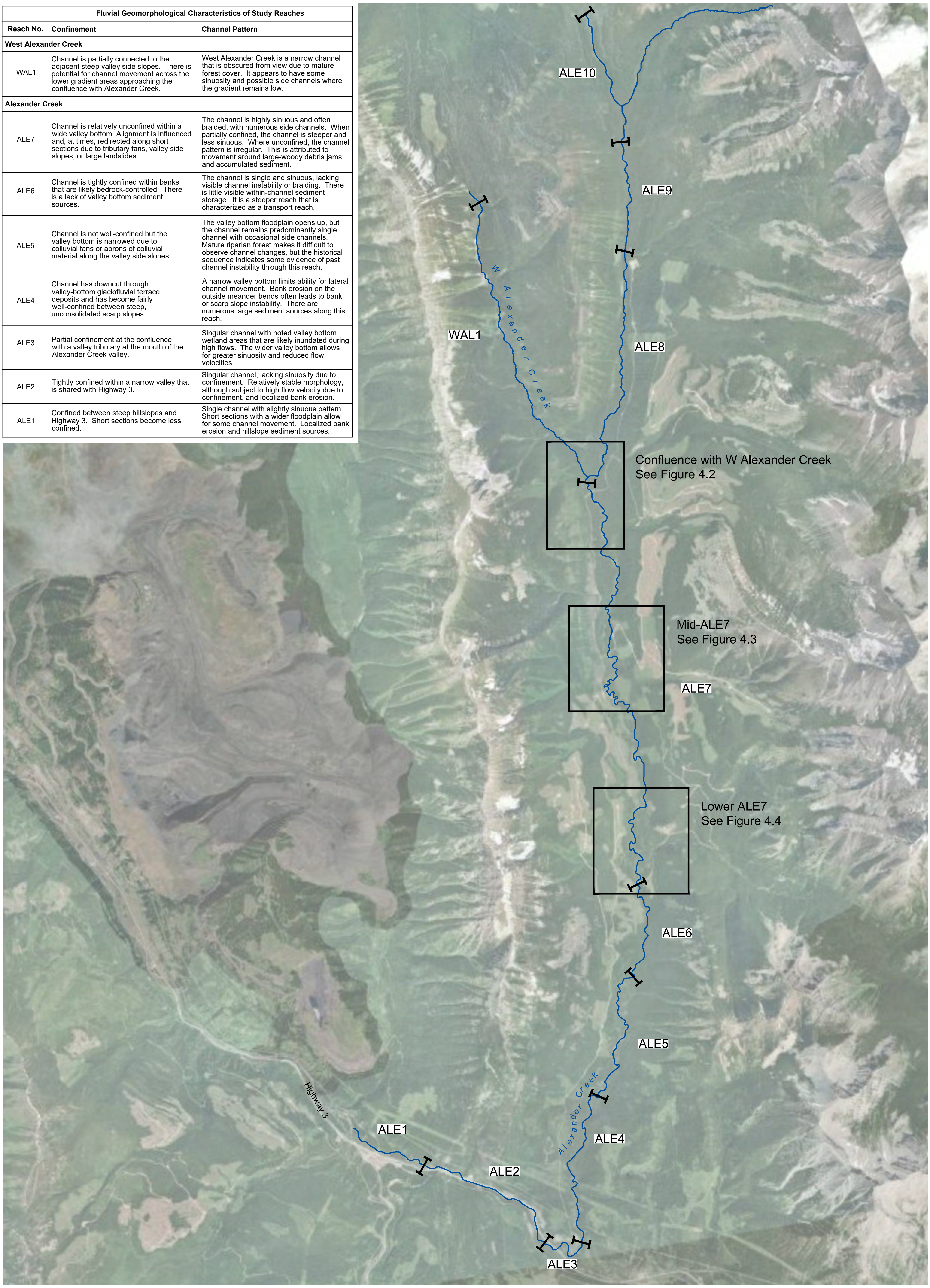
[2] Reach 7: 1962 channel length = 16.1 km versus 2017 channel length = 10.6 km

Table 4.4: Observed Channel Changes between 1962 and 2017 for Select Areas along Alexander Creek (Reach 7)

Area of Interest on Alexander Creek (Reach 7)	Observed channel changes between 1962 and 2017
Area 1 (see Figure 4.2)	Decreased channel length, increased channel gradient, decreased channel width, decreased number of visible flow splits/side channels, decreased sinuosity. In 2017 a large wetland area off the right bank is well developed with some surface water connectivity. This area was a grassy open area with little visible standing water on the 1962 photos.
Area 2 (see Figure 4.3)	Decreased channel length, increased channel gradient, decreased channel width, significantly decreased sinuosity. The channel has cutoff several meanders, resulting in an increased number of flow splits and side channels, where remnants of the historic channels remain.
Area 3 (see Figure 4.4)	Decreased channel length, increased channel gradient, decreased channel width, and decreased sinuosity. Area lies at a slight valley narrowing due to tributary fans on either side of valley. Area is also immediately downstream of the large valley landslide feature that resulted in diverting the mainstem. There remains a groundwater-fed valley sidewall channel along the toe of the slope. The area of interest lacks confinement and has exhibited notable changes in alignment over the period of record.

Fluvial Geomorphological Characteristics of Study Reaches

Reach No.	Confinement	Channel Pattern
West Alexander Creek		
WAL1	Channel is partially connected to the adjacent steep valley side slopes. There is potential for channel movement across the lower gradient areas approaching the confluence with Alexander Creek.	West Alexander Creek is a narrow channel that is obscured from view due to mature forest cover. It appears to have some sinuosity and possible side channels where the gradient remains low.
Alexander Creek		
ALE7	Channel is relatively unconfined within a wide valley bottom. Alignment is influenced and, at times, redirected along short sections due to tributary fans, valley side slopes, or large landslides.	The channel is highly sinuous and often braided, with numerous side channels. When partially confined, the channel is steeper and less sinuous. Where unconfined, the channel pattern is irregular. This is attributed to movement around large-woody debris jams and accumulated sediment.
ALE6	Channel is tightly confined within banks that are likely bedrock-controlled. There is a lack of valley bottom sediment sources.	The channel is single and sinuous, lacking visible channel instability or braiding. There is little visible within-channel sediment storage. It is a steeper reach that is characterized as a transport reach.
ALE5	Channel is not well-confined but the valley bottom is narrowed due to colluvial fans or aprons of colluvial material along the valley side slopes.	The valley bottom floodplain opens up, but the channel remains predominantly single channel with occasional side channels. Mature riparian forest makes it difficult to observe channel changes, but the historical sequence indicates some evidence of past channel instability through this reach.
ALE4	Channel has downcut through valley-bottom glaciofluvial terrace deposits and has become fairly well-confined between steep, unconsolidated scarp slopes.	A narrow valley bottom limits ability for lateral channel movement. Bank erosion on the outside meander bends often leads to bank or scarp slope instability. There are numerous large sediment sources along this reach.
ALE3	Partial confinement at the confluence with a valley tributary at the mouth of the Alexander Creek valley.	Singular channel with noted valley bottom wetland areas that are likely inundated during high flows. The wider valley bottom allows for greater sinuosity and reduced flow velocities.
ALE2	Tightly confined within a narrow valley that is shared with Highway 3.	Singular channel, lacking sinuosity due to confinement. Relatively stable morphology, although subject to high flow velocity due to confinement, and localized bank erosion.
ALE1	Confined between steep hillslopes and Highway 3. Short sections become less confined.	Single channel with slightly sinuous pattern. Short sections with a wider floodplain allow for some channel movement. Localized bank erosion and hillslope sediment sources.



LEGEND

ALE7 — REACH BREAK

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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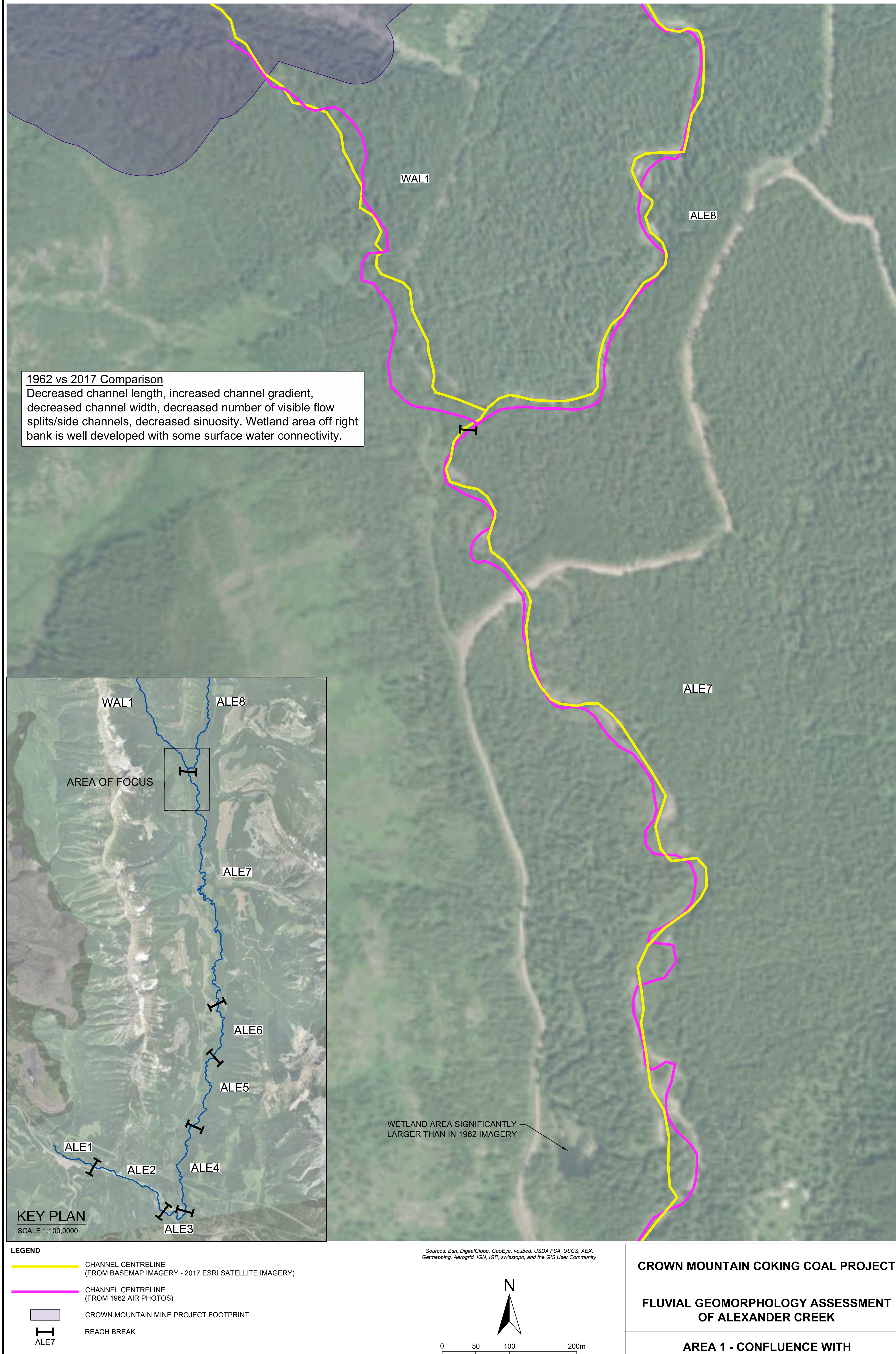
CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

CHARACTERISTICS OF STUDY REACHES

Scale: 1:60,000	NAD 1983 UTM Zone 11 U	Figure No. 4.1
Project No: 21-0104	Date: September 30, 2021	



1962 vs 2017 Comparison
Decreased channel length, increased channel gradient, decreased channel width, decreased number of visible flow splits/side channels, decreased sinuosity. Wetland area off right bank is well developed with some surface water connectivity.

LEGEND

- CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)
- CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)
- CROWN MOUNTAIN MINE PROJECT FOOTPRINT
- REACH BREAK (ALE7)

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 50 100 200m

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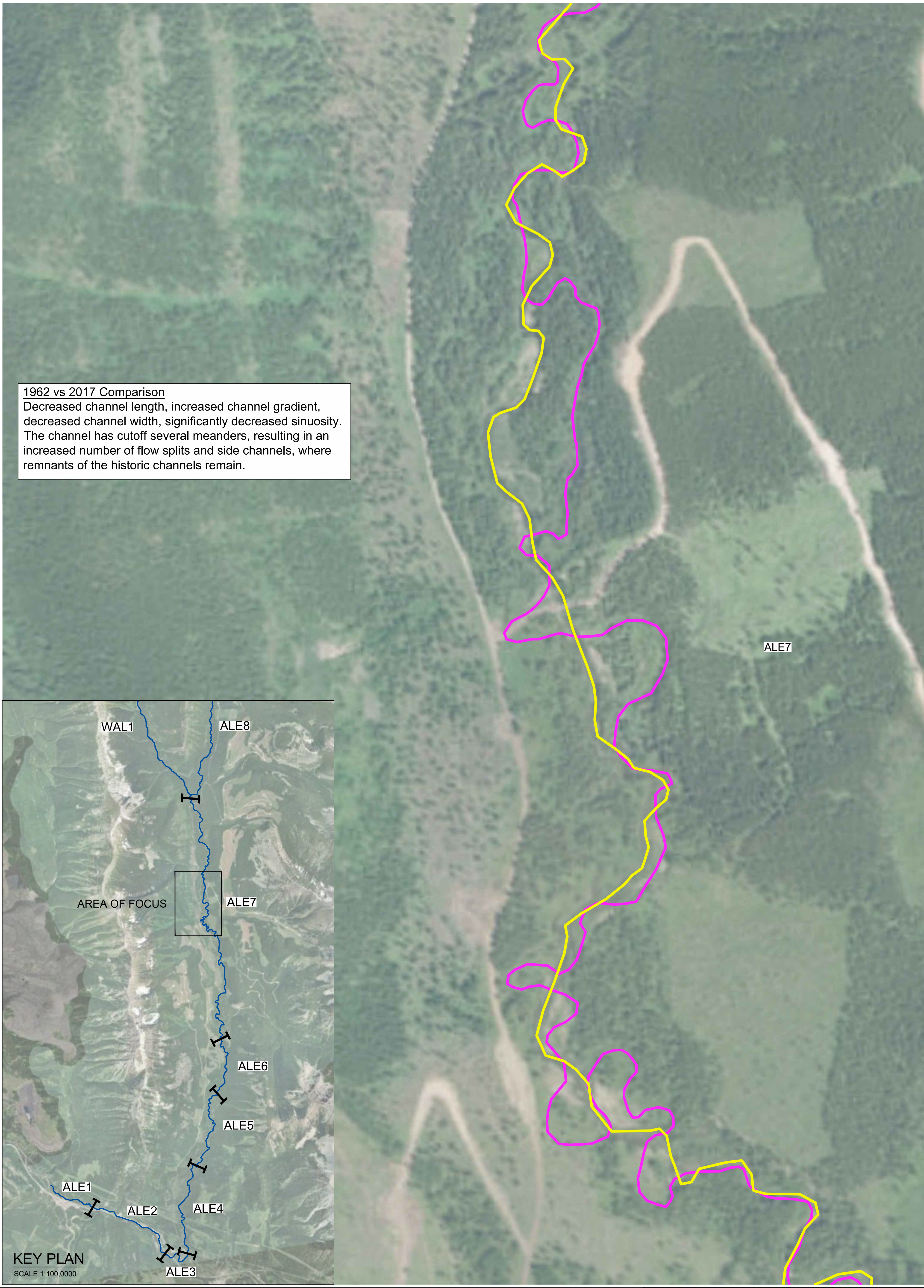
CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

AREA 1 - CONFLUENCE WITH WEST ALEXANDER CREEK

Scale: 1:5,000	NAD 1983 UTM Zone 11 U	Figure No. 4.2
Project No: 21-0104	Date: September 30, 2021	



LEGEND

CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)

CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)

REACH BREAK (ALE7)

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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0 50 100 200m

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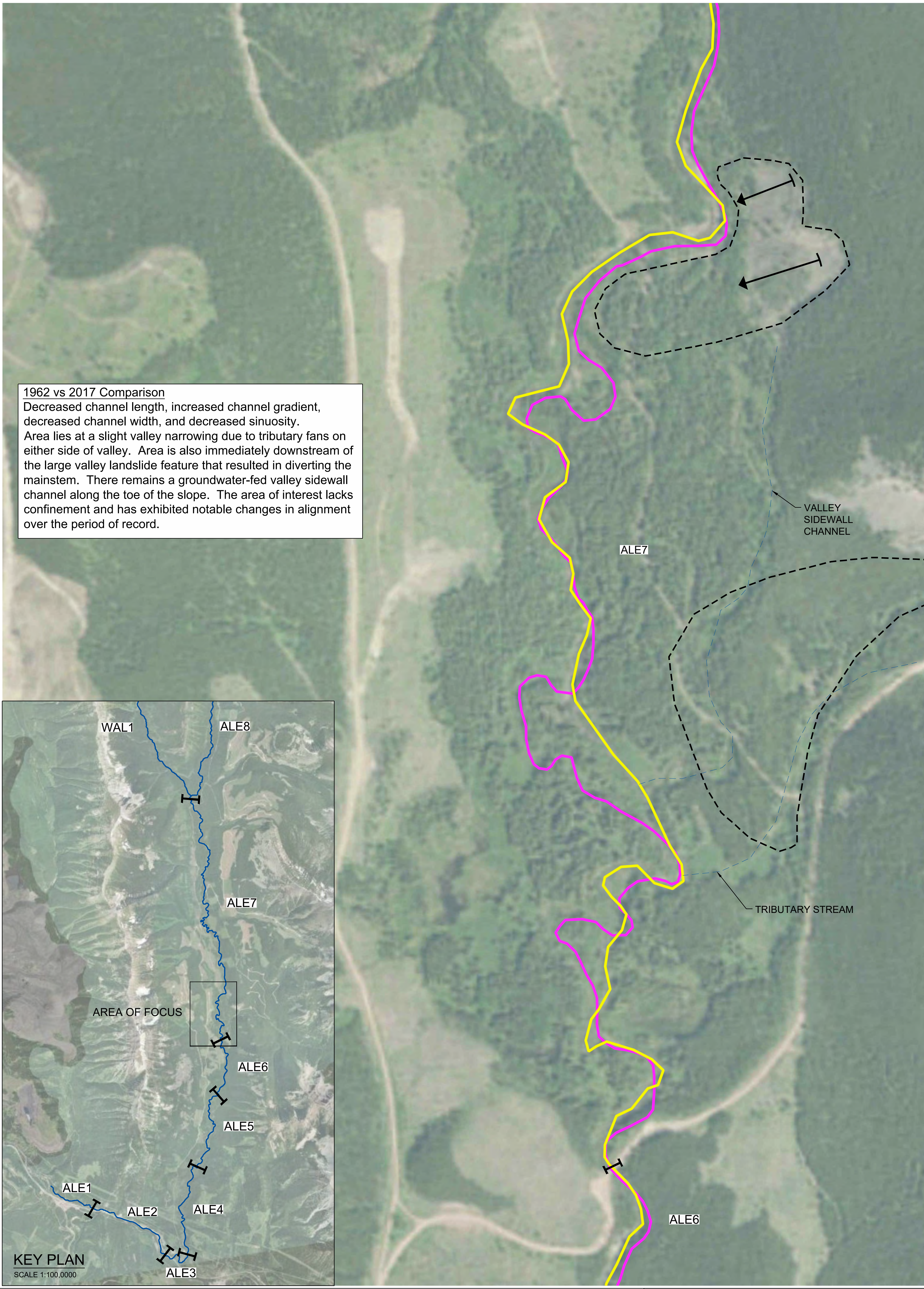
AREA 2 - MID-ALE7

Scale: 1:5,000 | NAD 1983 UTM Zone 11 U | Figure No. 4.3

Project No: 21-0104 | Date: September 30, 2021



LEGEND

- CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)
- CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)
- SEDIMENT SOURCE (TRIBUTARY STREAMS OR LANDSLIDES)
- TRIBUTARY FAN AREA
- REACH BREAK (ALE7)

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 50 100 200m

Clarke Geoscience Ltd.

CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

AREA 3 - LOWER ALE7

Scale: 1:5,000	NAD 1983 UTM Zone 11 U	Figure No. 4.4
Project No: 21-0104	Date: September 30, 2021	

5.0 Potential Project Effects on Stream Channel Geomorphology

5.1 Background Research on Downstream Effects on Fluvial Geomorphology

Downstream effects on fluvial geomorphology are influenced by changes in hydrology (i.e., stream flows that mobilize sediment) and by changes in sediment load (i.e., the amount of sediment available for transport) (Brandt, 2000) (Grant, et al., 2003). Effects on channel pattern and form are influenced by the geologic setting and physical character of the channel.

Grant, et al. (2003) present an analytical framework for predicting channel response. The framework examines the potential for response based on changes in the frequency of sediment-transporting flows and relative changes to sediment supply.

Stream channel sensitivity (or resilience) to change is complex and not easy to predict. The ability to forecast change is difficult due to the inherent variability in the ability for landforms to respond or resist change. The likelihood that changes in a system will produce a response are a function of the channels propensity for change, and the system's ability to absorb that change (Fryirs, 2017).

Although changes occur at different scales, this fluvial geomorphology study focuses on reach-level effects. We acknowledge that there is inherent uncertainty associated with predicting spatial and temporal components of change.

5.2 Summary of Predicted Project Effects on Water Quantity and Sediment Transport

The draft Surface Water Quantity Assessment completed by NWP Coal Ltd. (2021) indicates that the Project, in general has the potential to adversely affect surface water quantity in Alexander Creek through the changing of streamflow characteristics (flow, volume, timing) attributed to modifications to topography and surface cover, and alterations of natural drainage pathways.

Based on the above assessment, the Project will result in flow decreases up to 40% below baseline values downstream of the Sediment Detention Pond on West Alexander Creek. Overall flow decreases on the mainstem Alexander Creek below the confluence are approximately 10% below baseline and decrease in magnitude in a downstream direction (NWP Coal Ltd., 2021).

A summary of project activities and the predicted effect on water quantity and sediment transport is provided in Table 5.1.

The Surface Water Quantity assessment indicates flow decreases through the spring freshet period but does not specifically investigate effects of the Project on flood frequency. It is anticipated that the Pond may reduce the frequency (and magnitude) of peak flows on West Alexander Creek and may have a corresponding (albeit less) effect reducing peak flows on Alexander Creek, downstream of the Project.

Table 5.1: Predicted Surface Water Quantity and Sediment Transport Effects (from NWP Coal Ltd., 2021)

Project Activities	Surface Water Quantity and Sediment Transport Effect
Forest harvest, land clearing and grubbing vegetation from the development footprint	Potential increase in water yield and runoff rates. Potential increase in sediment input to the stream channel due to surface erosion. Potential increase in sediment transport rates to downstream reaches due to changes in runoff and sediment inputs.
Site water management and discharge including construction, operation and eventual decommissioning of the Interim and Main Sediment Pond. Pond will discharge via a controlled outlet structure to West Alexander Creek.	Potential reductions in downgradient stream flow due to sequestering in ponds. Potential increase in downgradient flow due to release of treated wastewater. Upon decommissioning (after 16 year project) flows to downgradient water courses will be restored. Unconfirmed potential decrease in flood frequency (attenuation of peak flows) due to detention at Sediment Pond.

5.3 Potential Effects on Fluvial Geomorphology

Decreases in stream flow (water quantity) and flood frequency may have a corresponding effect on downstream fluvial geomorphology and stream channel condition. Stream channel patterns develop as a function of discharge, timing, the frequency of channel-forming flows, and the movement of sediment (and woody debris). These factors, combined with the physical channel character such as bank materials, confinement, gradient, and substrate manifest in the stream channel.

The primary Project-related component affecting stream channel geomorphology is the Sediment Pond. During Operation the Pond will result in decreased flows and will cut off the supply of sediment from West Alexander Creek to the downstream reaches of Alexander Creek. During Construction and Operation, the Sediment Pond will detain all coarse sediment but will potentially increase inputs of fine sediment that pass through the outlet. During Pond Decommissioning, the coarse sediment and fine sediment input could significantly increase, before eventually returning to pre-development conditions.

Within the context of natural sediment sources, the overall Project-related effects on sediment load are unlikely to dominate in any reach other than the first reach of West Alexander Creek (WAL1). The downstream sections of WAL1 will experience the greatest level of change (water quantity and sediment load) based on the major changes to occur within the contributing catchment area.

The overall effect of reduced mean annual, or mean monthly, flow may decrease the stream's ability to mobilize and transport bedload. This may result in morphological changes consistent with "channel aggradation".

Characteristics of an aggraded channel having a gravel riffle-pool morphology similar to the downstream reaches of Alexander Creek are summarized in Table 5.2, below. Characteristics of an aggraded channel are adapted from Hogan, et al. (1996) to account for the fact that aggradation on the downstream reaches of Alexander Creek is the result of a decreased mean annual, or mean monthly, flow. Streams that are aggraded have excess sediment and channel character includes: shallow pools and low frequency of pools, extensive uniform riffles, and a high channel width/depth ratio with braided channels.

Table 5.2: Characteristics of an Aggraded Channel (with a gravel Riffle-Pool Morphology)

Channel Attribute	**Aggraded Channel Characteristics** (where aggradation is associated with decreased flow, as opposed to increased sediment load)
Morphology	• Extensive riffles and runs • Small, shallow pools (due to infilling) • Multiple channels on a braided bed surface • Lacking habitat diversity due to uniform riffle and run character
Substrate	• Mainly gravel and finer textures (although this will vary depending on baseline substrate character and the nature of sediment sources) • Increased substrate embeddedness due to reduced sediment transport potential and increased fine sediment load
Channel Width/Depth	• Reduced channel width and stabilized bars • Increased width/depth ratio where banks are erodible and where aggradation results in loss of channel confinement • Reduction in undercut/overhanging banks as width decreases
Large Woody Debris (LWD)	• LWD reoriented parallel to bank, as opposed to across/spanning the channel due to loss of stability in a shallower channel

Source: adapted from Hogan, et al. (1996)

Reach WAL1, downstream of the Project and Reach ALE7, downstream of the confluence with West Alexander Creek, are the reaches most likely to experience aggradation. As the overall contributing catchment area increases downstream on Alexander Creek, aggradation may occur to a lesser degree. The characteristics listed in Table 5.2, including more extensive riffles, smaller pools, and increased substrate embeddedness, are anticipated along the affected reaches.

5.4 Sensitivity to Channel Change

Sensitivity, as a geomorphic concept, describes the likelihood and/or severity of a landform to respond or adapt to disturbance (Fryirs, 2017). Disturbances are described as predicted future conditions, or changes, whether they are Project-related or perhaps related to changes in climate or other land use activities in the watershed.

Figure 5.1 illustrates how stream channel sensitivity varies by channel type. This figure forms the basis for a sensitivity classification that is applied to the study area reaches. The classification scheme is presented in Table 5.3. Reaches that are characterized as being high energy, steep gradient, and have a coarser (cobble, boulder, bedrock) substrate are morphologically resilient and have a "low" sensitivity to change. Conversely, reaches that lack competence, have medium energy and moderate slope, with a finer (gravel, sand) substrate are morphologically sensitive and have a "high" sensitivity to change.

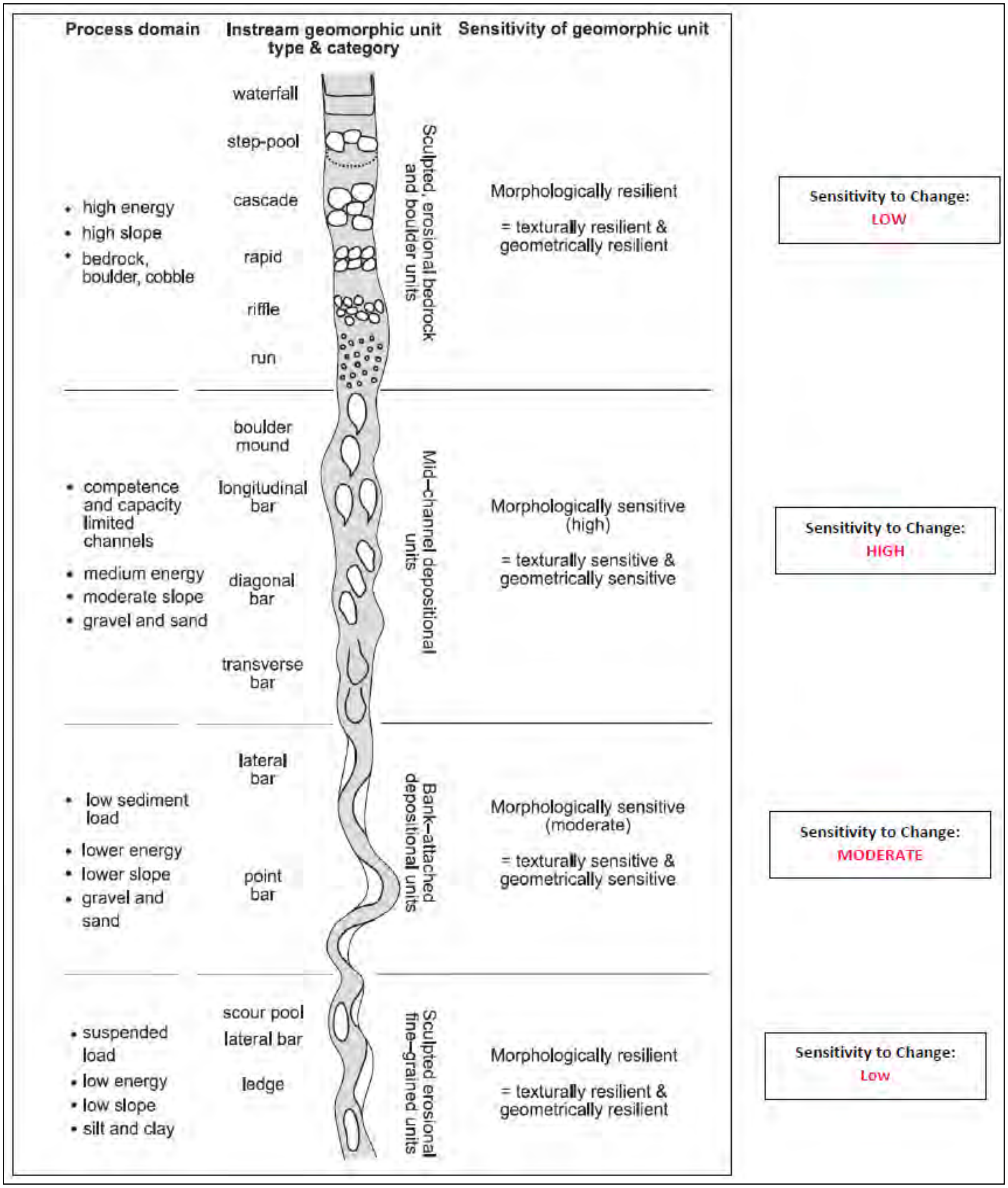


Figure 5.1: Geomorphic Sensitivity for Different Channel Types (adapted from Fryirs, 2017)

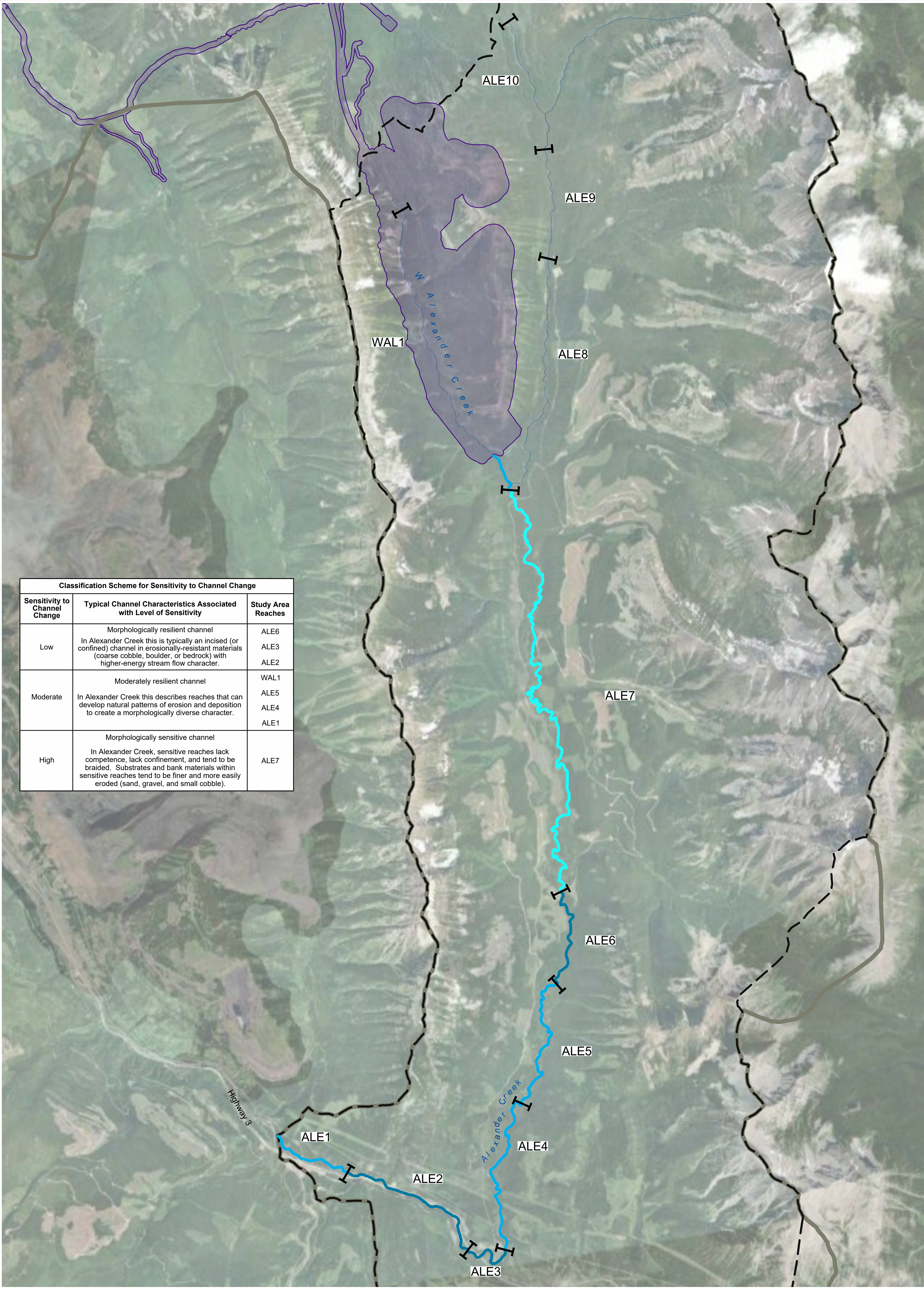
Table 5.3: Classification Scheme for Sensitivity to Channel Change

Sensitivity to Channel Change	Typical Channel Characteristics Associated with Level of Sensitivity	Study Area Reaches
Low	Morphologically resilient channel In Alexander Creek this is typically an incised (or confined) channel in erosionally-resistant materials (coarse cobble, boulder, or bedrock) with higher-energy stream flow character.	ALE6 ALE3 ALE2
Moderate	Moderately resilient channel In Alexander Creek this describes reaches that can develop natural patterns of erosion and deposition to create a morphologically diverse character.	WAL1 ALE5 ALE4 ALE1
High	Morphologically sensitive channel In Alexander Creek, sensitive reaches lack competence, lack confinement, and tend to be braided. Substrates and bank materials within sensitive reaches tend to be finer and more easily eroded (sand, gravel, and small cobble).	ALE7

Based on observed and interpreted stream channel geomorphological characteristics (see Section 4.3) a qualitative measure of sensitivity is assigned to each study reach. A summary of assigned channel sensitivity is provided in Table 5.3 and illustrated in Figure 5.2.

The results indicate that, although Reach 1 of West Alexander Creek (WAL1) is morphologically more resilient, it lies in direct proximity to the Project and its entire contributing catchment is affected. Reach WAL1 will experience the greatest level of change associated with stream flow and with sediment load. Changes are anticipated but not because of the channel sensitivity. Rather, with decreased flow and increased fine sediment load, effects are more likely to include decreased stream width, depth, and increased substrate embeddedness.

Downstream of the confluence with West Alexander Creek, Reach ALE7 of the mainstem channel will be less affected by changes in flow and in sediment load because the Project is affecting only a portion of the contributing catchment area. However, because of its morphological character, it is rated as having a high sensitivity to change. Reach ALE7 is a wide, braided channel, lacking competence and confinement.



Classification Scheme for Sensitivity to Channel Change

Sensitivity to Channel Change	Typical Channel Characteristics Associated with Level of Sensitivity	Study Area Reaches
Low	Morphologically resilient channel In Alexander Creek this is typically an incised (or confined) channel in erosionally-resistant materials (coarse cobble, boulder, or bedrock) with higher-energy stream flow character.	ALE6 ALE3 ALE2
Moderate	Moderately resilient channel In Alexander Creek this describes reaches that can develop natural patterns of erosion and deposition to create a morphologically diverse character.	WAL1 ALE5 ALE4 ALE1
High	Morphologically sensitive channel In Alexander Creek, sensitive reaches lack competence, lack confinement, and tend to be braided. Substrates and bank materials within sensitive reaches tend to be finer and more easily eroded (sand, gravel, and small cobble).	ALE7

LEGEND:

- LOCAL STUDY AREA (LSA) BOUNDARY
- ALEXANDER CREEK WATERSHED BOUNDARY
- CROWN MOUNTAIN MINE PROJECT FOOTPRINT
- ALE1 — REACH BREAK AND NUMBER

SENSITIVITY TO CHANGE

- HIGH
- MODERATE
- LOW

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 0.5 1 2km

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CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

GEOMORPHIC SENSITIVITY TO CHANGE

Scale: 1:60,000	NAD 1983 UTM Zone 11 U	Figure No. 5.2
Project No: 21-0104	Date: September 30, 2021	

5.5 Acknowledging Natural Variability in Channel Sensitivity

Natural systems are complex. Therefore, there is significant variability in the ability for landforms or systems to resist, or absorb, change. Change, and sensitivity to change, is a natural and inherent component of a natural system. It is often difficult to distinguish and/or quantify these changes, thresholds for change, or predict what changes lie within a range of natural variability. Therefore, it is also difficult to determine whether a management response may be warranted.

6.0 Conclusions and Recommendations

6.1 Channel Sensitivity and/or Resiliency to Predicted Changes

The study provides an overview of the fluvial geomorphological context of the study area, including watershed processes, natural sediment supply, and characteristic disturbances impinging the channel. A comparative analysis of the stream channel alignment spanning a period of time that includes at least three past flood events (1974, 1995, and 2013) allows for an assessment of channel sensitivity and/or resiliency to potential future changes in hydrology and sediment load.

The proposed Project-site is located entirely within the West Alexander Creek sub-basin (Figure 1.2). Downstream from this sub-basin, Alexander Creek is an irregularly sinuous channel that extends approximately 25km downstream to Michel Creek.

The assessment results identify and highlight the study area reaches having a greater propensity for channel adjustment or changes to the channel morphology. Reaches that exhibit historic instability and/or have characteristics that make them more vulnerable are identified as being sensitive to the predicted changes in hydrology and sediment load (decreased flow and decreased sediment load).

The study area reach identified as having a “high” sensitivity to change is:

- Reach ALE7 of Alexander Creek, due to immediate downstream location to West Alexander Creek but also because the channel is relatively unconfined, with unconsolidated bank materials, low-gradient, cobble-gravel substrate, and with evidence of significant historical channel changes.

Due to a steeper channel gradient, coarser substrate, and moderate confinement, the morphology of Reach WAL1 of West Alexander Creek is considered slightly more resilient. Due to the anticipated Project effects on flow and sediment load within the West Alexander Creek subbasin catchment, the effects are more likely to affect channel geometry and substrate character.

6.2 Recommendations for Detailed Assessment and Future Monitoring

This fluvial geomorphology assessment is a desktop study that relied on available background information, previous studies, and was based on interpretation of historical air photos and orthoimagery. The scale and resolution of the imagery does not allow for detailed, site-specific analysis. Rather, the study provides an overview-level assessment of stream channel characteristics.

Results of the study identify areas that are more sensitive and subject to channel changes. If these changes are determined to be significant from a fisheries perspective, then more detailed assessment may be warranted. More detailed assessment may include ground-based measurements and site observations to better define channel character and substrate texture and quality.

As the Project moves forward, monitoring the sensitive channel reaches is recommended. Large-scale channel response to changes, whether associated with Project effects or with a natural event, may be recognized by air photo interpretation. This may be completed by repeating the comparative analysis between the most recent imagery (2017) and another future set of images.

Alternatively, monitoring may be completed by establishing downstream reference sites that may be used to compare baseline condition to future conditions. Establishing monitoring sites and parameters would form parts of a Stream Channel Monitoring Plan, which may be developed in conjunction with a Fish Habitat Monitoring Plan. It is recommended that consideration be given for the development of a Monitoring Plan suited to monitor short and long-term effects of the Project.

Ideally the reaches and valley bottom of Alexander Creek (especially Reach 7 and West Alexander Creek) would be captured with high resolution drone imagery to form part of the baseline data. The georeferenced drone orthoimagery would be collected at a low altitude showing far more detail than what would be captured with publicly available air photos or satellite imagery. Drone imagery data can be a very valuable and cost-effective alternative to ground-truthing where access by foot is challenging and time consuming.

7.0 Closure and Limitations

This report has been prepared exclusively for the use of NWP Coal Ltd. and Lotic Environmental. The assessment has been carried out in accordance with generally accepted practice. Professional judgment has been applied in the interpretations provided in this report. No other warranty is made, either expressed or implied.

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Permit to Practice #1000143

Reviewed by:

STIRLING GEOSCIENCE LTD.

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APPENDIX A

List of Historical Imagery Reviewed for the Assessment

Historical Air Photos (stereoscopic hard copy images obtained on loan from UBC)

Year	Flight Line	Photo Numbers	Image quality
1948	A11656 A11650	147-148, 247-248 279	Small scale image
1952	BC1488	39-40	Small scale image, poor quality
1962	BC4105 BC4106 BC4094 BC4095	88-89, 104-105 45-46, 32-33 181-182 7-8, 124-125	Large scale
1969	BC5356	229-232	Small scale
1972	BC7425	112-121, 217-219	Large scale
1977	BC77036 BC77030	27-28 174-175	
1981	BC81038	172-173, 117-118	Small scale
1984	BC84021	275-276, 266-267	Small scale
1994	BCC94132 BCC94133 BCC94135 BCC94127	43-44, 57-58 70-71, 83-84 36-37 43-44	Dark image
2000	BCC00064 BCC00058 BCC00057	9-10 9-10, 205-206 208-209, 8-9	Colour
2005	BCC05022 BCC05077 BCC05078	149-150 211-212 11-12, 34-35	Colour

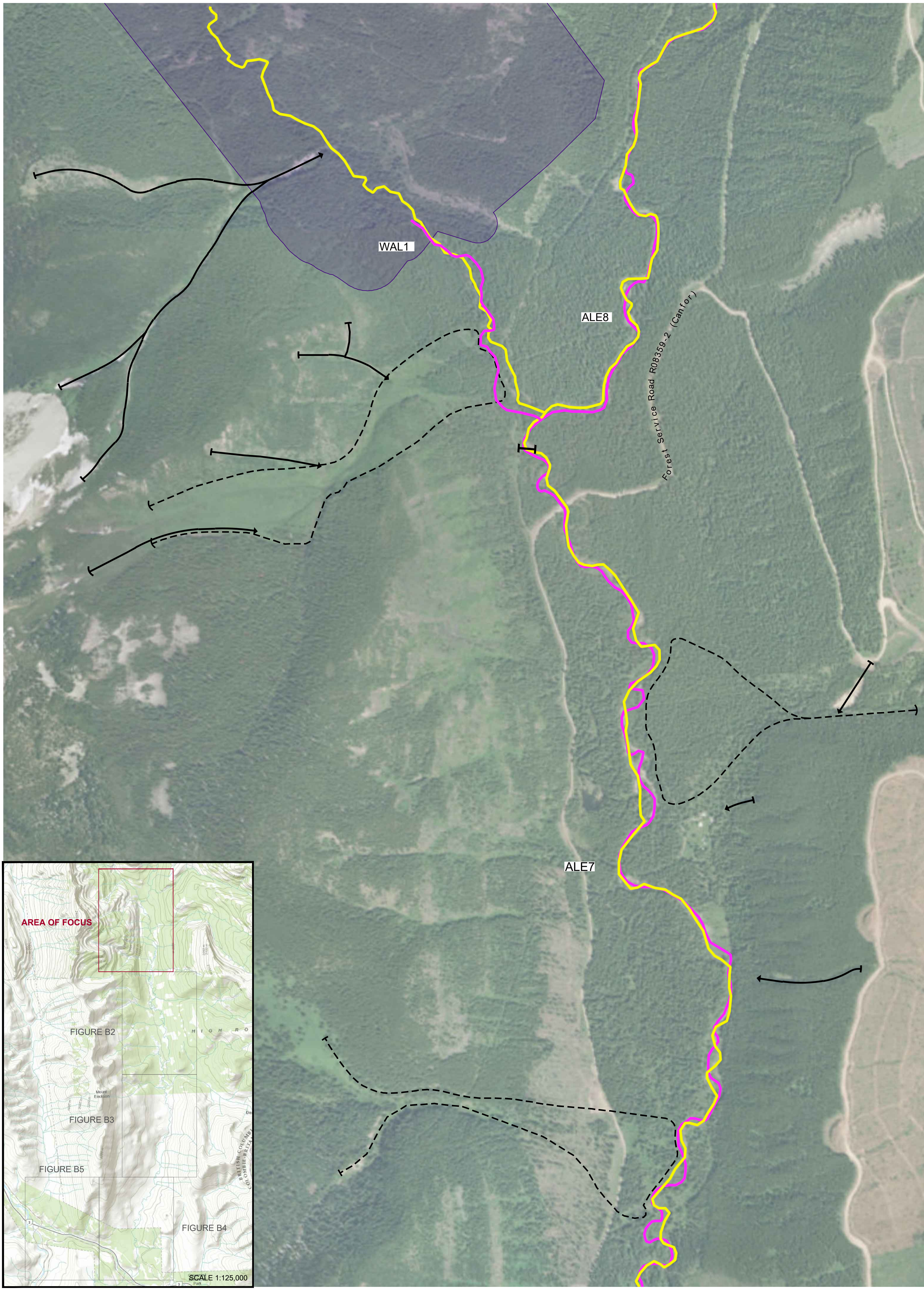
Orthoimagery Obtained from Other Sources

Year	Source	Comment
1962	Google Earth	
1972	Google Earth	
2000	Google Earth	
2017	ESRI World Imagery, sourced from Regional District of East Kootenay	

- Image year selected for comparative analysis

APPENDIX B

Figures B1 to B5 2017 Orthophoto showing 2017 and 1962 Channel Alignment Comparison and Sediment Sources



LEGEND

- CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)
- CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)
- SEDIMENT SOURCE (TRIBUTARY STREAMS OR LANDSLIDES)
- TRIBUTARY FAN AREA
- CROWN MOUNTAIN MINE PROJECT FOOTPRINT
- ALE7 REACH BREAK

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 100 200 400m

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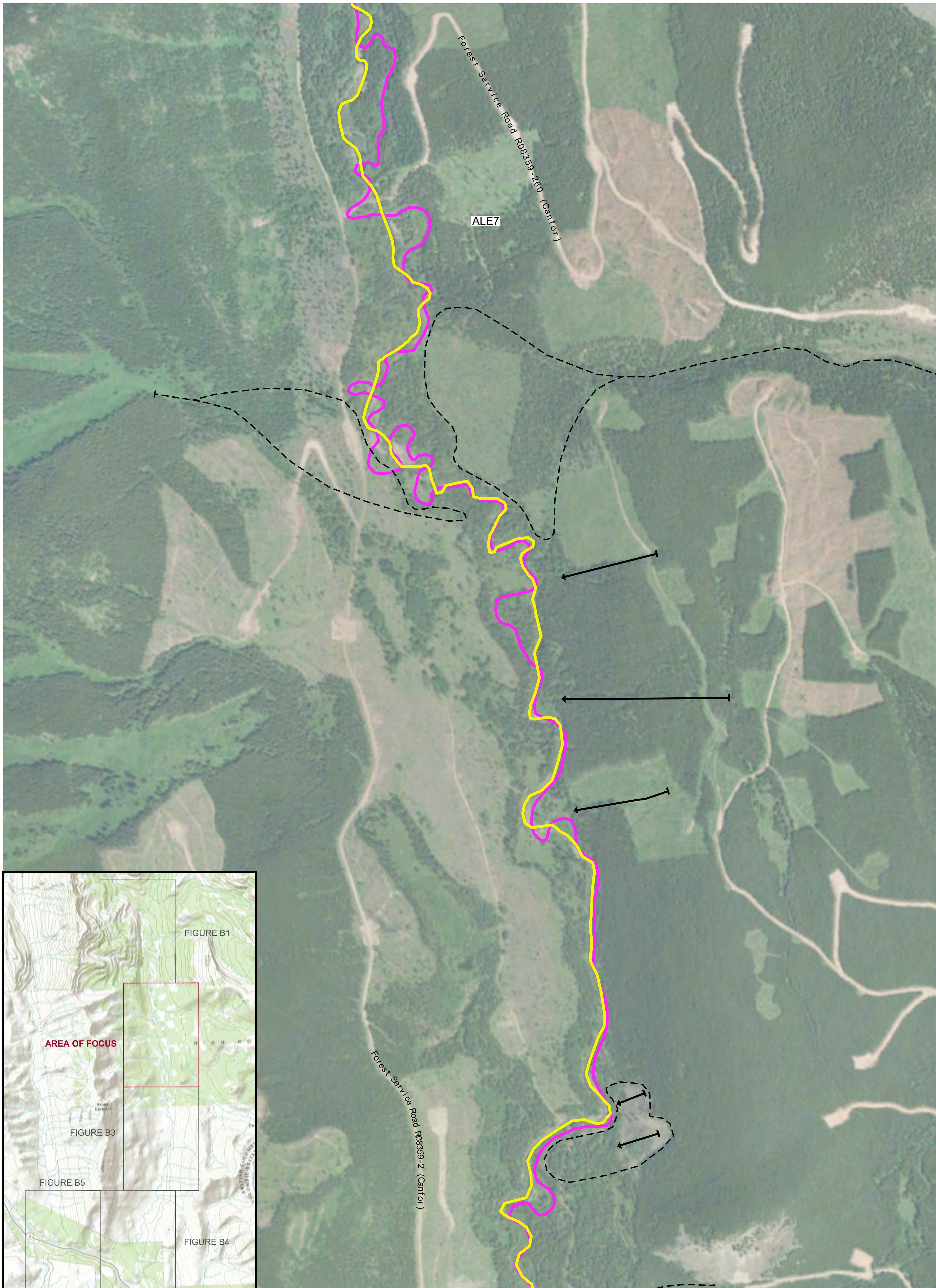
FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

2017 ORTHOPHOTO SHOWING 2017 AND 1962 CHANNEL ALIGNMENT COMPARISON AND SEDIMENT SOURCES

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No. B1
Project No: 21-0104	Date: September 30, 2021	



LEGEND

CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)

CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)

SEDIMENT SOURCE (TRIBUTARY STREAMS OR LANDSLIDES)

TRIBUTARY FAN AREA

ALE7 REACH BREAK

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 100 200 400m

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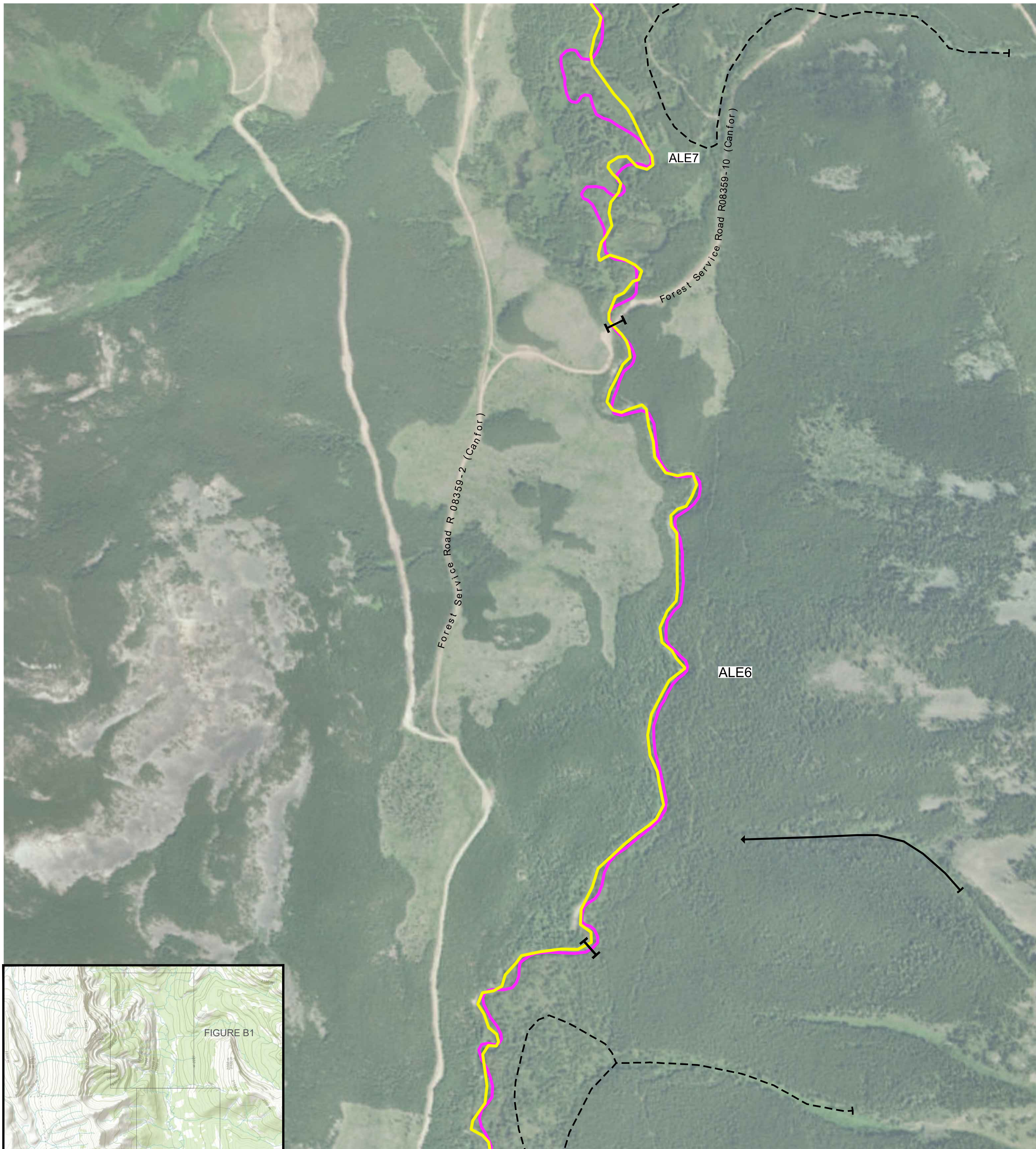
FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

2017 ORTHOPHOTO SHOWING 2017 AND 1962 CHANNEL ALIGNMENT COMPARISON AND SEDIMENT SOURCES

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No. B2
Project No: 21-0104	Date: September 30, 2021	



LEGEND

- CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)
- CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS)
- SEDIMENT SOURCE (TRIBUTARY STREAMS OR LANDSLIDES)
- TRIBUTARY FAN AREA
- ALE5 REACH BREAK

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 100 200 400m

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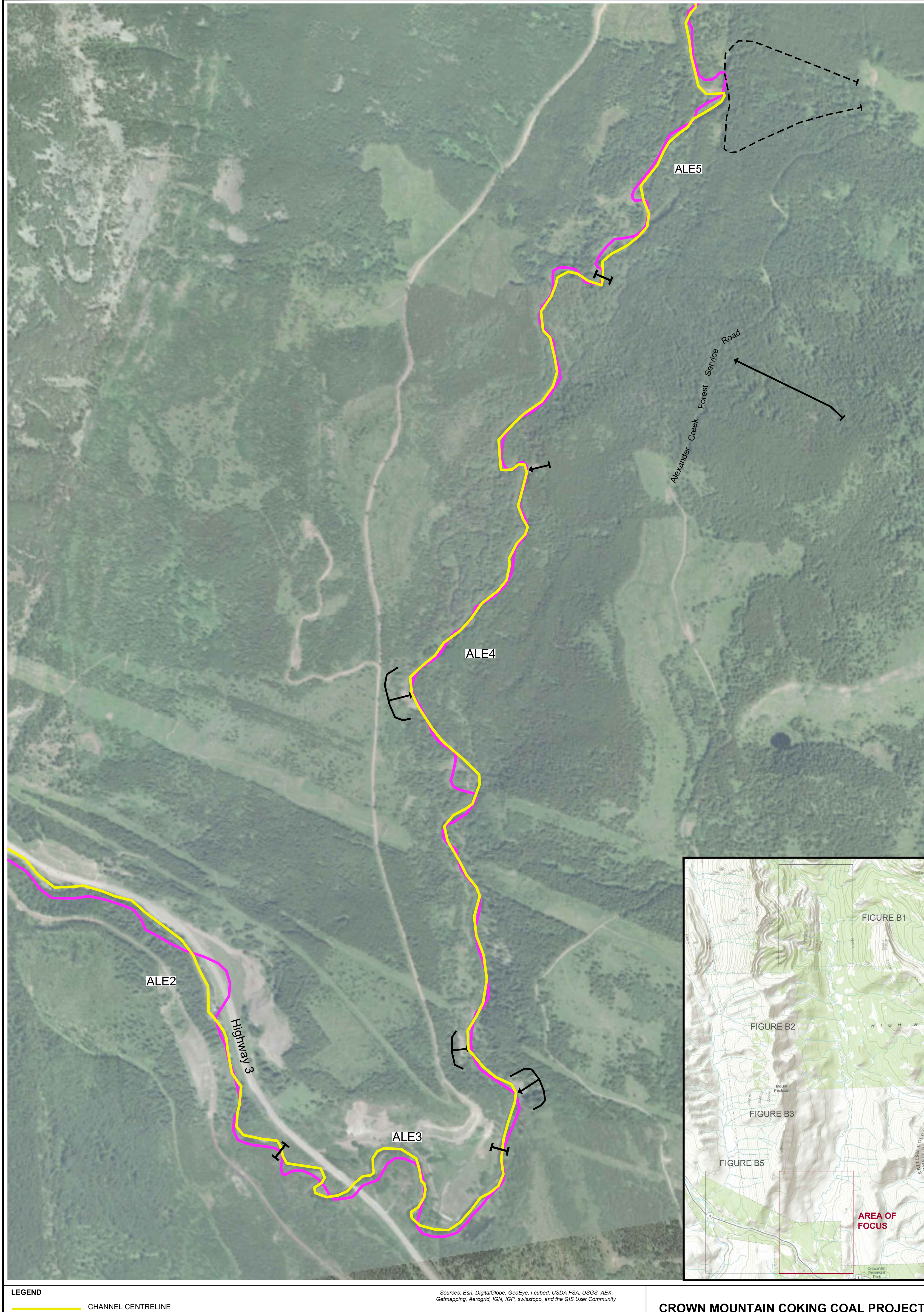
FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

2017 ORTHOPHOTO SHOWING 2017 AND 1962 CHANNEL ALIGNMENT COMPARISON AND SEDIMENT SOURCES

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No. B3
Project No: 21-0104	Date: September 30, 2021	



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FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

2017 ORTHOPHOTO SHOWING 2017 AND 1962 CHANNEL ALIGNMENT COMPARISON AND SEDIMENT SOURCES

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No.
Project No: 21-0104	Date: September 30, 2021	B4

LEGEND

CHANNEL CENTRELINE (FROM BASEMAP IMAGERY - 2017 ESRI SATELLITE IMAGERY)

CHANNEL CENTRELINE (FROM 1962 AIR PHOTOS) HISTORIC AIR PHOTO COVERAGE IS MISSING ALONG REACH ALE1 AND THE DOWNSTREAM PORTION OF ALE2

ALE1 — REACH BREAK

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 100 200 400m

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CROWN MOUNTAIN COKING COAL PROJECT

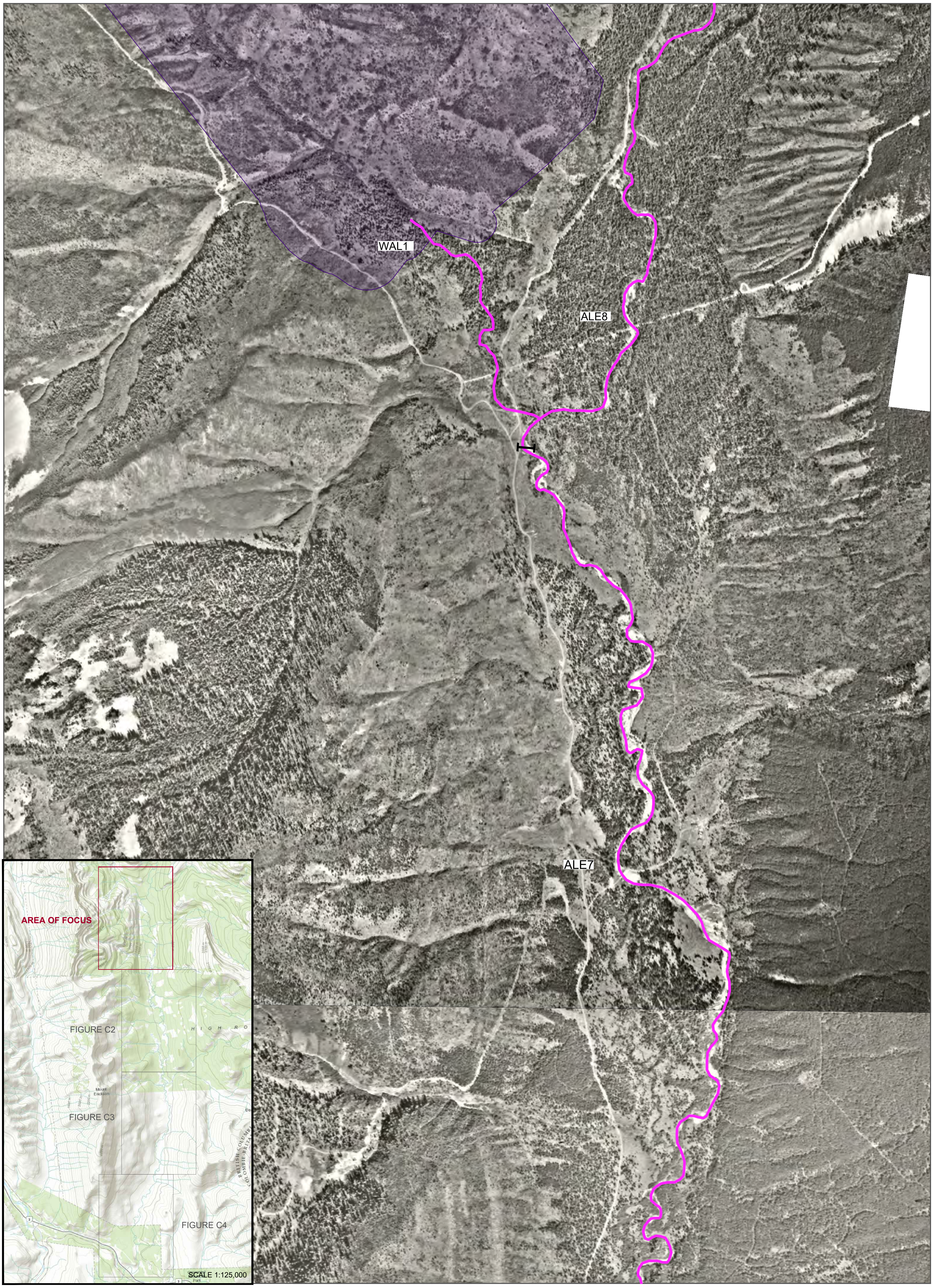
FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

2017 ORTHOPHOTO SHOWING 2017 AND 1962 CHANNEL ALIGNMENT COMPARISON AND SEDIMENT SOURCES

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No.
Project No: 21-0104	Date: September 30, 2021	B5

APPENDIX C

Figures C1 to C4 1962 Historical Air Photo showing Channel Alignment



LEGEND

- CHANNEL CENTRELINE (1962)
- CROWN MOUNTAIN MINE PROJECT FOOTPRINT
- REACH BREAK (ALE7)

Air Photo Source: National Air Photo Library

N

0 100 200 400m

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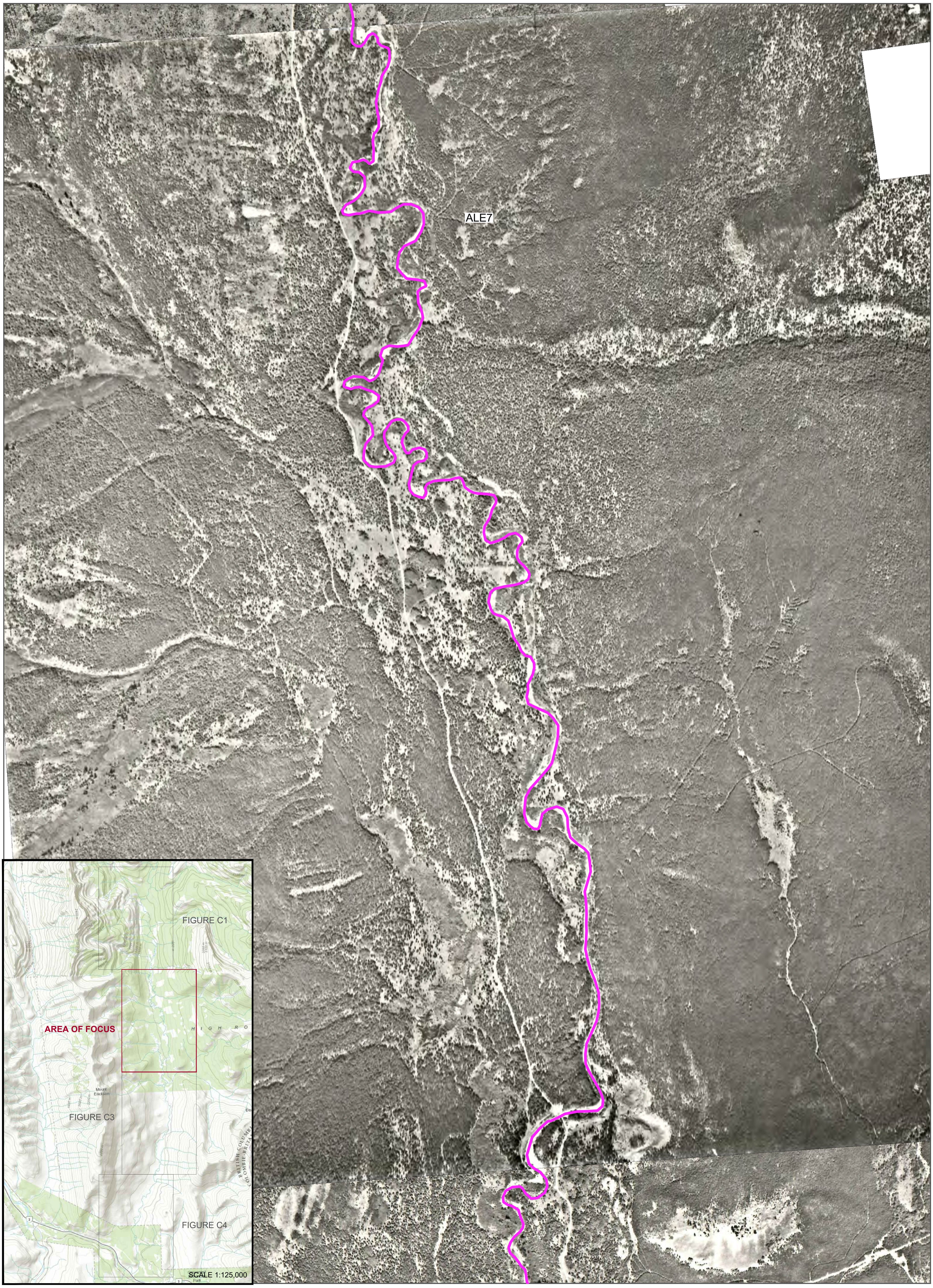
CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

1962 HISTORICAL AIR PHOTO SHOWING CHANNEL ALIGNMENT

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No.
Project No: 21-0104	Date: September 30, 2021	C1



LEGEND

CHANNEL CENTRELINE (1962)

ALE7 REACH BREAK

Air Photo Source: National Air Photo Library

N

0 100 200 400m

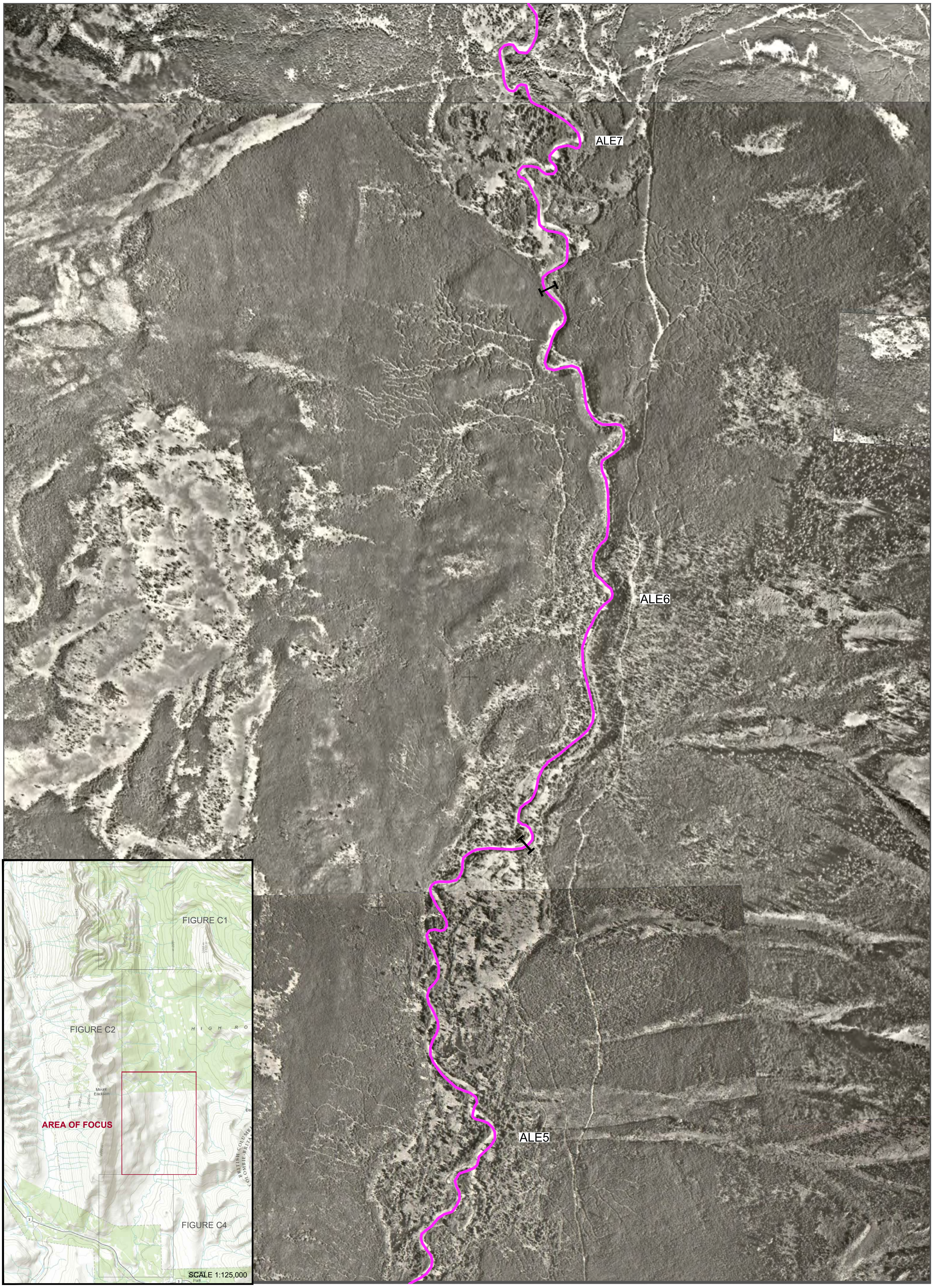
Clarke Geoscience Ltd.

CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

1962 HISTORICAL AIR PHOTO SHOWING CHANNEL ALIGNMENT

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No.
Project No: 21-0104	Date: September 30, 2021	C2



LEGEND

CHANNEL CENTRELINE (1962)

ALE6 — REACH BREAK

Air Photo Source: National Air Photo Library

N

0 100 200 400m

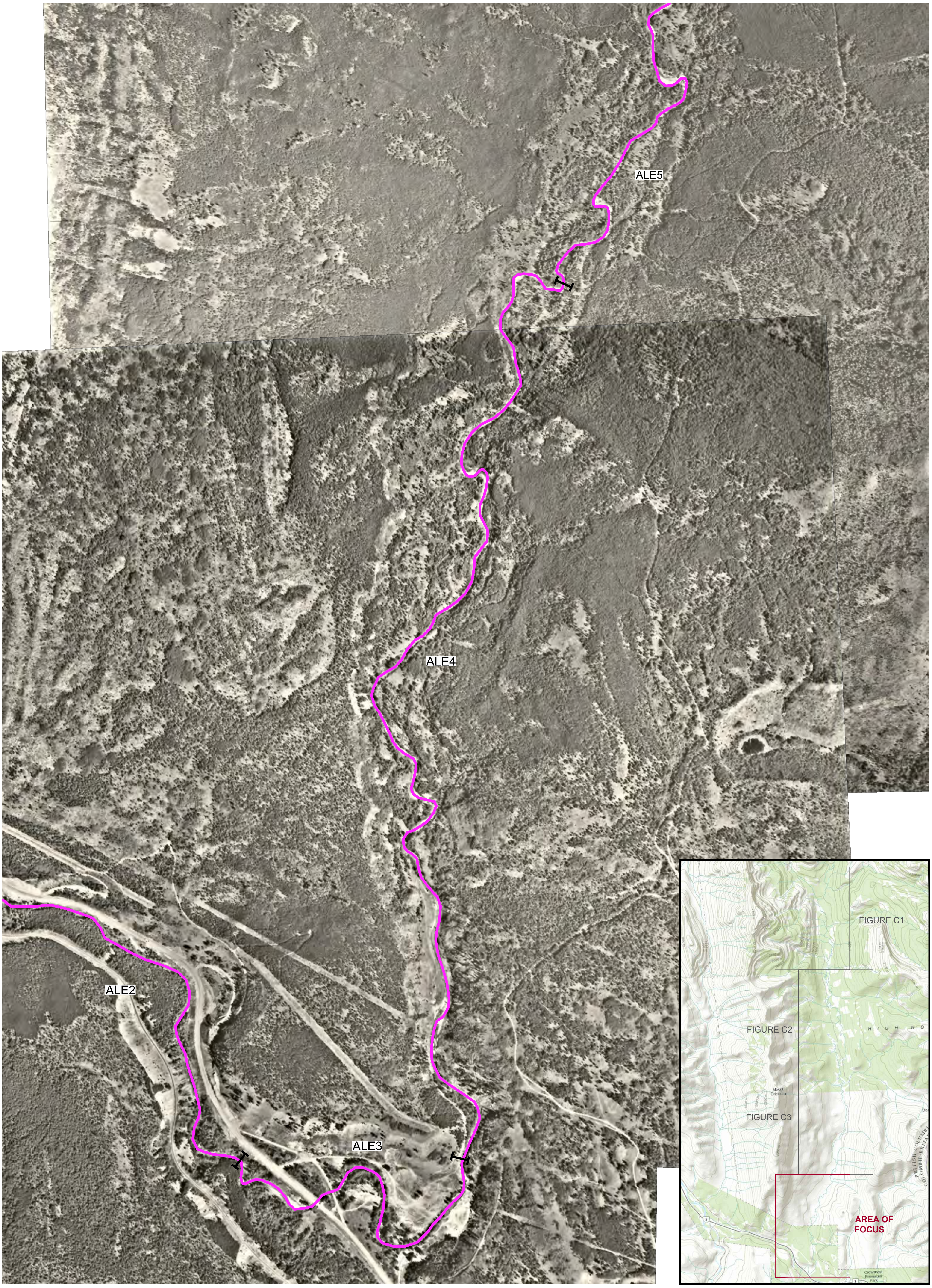
Clarke Geoscience Ltd.

CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

1962 HISTORICAL AIR PHOTO SHOWING CHANNEL ALIGNMENT

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No.
Project No: 21-0104	Date: September 30, 2021	C3



LEGEND

CHANNEL CENTRELINE (1962)

ALE4 REACH BREAK

Air Photo Source: National Air Photo Library

N

0 100 200 400m

Clarke Geoscience Ltd.

CROWN MOUNTAIN COKING COAL PROJECT

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF ALEXANDER CREEK

1962 HISTORICAL AIR PHOTO SHOWING CHANNEL ALIGNMENT

Scale: 1:10,000	NAD 1983 UTM Zone 11 U	Figure No. C4
Project No: 21-0104	Date: September 30, 2021	