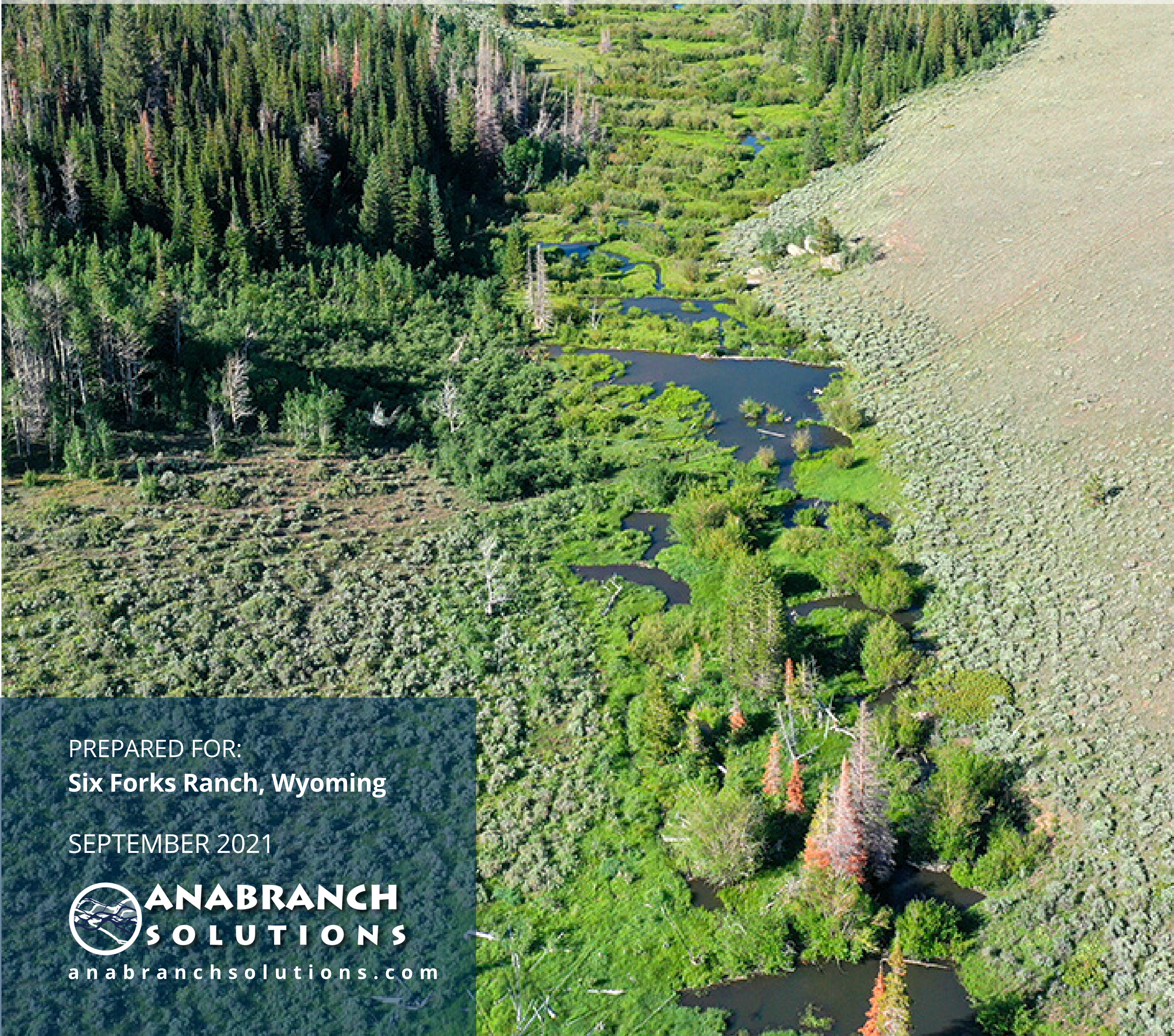
SIX FORKS RANCH

GEOMORPHIC ASSESSMENT & OPPORTUNITIES FOR IMPROVING STREAM & RIPARIAN CONDITION



PREPARED FOR:
Six Forks Ranch, Wyoming

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ANABRANCH SOLUTIONS
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EXECUTIVE SUMMARY

Six Forks Ranch, located in the Sierra Madre mountains of southern central Wyoming, hosts several perennial streams, including East Fork Calf Creek, Middle Fork Calf Creek, West Fork Calf Creek, lower Calf Creek and Shingle Creek. As part of a long-term management plan to ensure the physical and ecological health of perennial streams on Six Forks Ranch, Anabranch Solutions was contracted to assess all perennial streams and provide recommendations and guidance on how low-tech process-based restoration (LTPBR) practices can maintain or improve the condition of streams and floodplains on Six Forks Ranch. Our assessment concludes that:

- The majority of streams on Six Forks Ranch are in good or intact geomorphic, hydrological and ecological condition
- Beaver dam activity, or lack thereof, is the most important factor influencing condition on all streams on Six Forks Ranch
- Beaver ponds have been dynamic over the past 70 years along all streams on Six Forks Ranch, with ponded areas ranging from 0 – 23% of the total valley bottom area
- Current and historic beaver dam activity has created a patchwork of wetland habitats across all streams on Six Forks Ranch that support an array of woody and herbaceous riparian species
- The long-term health of riverscapes on Six Forks Ranch depends on natural beaver dam activity

Based on our assessment, we recommend:

- Lower Calf Creek is the highest priority for LTPBR, and should include the construction of beaver dam analogues (BDAs) to mimic natural beaver dam activity and provide immediate deep-water habitat for dispersing beaver
- Active beaver translocation to streams on Six Forks Ranch to stream reaches with inactive or breached dams. Active translocation seeks to replace the natural dispersal of beaver which is likely severely limited by degraded conditions downstream due to current land use.
- Selective patching of breached dams along EF, WF, MF Calf Creek and Shingle Creek
- Developing an adaptive management plan based on monitoring future beaver dam activity on all perennial streams on Six Forks Ranch.

PURPOSE AND APPROACH

The purpose of this report is to assess the current condition of perennial streams on Six Forks Ranch and identify opportunities for the improvement of stream and riparian health. The outline of the report is as follows: first, we provide a brief description of the regional setting and hydrologic and geomorphic attributes of perennial streams on Six Forks Ranch; second, we use historic aerial imagery to assess beaver dam dynamics over the past 70 years; third, we present an assessment of condition based on the geomorphic setting, beaver dam dynamics and wetland inventory (both past and current); fourth, we summarize observations from a field visit in June 2021; fifth we provide a brief background of low-tech process-based restoration (LTPBR) and other concepts relevant to understanding current conditions and potential for restoration; finally, we describe how LTPBR can be used on Six Forks Ranch to improve stream and riparian health.

SITE DESCRIPTION

REGIONAL SETTING

Six Forks Ranch is in southern central Wyoming, approximately 16 miles south, southwest of Saratoga, WY (Figure 1). The perennial streams located on the property are all within the Upper North Platte watershed (HUC no. 10180002). Calf Creek is a tributary to Cow Creek, which flows directly into the North Platte River. Shingle Creek is tributary to Heather Creek, which joins South Spring Creek, and turns into Spring Creek before finally reaching the North Platte River.

Elevation across the ranch ranges from roughly 7750 – 8550 ft (2360 – 2610 m). The local geology is varied, but dominated by metamorphic and igneous rocks.

HYDROLOGIC SETTING AND STREAMFLOW

Precipitation varies with elevation, ranging from roughly 500 mm at the lower elevations to 1500 mm at the highest elevations in the watershed (outside of Six Forks Ranch property boundaries). Streamflow data is unavailable for the area. Streamflow in all streams is influenced by snowmelt runoff as well as numerous perennial springs.

Most relevant to LTPBR, flows are not high enough to limit dam building by beaver, and all streams are perennial, and therefore capable of supporting beaver dam activity.

GEOMORPHIC SETTING

Each of the streams surveyed is a headwater stream, characterized by moderate-to-steep valley bottom slopes, and variable valley bottom widths. We briefly present basic stream and valley bottom characteristics because they help inform current stream form and function, opportunities for stream restoration, and development of realistic expectations for future condition. The valley bottom is comprised of the channel(s) and its contemporary floodplain. It represents the maximum extent that can be influenced by contemporary stream processes and stream restoration. We refer to this area as the *riverscape*.

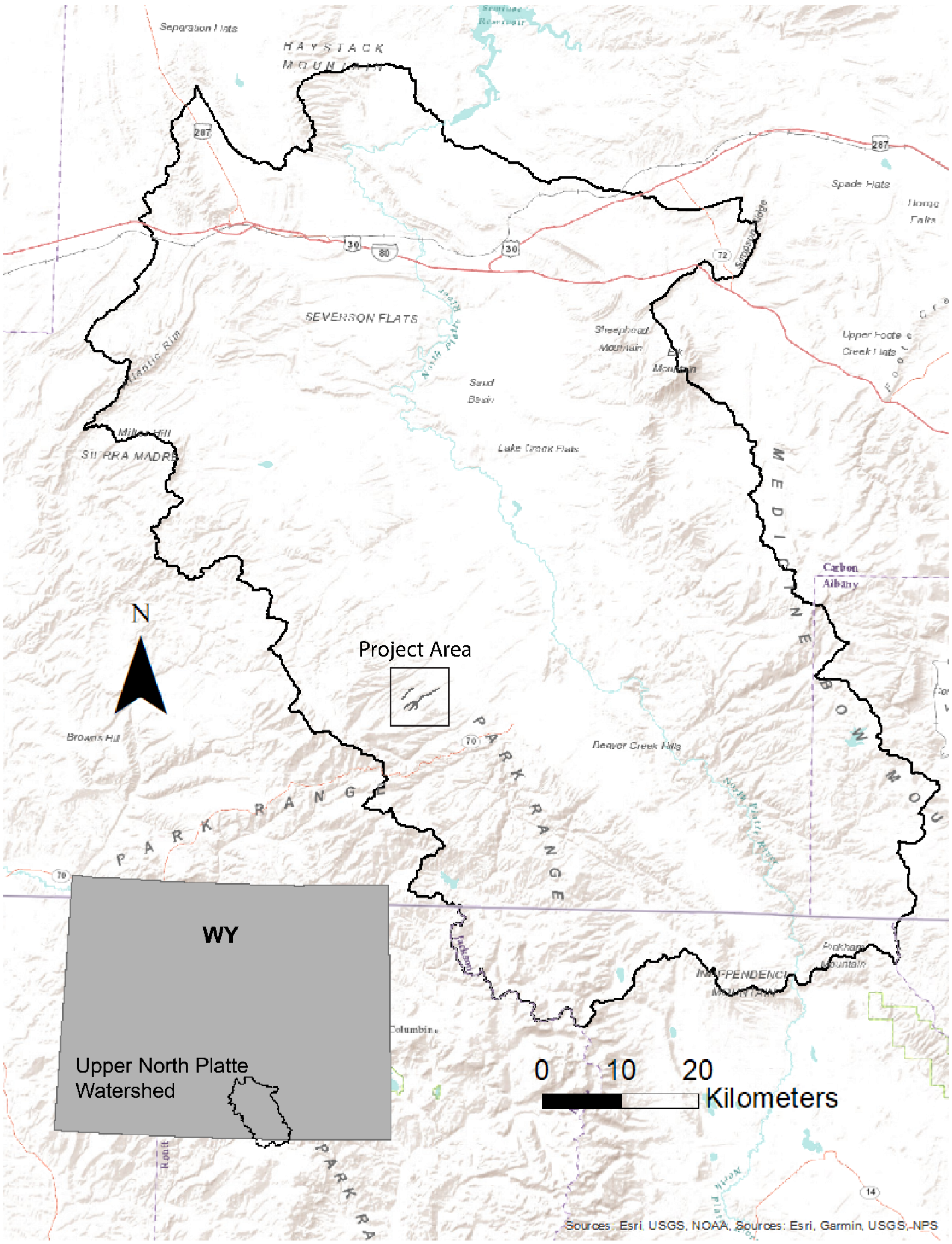

Figure 1 – Six Forks Ranch is located in the Sierra Madre mountains of southern Wyoming, in the Upper North Platte Watershed.

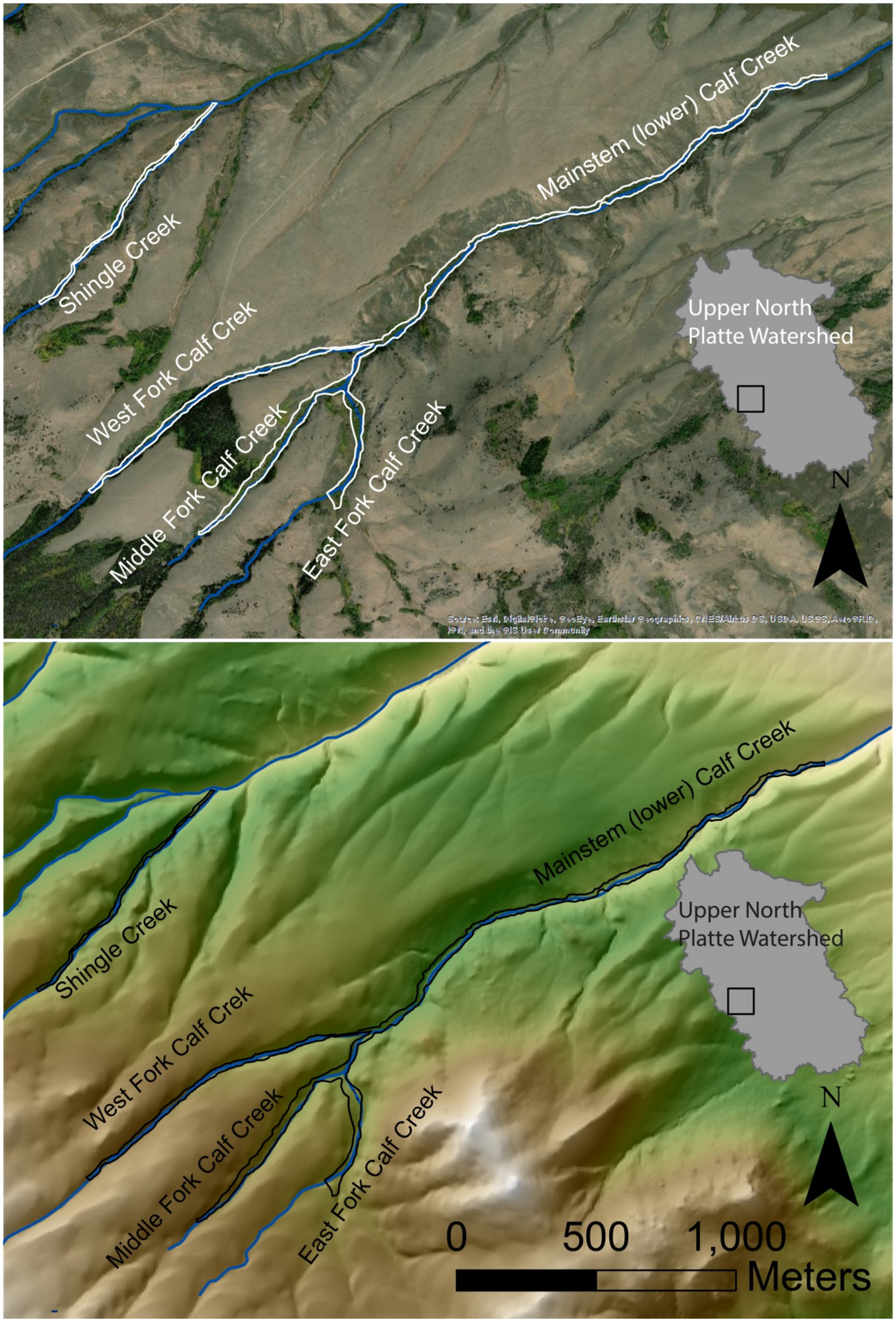

Figure 2 - Streams and valley bottoms on perennial streams on Six Forks Ranch. The valley bottom is delineated in white (upper) and black (lower) polygons.

VALLEY BOTTOM GRADIENT AND WIDTH

In this section we summarize the valley bottom gradient and width of each of the streams on Six Forks Ranch. Valley bottom width and gradient are fundamental geomorphic attributes that influence the form of riverscapes. They may also be important in contextualizing the nature of beaver activity and developing realistic expectations for restoration.

East Fork Calf Creek

East Fork (EF) Calf Creek flows in a valley bottom that ranges from 35 – 75 m wide, and has a valley bottom gradient of approximately 4.4% over the study area, which is roughly 730 m long.

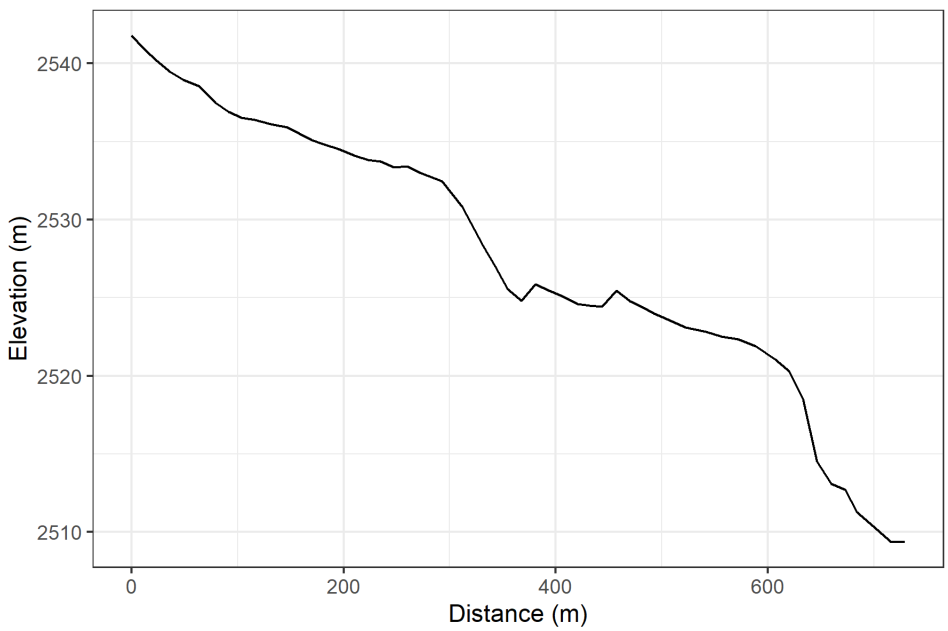

Figure 3 – Longitudinal profile for the valley bottom centerline for EF Calf Creek. The valley bottom was delineated manually using a combination of elevation data and drone-derived aerial imagery. Elevation data was acquired from the National Elevation Dataset (NED). Elevation values were extracted from the valley bottom centerline in QGIS.

Middle Fork Calf Creek

Middle Fork Calf Creek flows through a valley bottom ranging from 25 – 65 m wide, and has a valley bottom gradient of 4.7 % over the study area, which is 1320 m long. There is a significant slope break approximately 400 m from the top of the property, with the upper section characterized by a slope of roughly 2.5% and the lower section with a slope of 5.8%.

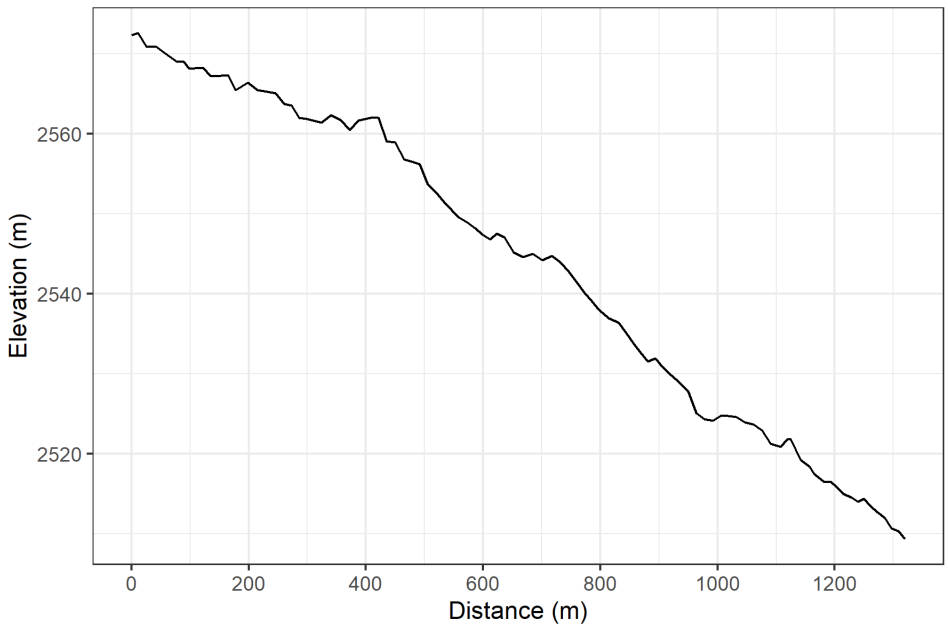

Figure 4 - Longitudinal profile for the valley bottom centerline for Middle Fork Calf Creek. The valley bottom was delineated manually using a combination of elevation data and drone-derived aerial imagery. Elevation data was acquired from the National Elevation Dataset (NED). Elevation values were extracted from the valley bottom centerline in QGIS.

West Fork Calf Creek

West Fork Calf Creek flows through a valley bottom ranging in width from as low as 5 m wide, immediately upstream of the confluence with the mainstem Calf Creek, to 45 m wide in the upper sections. The valley bottom gradient is uniform, with an overall slope of 5.2 % over roughly 2000 m.

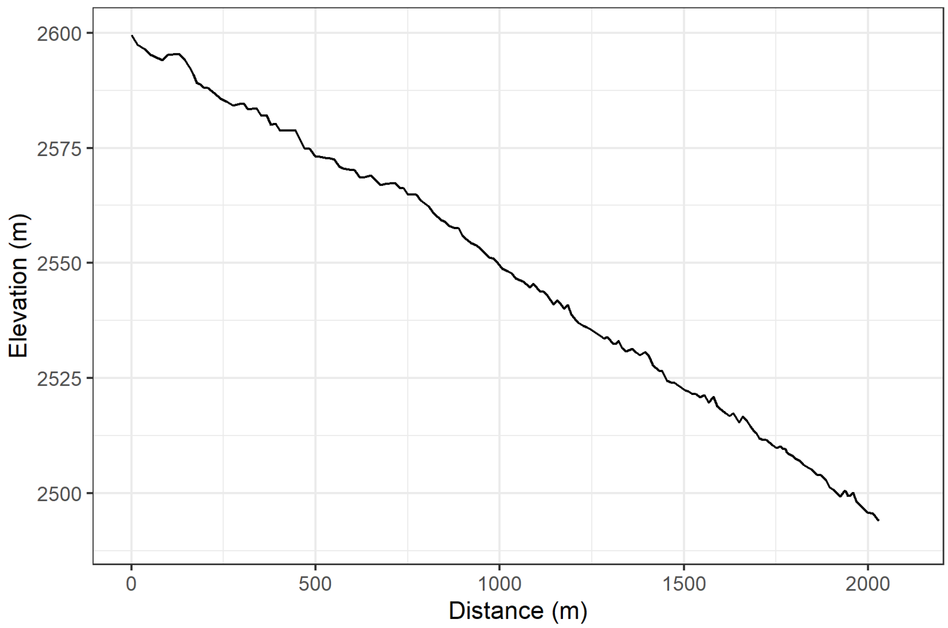

Figure 5 - Longitudinal profile for the valley bottom centerline for Middle Fork Calf Creek. The valley bottom was delineated manually using a combination of elevation data and drone-derived aerial imagery. Elevation data was acquired from the National Elevation Dataset (NED). Elevation values were extracted from the valley bottom centerline in QGIS.

Mainstem (lower) Calf Creek

Mainstem Calf Creek flows through a valley bottom ranging in width from 15 - 65 m. The valley bottom slope over the project area is 3.9%. There is a slope break at approximately 1500 m. The upper section has a gradient of 4.7% and the lower section has a gradient of 3.3%. The full project area is 3700 m long.

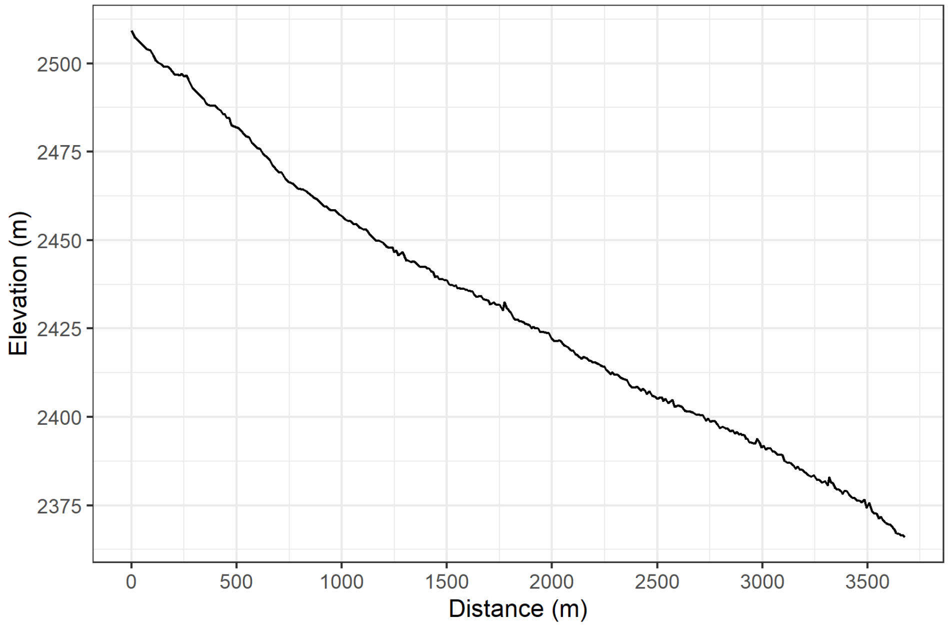

Figure 6 - Longitudinal profile for the valley bottom centerline for Mainstem Calf Creek. The valley bottom was delineated manually using a combination of elevation data and drone-derived aerial imagery. Elevation data was acquired from the National Elevation Dataset (NED). Elevation values were extracted from the valley bottom centerline in QGIS.

Shingle Creek

Shingle Creek flows through a valley bottom ranging in width from 10 - 35 m. The valley bottom gradient over the project area is 6.8%. There is a slope break at approximately 1060 m. The upper section has a gradient of 5.5% and the lower section has a gradient of 8.9%. The project area is 1700 m long.

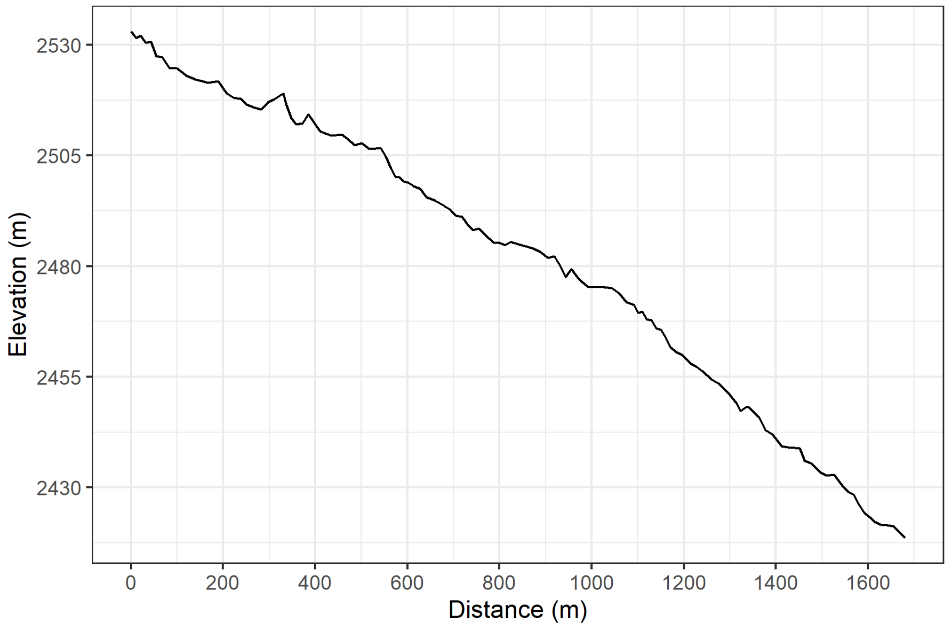

Figure 7 - Longitudinal profile for the valley bottom centerline for Shingle Creek. The valley bottom was delineated manually using a combination of elevation data and drone-derived aerial imagery. Elevation data was acquired from the National Elevation Dataset (NED). Elevation values were extracted from the valley bottom centerline in QGIS.

BEAVER DAM ACTIVTY AND RECENT HISTORY: 1947 - 2021

Beaver are ecosystem engineers that build dams in order to create deep water habitat that provides them refuge from predation, enables an underwater entrance to either a lodge or bank den, and expands the area that they may safely forage. Their dam building activity increases habitat heterogeneity that benefits both terrestrial and aquatic species. Extensive dam complexes also store surface water, raise groundwater levels and have the capacity to attenuate peak flows.

Beaver dams are not permanent fixtures on the landscape. Depending on a number of factors, including hydrogeomorphic setting, stream condition, and local vegetation characteristics as well as factors influencing beaver populations such as predation and disease, beaver dams may persist from 1-2 years to many decades. Importantly, this dynamism, the constant shifting of habitats from deep-water, to wetland, to free-flowing, constantly creates and recreates a diverse mosaic of habitats for both aquatic and terrestrial species. Intact, breached (partially removed) and blown-out (fully removed) dams each provide unique habitat for species that depend on diverse habitats to fulfill their specific life histories (Figure 8).

An assessment of stream condition and beaver activity depends on a watershed scale assessment. In other words, whether or not a given section of stream is in intact, good, moderate or poor condition may not be able to be determined without also evaluating that section of stream in the context of the larger watershed. For example, if a section of stream does not have current beaver activity and intact beaver dams, but sections both upstream and downstream do, then the beaver-less middle section is not necessarily indicative of degraded conditions. However, if large sections of stream lack current beaver dam activity, then we may more confidently assert that conditions are degraded.

In the following section we assess beaver dam dynamics over the past 70 years using freely-available historic aerial imagery from the US Geological Survey and Google Earth in order to contextualize the current amount of beaver dam activity and inform opportunities for restoration.

Figure 8 – Both intact and breached beaver dams provide important habitat for a range of aquatic and terrestrial species. Clockwise from top left: an intact and actively maintained dam provides deep water habitat; a breached dam exposes sediment to support the regeneration of new riparian vegetation and exposes gravels; an abandoned dam creates shallow, off-channel ponds; a breached dam creates a plunge pool; a breached dam allows for free-flowing sections of stream; an intact, but not actively maintained dam that has filled with sediment creates extensive shallow ponding.

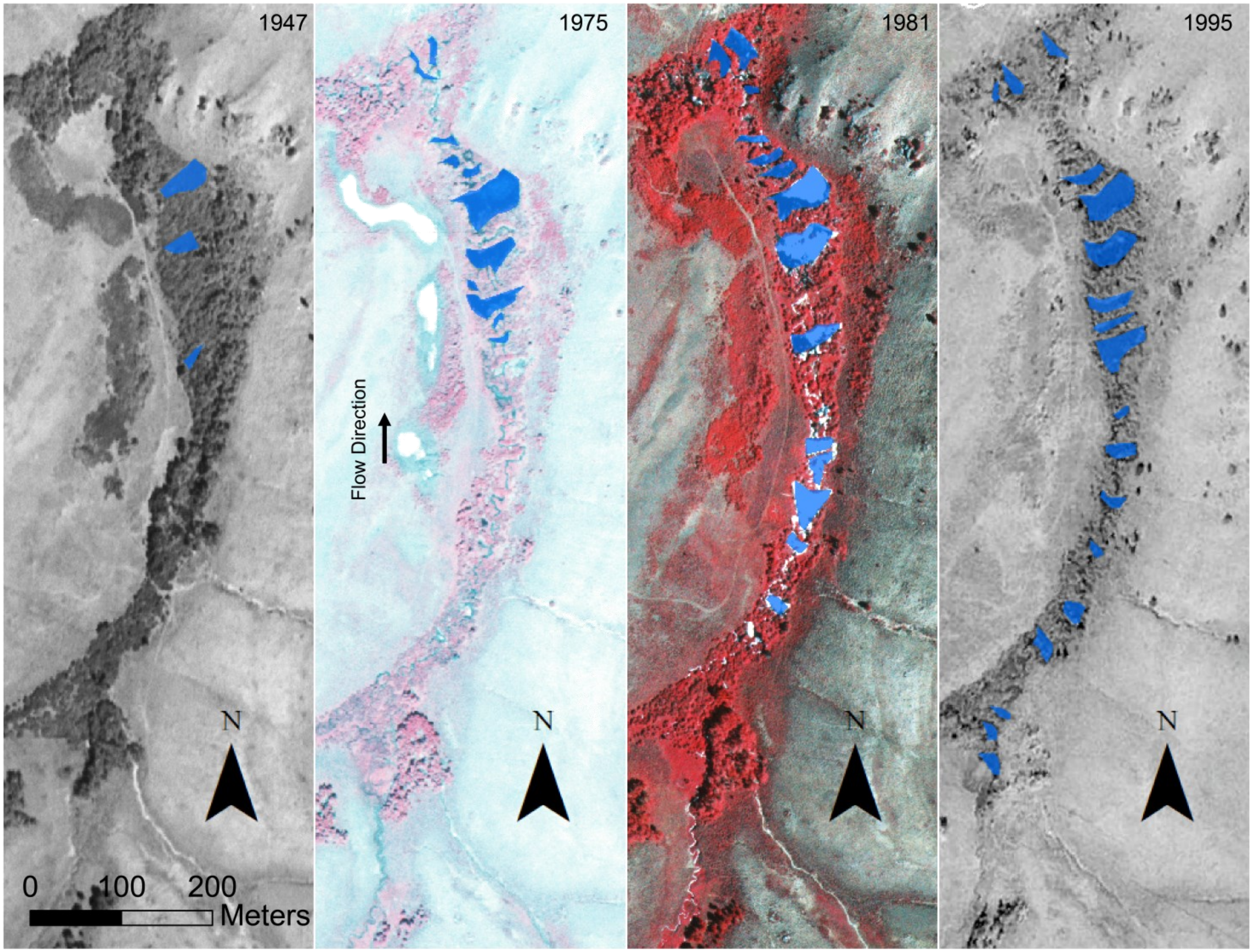

Figure 9 - Historic aerial imagery of EF Calf Creek illustrating beaver dam dynamics from 1947 – 1995. Ponds are shown in blue and were delineated manually in QGIS.

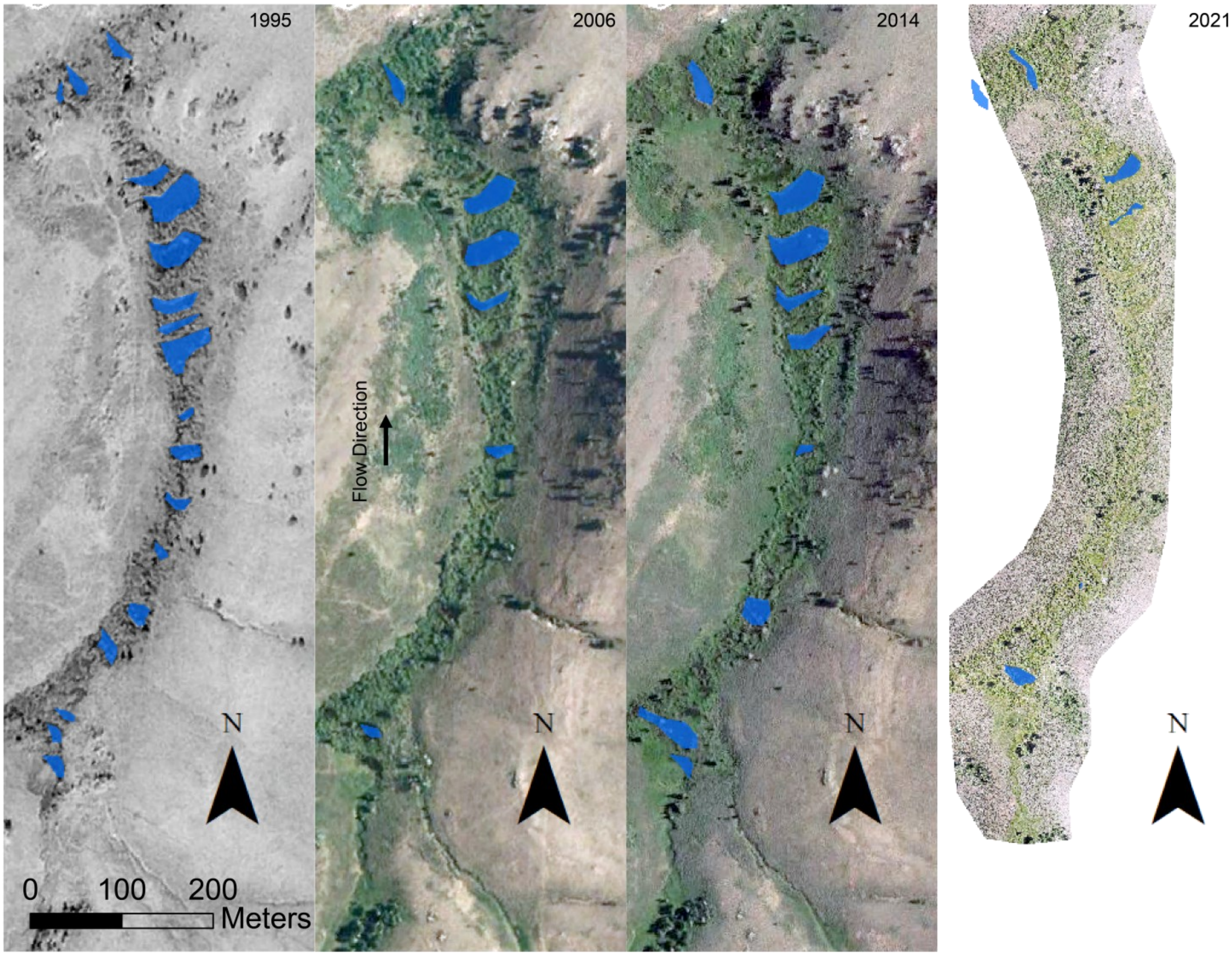

Figure 10 - Historic aerial imagery of EF Calf Creek illustrating beaver dam dynamics 1995 – 2021. 2021 imagery is the product of a drone-flight on June 28, 2021. Ponds are show in blue and were delineated manually in QGIS.

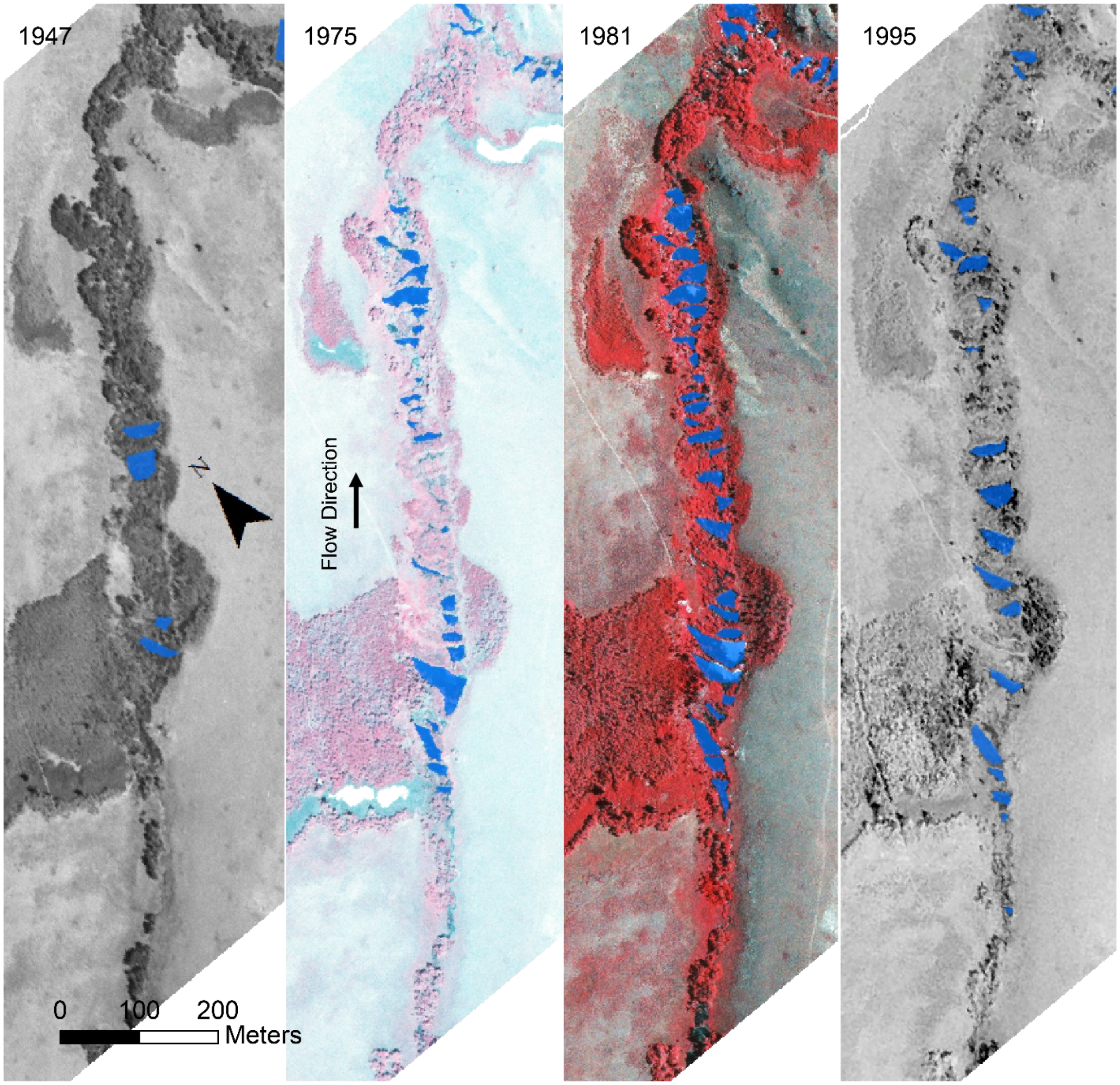

Figure 11 - Historic aerial imagery of MF Calf Creek illustrating beaver dam dynamics 1947 - 1995. Ponds are show in blue and were delineated manually in QGIS.

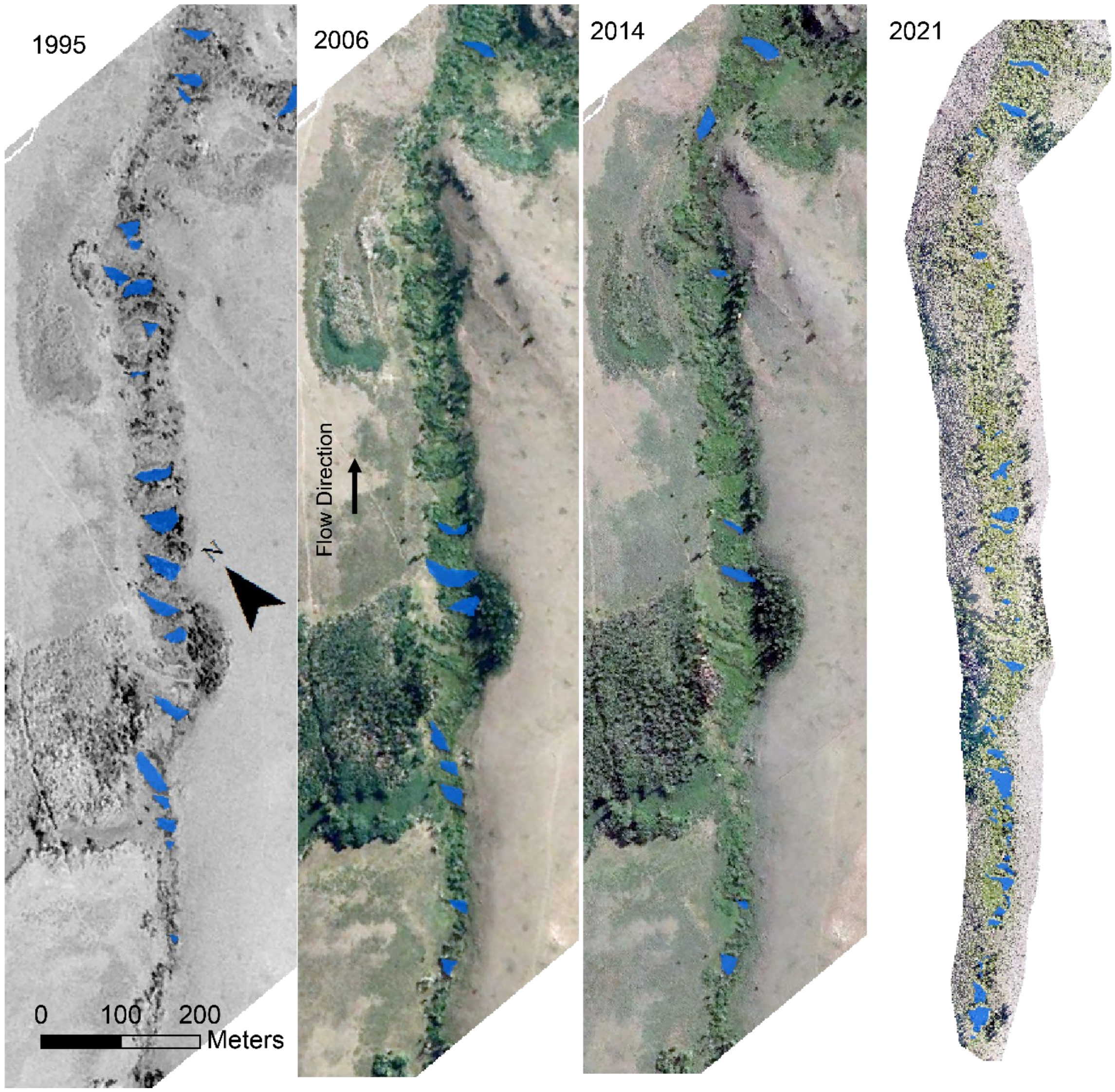

Figure 12 - Historic aerial imagery of MF Calf Creek illustrating beaver dam dynamics 1995 – 2021. 2021 imagery is the product of a drone-flight on June 28, 2021. Ponds are show in blue and were delineated manually in QGIS.

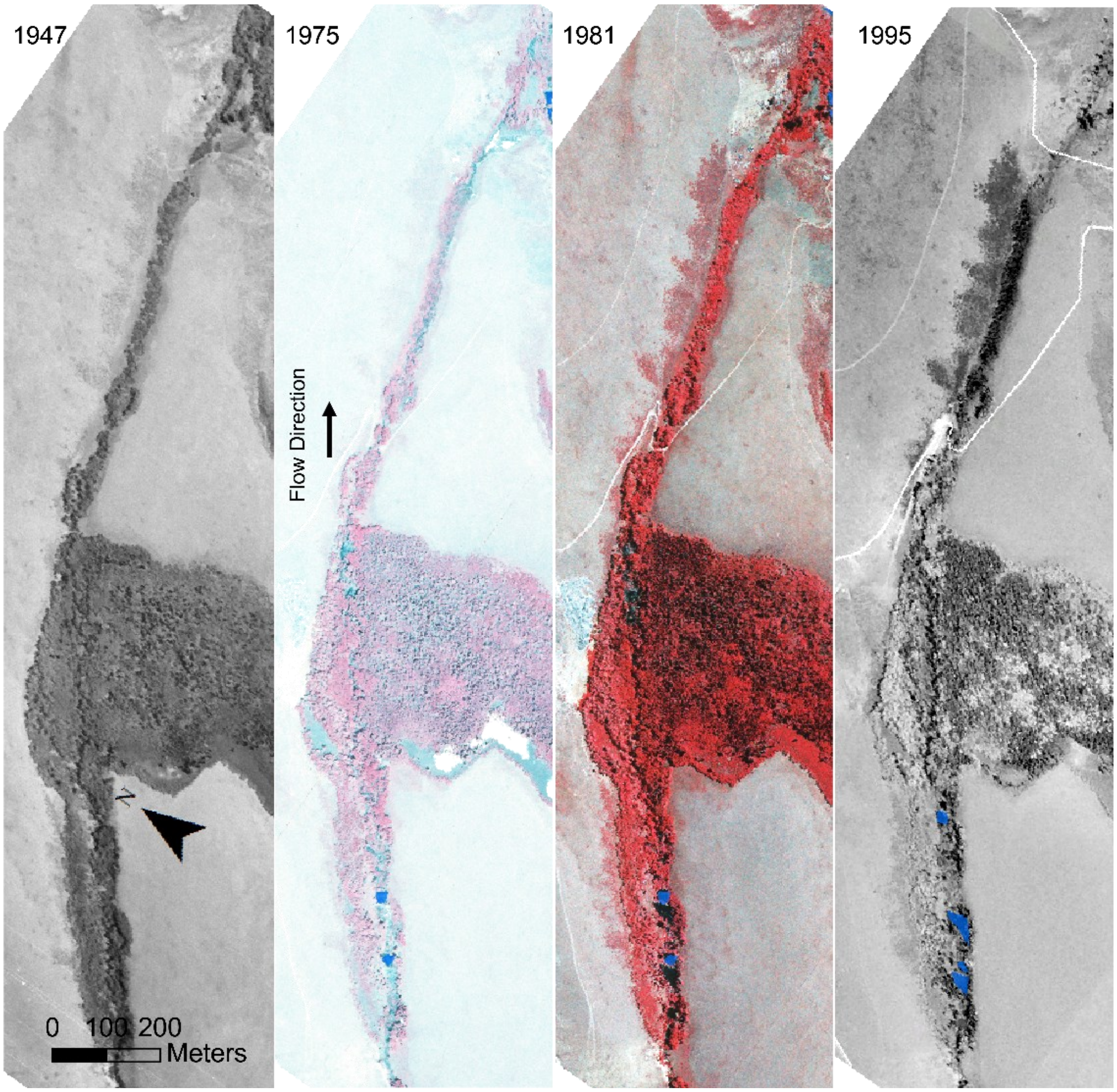

Figure 13 – Historic aerial imagery of WF Calf Creek illustrating beaver dam dynamics 1947 - 1995. Ponds are show in blue and were delineated manually in QGIS.

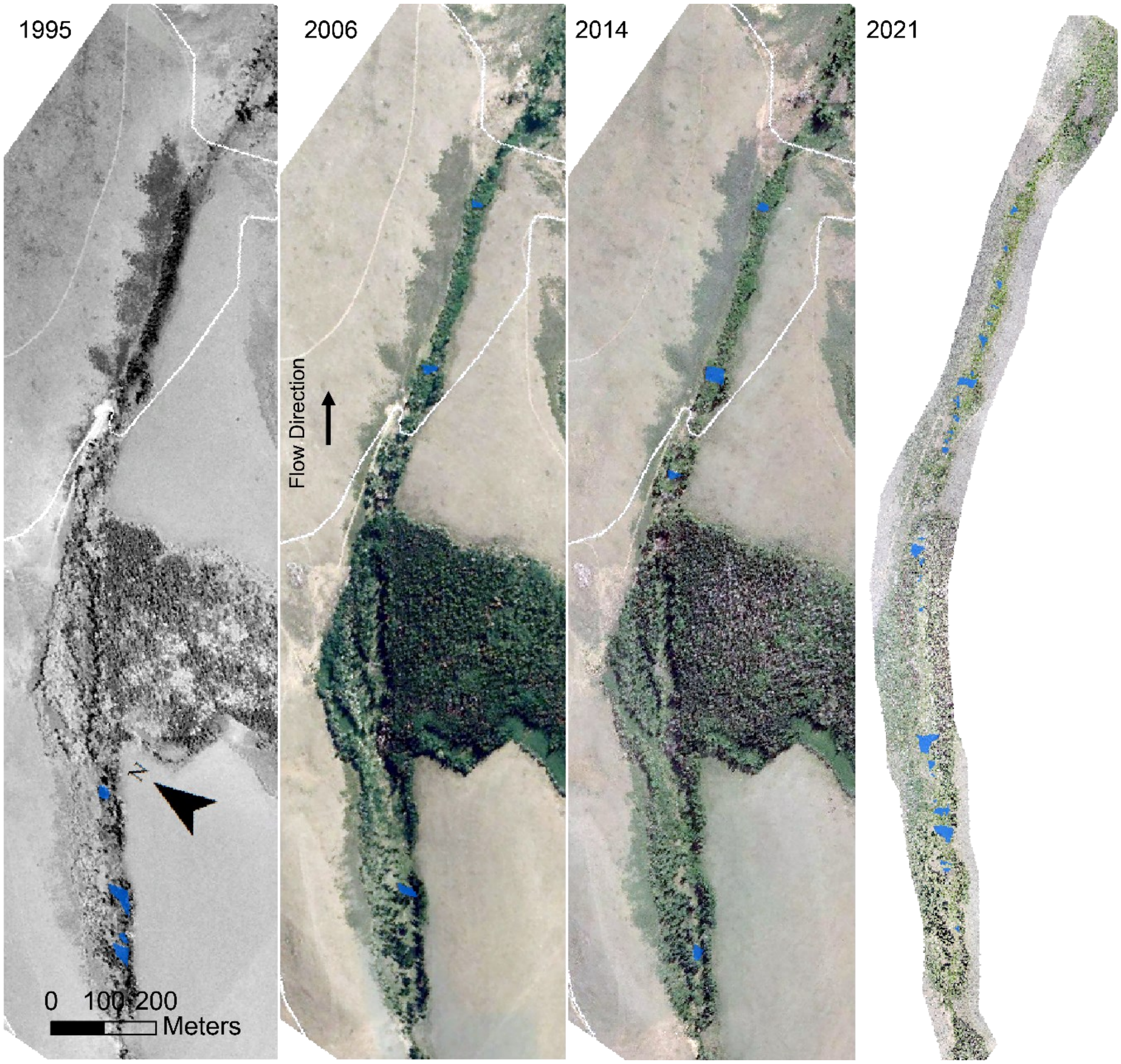

Figure 14 - Historic aerial imagery of MF Calf Creek illustrating beaver dam dynamics 1995 – 2021. 2021 imagery is the product of a drone-flight on June 28, 2021. Ponds are show in blue and were delineated manually in QGIS.

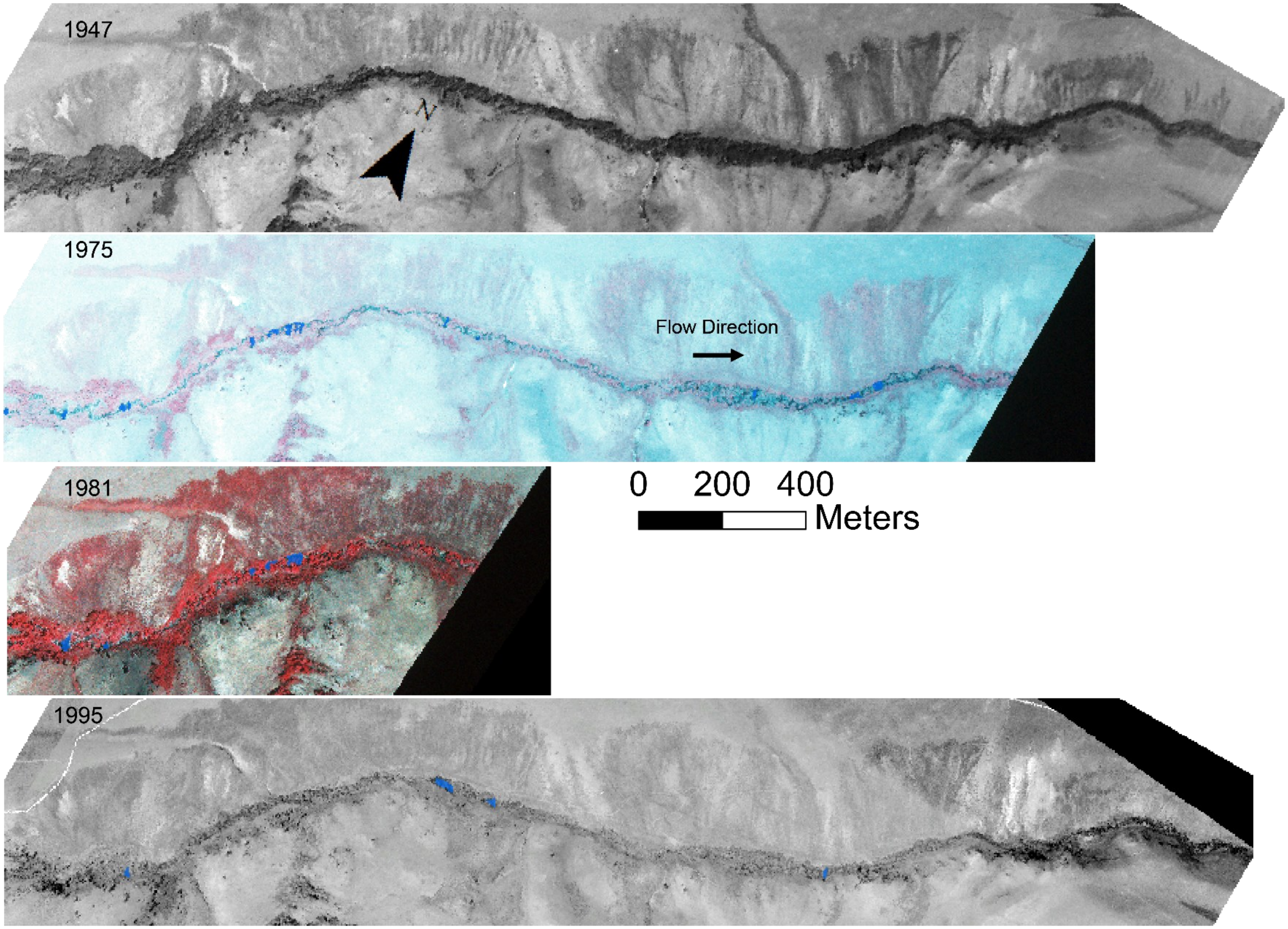

Figure 15 - Historic aerial imagery of mainstem Calf Creek illustrating beaver dam dynamics 1947 - 1995. Ponds are show in blue and were delineated manually in QGIS.

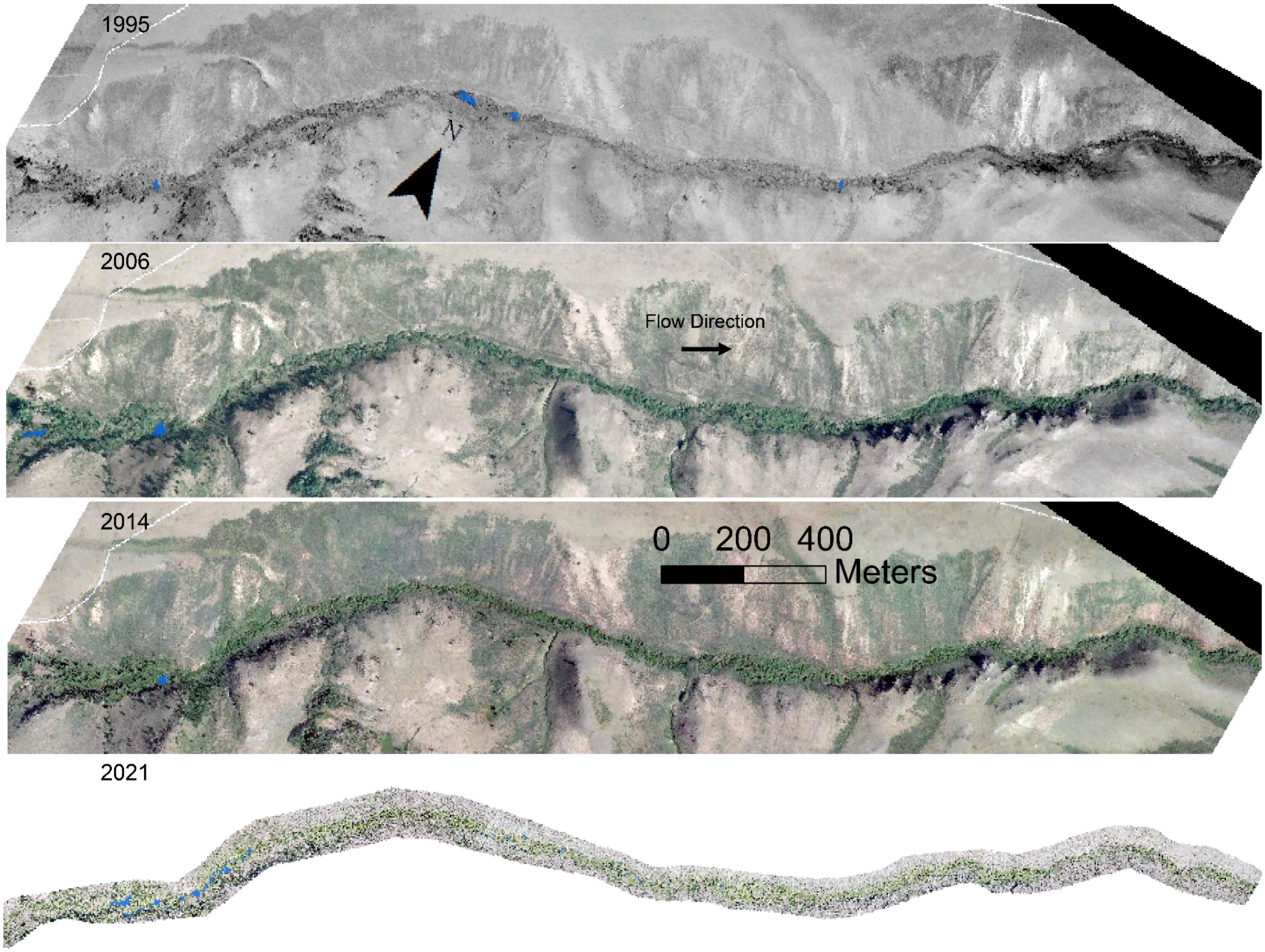

Figure 16 - Historic aerial imagery of mainstem Calf Creek illustrating beaver dam dynamics 1995 – 2021. 2021 imagery is the product of a drone-flight on June 28, 2021. Ponds are show in blue and were delineated manually in QGIS.

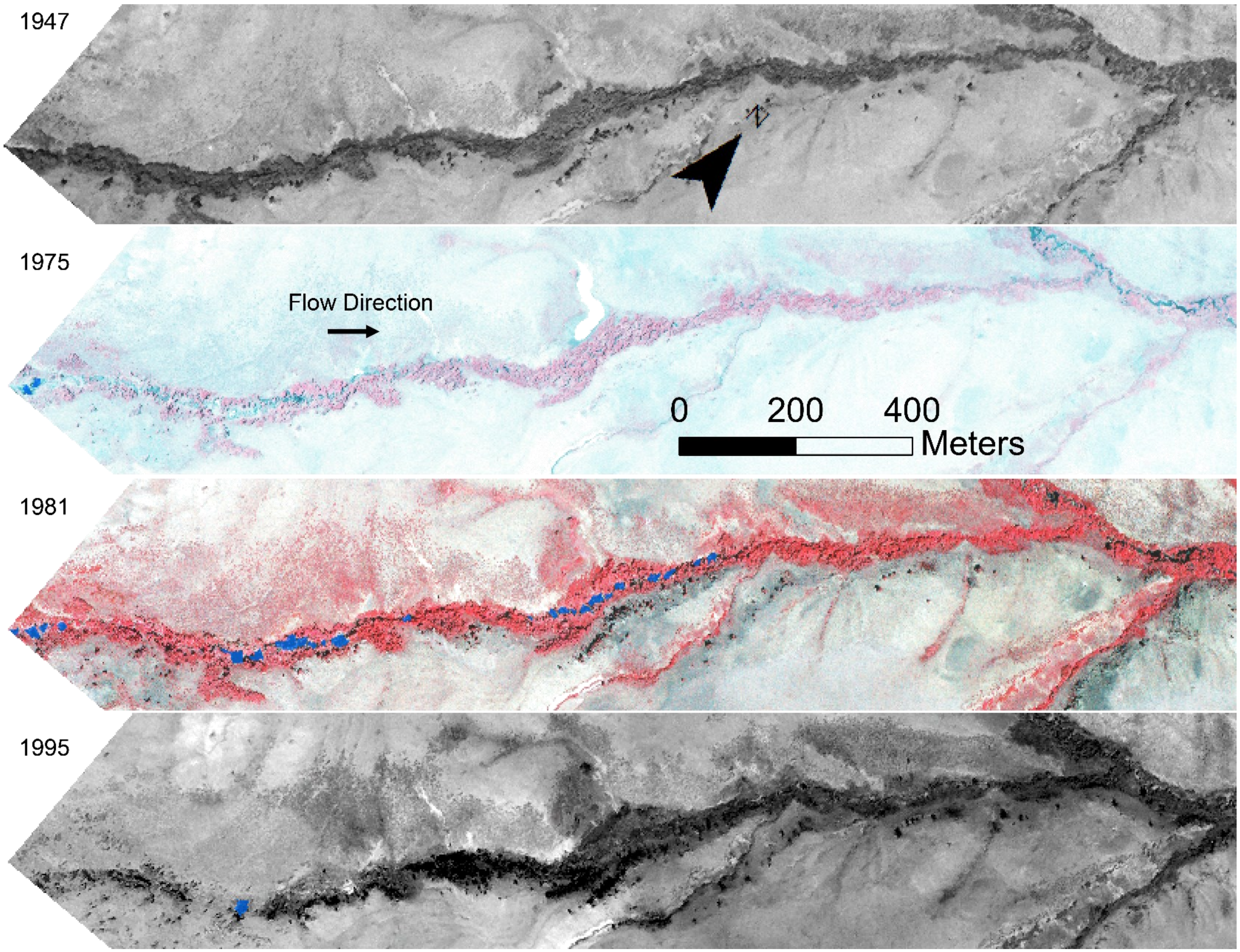

Figure 17 - Historic aerial imagery of Shingle Creek illustrating beaver dam dynamics 1947 - 1995. Ponds are show in blue and were delineated manually in QGIS.

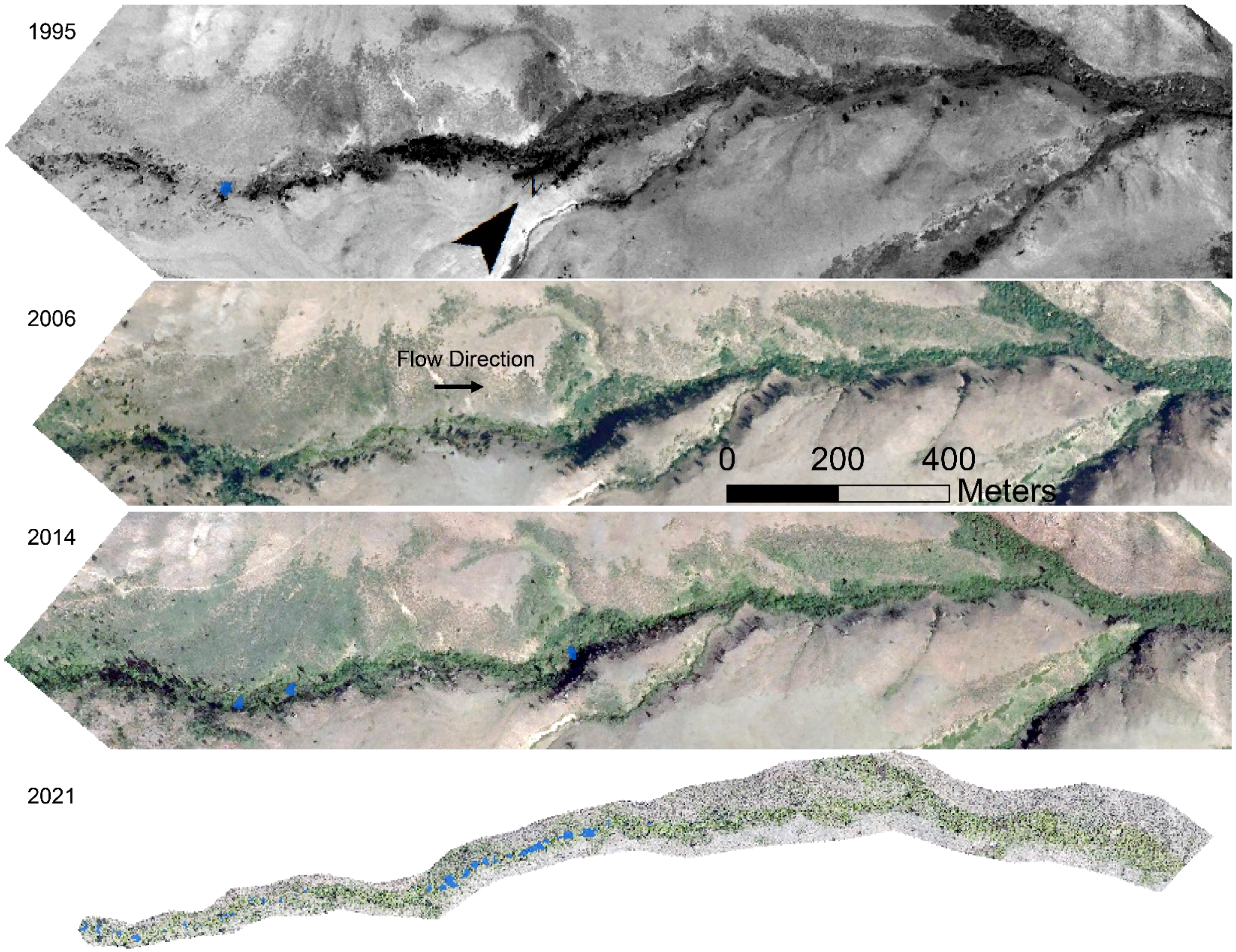

Figure 18 - Historic aerial imagery of Shingle Creek illustrating beaver dam dynamics 1995 – 2021. 2021 imagery is the product of a drone-flight on June 28, 2021. Ponds are show in blue and were delineated manually in QGIS.

We calculated both the total number of ponds as well as the total area of ponds as a percentage of the valley bottom for all streams on Six Forks Ranch (Figure 19 and Figure 20). We did not delineate beaver dams themselves because they are difficult to identify using historic imagery, while ponds tend to be more easily identified. However, a single pond is a reasonable surrogate for a single beaver dam. Because the 2021 imagery is a much higher resolution image we delineated significantly more ponds, many of which would likely not have been visible in the historic imagery. Therefore, despite the appearance of significantly more beaver dams in 2021, the increase is likely the product of a higher resolution which enabled the identification of much smaller ponds, some of which are forced not by intact beaver dams, but by abandoned or breached dams. Therefore, the ponded area as a percent of the total valley bottom area is likely a better indicator of beaver dam activity (Figure 20). Also, because beaver ponds may be either small or large, the total of number of dams is a less important indicator of their hydrologic impacts than the proportion of ponded area to valley bottom area.

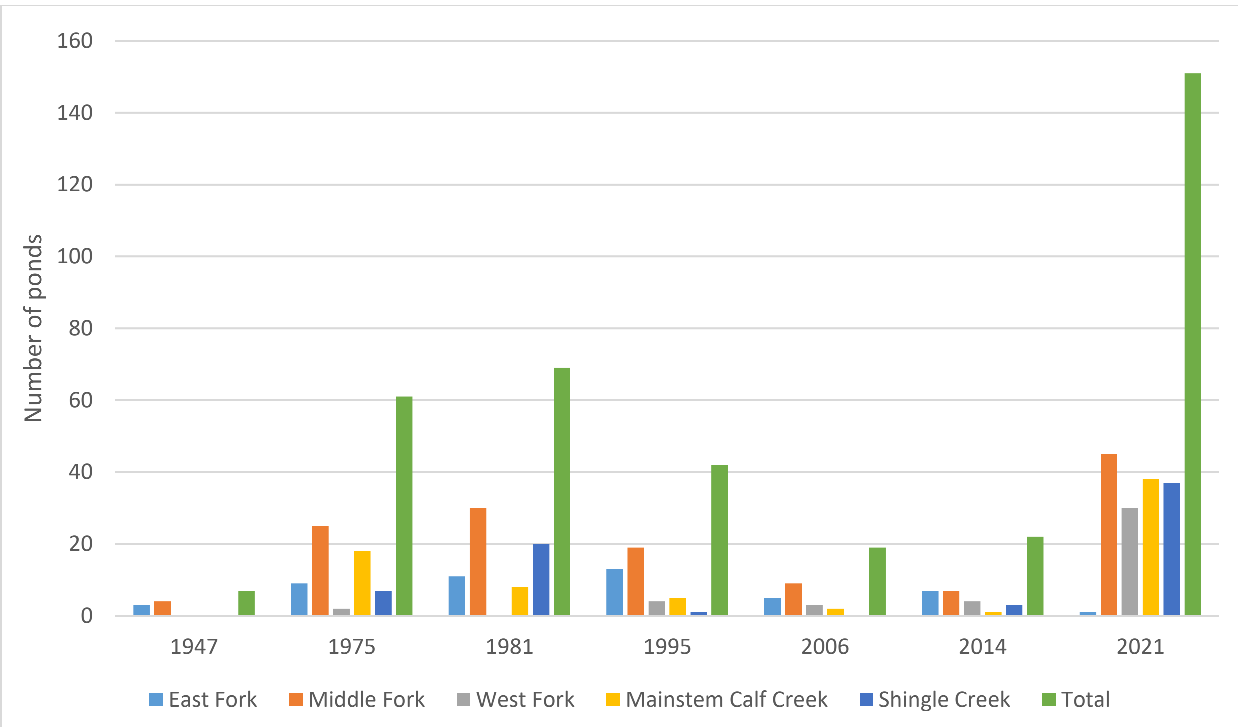

Figure 19 – Total number of ponds along East Fork, Middle Fork, West Fork, Mainstem Calf Creek, and Shingle Creek. Note that the large increase of total ponds in 2021 is likely due to higher resolution imagery that allowed for the identification of much smaller ponds. An assessment that is less sensitive to the resolution of imagery is shown in Figure 8.

The total area occupied by ponds, expressed as a percent of the total valley bottom area reveals that beaver dam activity across Six Forks Ranch was highest in the 1981 imagery. There was very little visible evidence of beaver dam activity in the oldest historic imagery (1947) with noticeable increase in both the 1975 and 1981 imagery. From 1981 – 2014 ponded area declined, before experiencing a slight rise in 2021. Caution should be used when interpreting the increase in 2021, as higher resolution imagery may have enabled the identification or additional ponds that would have been undetectable with coarser imagery. Nonetheless these results provide important guidance for restoration.

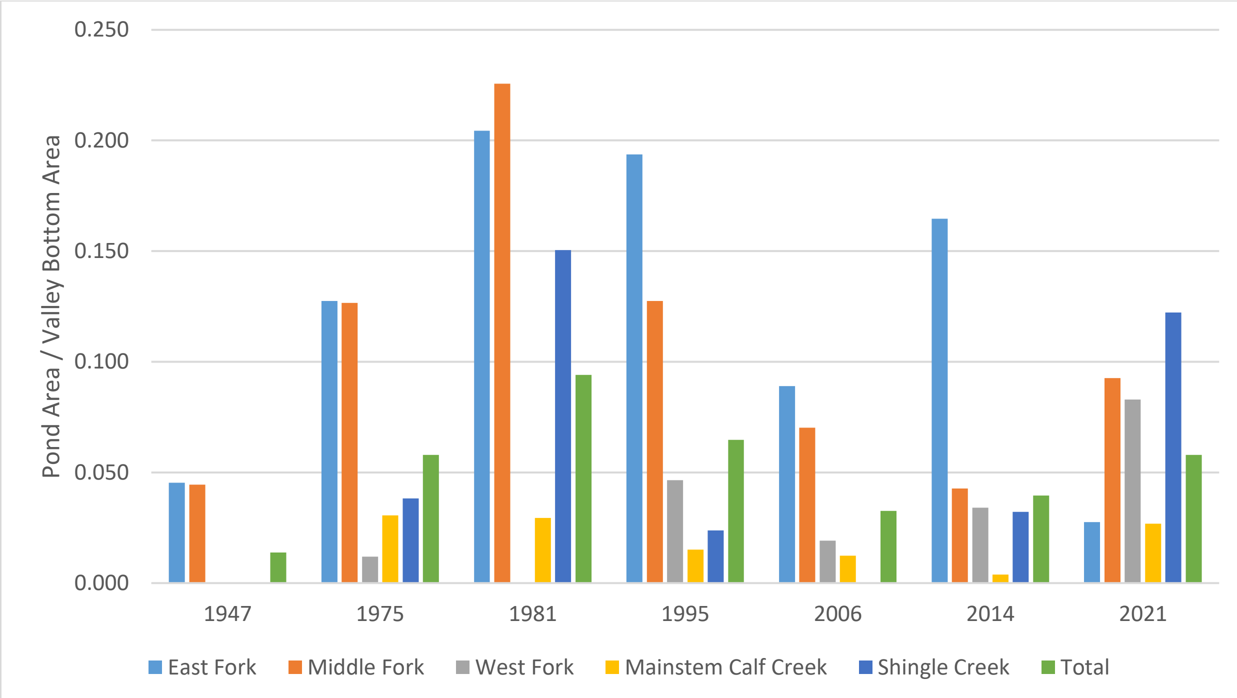

Figure 20 – Area of pond as a percent of the total valley bottom for the perennial streams on Six Forks Ranch. Pond to valley bottom area varies both between streams as well as through time. In streams similar to those found at Six Forks Ranch, areas that area actively dammed by beaver tend to have pond/valley bottom areas of 15-18% (Bartelt, 2021). The total inundation area, which would include both free flowing sections of stream as well as shallow overbank flows is necessarily larger, however free-flowing and overbank flows were not possible to identify from the historic aerial imagery.

There is significant variability in ponded area between the streams on Six Forks Ranch. Over the past 70+ years the ponded area as a proportion of the total valley bottom has been as high as 23% (MF Calf Creek 1981) while the mainstem has fluctuated between 0 - 3 %. A recent study of actively maintained beaver dam complexes showed that in streams similar to those found on Six Forks Ranch, the ponded proportion of the valley bottom ranges from 15 - 18%. This is consistent with the results from EF and MF Creeks from 1975 – 1995. It is essential to understand that this range of values is for actively maintained beaver dams, and that the study did not track how these values change over time in response to natural factors such as high flows, sediment deposition, predation or decreases in food and dam building materials, and we suggest that it would be inappropriate to suppose that this range would be maintained across all streams through time. Nonetheless, neither the WF Calf Creek or mainstem Calf Creek appear to have reached these levels at any point in the last 70 years, though here again we caution that the time between photos may be too large to capture a more nuanced understanding of beaver dam dynamics. Also note that due to only partial coverage of the mainstem Calf Creek in the 1975 and 1981 imagery, the true value would likely be higher than reported here.

Table 1 – Ponded area as a proportion of the total valley bottom area for all streams on the Six Forks Ranch.

Year	East Fork	Middle Fork	West Fork	Mainstem Calf Creek	Shingle Creek	Total
1947	0.045	0.045	0.000	0.000	0.000	0.014
1975	0.128	0.127	0.012	0.031	0.038	0.058
1981	0.204	0.226	0.000	0.029	0.151	0.094
1995	0.194	0.127	0.047	0.015	0.024	0.065
2006	0.089	0.070	0.019	0.012	0.000	0.033
2014	0.165	0.043	0.034	0.004	0.032	0.040
2021	0.027	0.093	0.083	0.027	0.122	0.058

WETLAND INVENTORY AND ASSESSMENT

The short and long-term impacts of beaver dam activity can further be understood by assessing wetlands. According to the National Wetlands Inventory (NWI) wetlands on Six Forks Ranch are grouped into freshwater pond, freshwater emergent wetland, and freshwater forested wetland. It is important to note that beavers are explicitly recognized as an important creator of wetlands throughout Six Fork Ranch. Furthermore, the different types of wetlands found throughout Six Forks Ranch are likely the direct result of different geomorphic trajectories and conditions of beaver dams. Most obviously, intact, actively maintained dams will promote freshwater ponds; dams that have filled with fine sediment but not breached significantly can promote freshwater emergent wetlands, which are characterized by herbaceous vegetation; breached dams that still maintain seasonally high-water tables can promote freshwater forested/shrub wetlands characterized by woody riparian vegetation. In beaver influenced systems, all of these wetland types are to be expected, though their specific locations may change with time as beaver activity moves throughout the watershed.

The most recent wetland delineation along MF Calf Creek (performed by the NRCS in June 2021) identified the entire valley bottom as a wetland, suggesting that MF Calf Creek is in good - intact condition. This delineation is also supported by the high amount of historic beaver dam activity evidenced by historic aerial imagery.

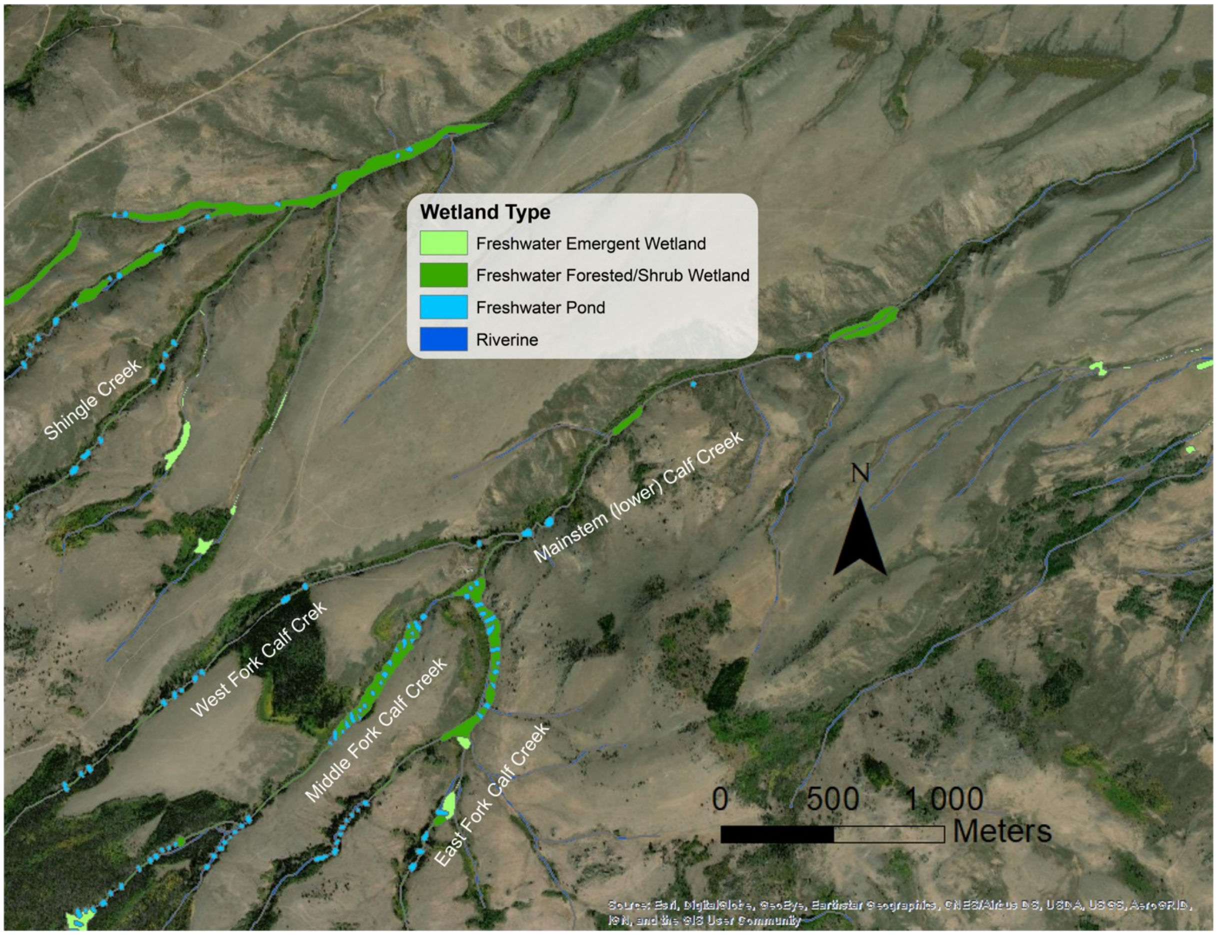

Figure 21 – Wetlands delineated by the National Wetland Inventory (NWI) based on aerial imagery assessed in 1981.

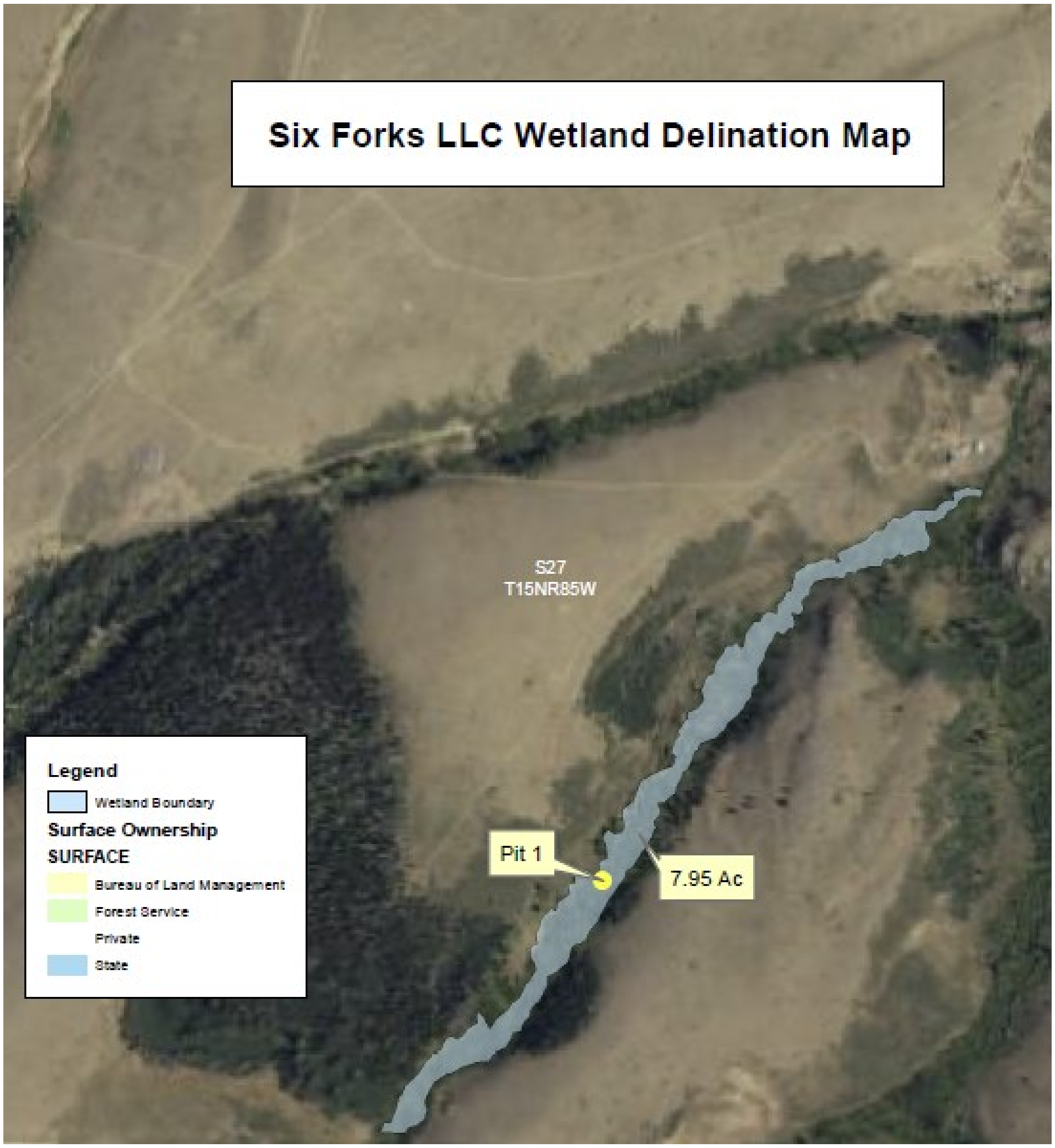

Figure 22 - Map of wetland delineation on Middle Fork Calf Creek performed by the Natural Resources Conservation Service (NRCS) in June 2021.

FIELD OBSERVATIONS

A full field reconnaissance of streams on Six Forks Ranch revealed that beaver have been, and continue to be the most dominant influence affecting hydrologic and geomorphic processes, which together exert a strong influence on riparian vegetation. In most areas, beaver dams span the valley bottom with lengths approaching 60 m (Figures 21-22). Intact and breached dams vary in height, but in some cases exceed 2 m (Figure 25).

Figure 23 - Active beaver dam spanning the valley bottom on MF Calf Creek at the upstream property boundary.

Figure 24 - Series of valley-bottom spanning dams on Shingle Creek.

Figure 25 – Abandoned, but intact beaver dam on WF Calf Creek exceeding 2 m in height. (Measuring tape (center) is 2 m tall.) This dam spans the valley bottom and was measures approximately 40 m across.

The condition of beaver dams was the most important factor determining vegetation composition and stream characteristics (Figure 8). Where dams are breached, the stream channel has often incised through the sediments that were initially captured by the dam, resulting in channel banks up to 1 – 1.5 m tall, which likely correlates with the deposition forced while the dam was intact and maintained (Figure 26). In other areas, minor breaches or abandonment have resulted in free-flowing waters and channels that are not incised and support abundant herbaceous wetland vegetation such as sedges (Figure 27).

Vegetation Condition

A systematic study of vegetation characteristics across Six Forks Ranch was not undertaken during our assessment, however field observations suggest that riparian vegetation across Six Forks Ranch is in good-to-intact condition. Vegetation dynamics within the valley bottom appear to largely be driven by the condition of beaver dams. In many locations throughout Six Forks Ranch lines of willow perpendicular to the valley show the previous or current location of inactive beaver dams, while upstream of these areas the formerly ponded area has been colonized by herbaceous riparian vegetation (e.g., sedges). In general, there is abundant woody riparian vegetation within the valley bottom that is supporting, and could support beavers' forage and dam building needs. Herbivory, whether livestock or wild game, does not appear to be limiting woody riparian vegetation or herbaceous vegetation growth or recruitment.

Adjacent to the valley bottom there are numerous patches of aspen. These stands do not appear to be characterized by a single age. In light of the history of beaver dam activity throughout Six Forks Ranch, it is likely that these stands have been an important source of forage and dam building material for beaver, and that aspen stand dynamics (decline and rejuvenation) have been intimately linked to beaver activity.

Importantly, aspen and beaver have co-evolved such that temporary, intense herbivory by beaver can lead to additional sprouting, and is not inherently detrimental to long-term aspen stand health.

Figure 26 - Free-flowing section of stream on mainstem Calf Creek where the breaching of a beaver dam led to channel incision that has disconnected the channel from its floodplain.

Figure 27 – Abandoned beaver dam on WF Calf Creek no longer ponding water, but where channel is closely connected to the floodplain, which was formed by deposition in the beaver pond, and supporting herbaceous riparian vegetation.

Figure 28 - Mainstem Calf Creek has significantly less recent beaver dam activity than all other streams, and is characterized by the greatest amount of free-flowing water and disconnected floodplain.

INTERPRETATION AND DISCUSSION OF STREAM CONDITION

Across Six Forks Ranch streams and floodplains are generally in good and fully intact conditions. On the lower portions of Calf Creek condition may approach a good/moderate quality based on the current and recent amount of beaver dam activity which is lower than on other streams.

This evaluation is based on two lines of evidence: 1) the assessment of beaver dam activity from 1947 – present, and 2) field observations of channel and floodplain conditions. These conclusions are also rooted in a conceptual understanding of how headwater streams influenced by beaver behave. As such, we briefly cover some underlying concepts here.

BEAVER DAMS AND RIVERSCAPE EVOLUTION

Beaver modifications to streams were historically extensive across most of North America. Despite their historic ubiquity, due to near extirpation by the 19th century, the full extent and impact of beaver across a range of geographies is difficult to precisely identify. As noted above, the persistence of beaver dams and the hydrologic and geomorphic influence they exert can be reasonably conceptualized, but is much more difficult to prescribe at any specific location. In other words, it is possible to state that beaver are and should be present on streams on Six Forks Ranch, however it is not possible to say they should occupy a specific 10 m section of stream. Beaver dams may be valley bottom spanning or channel spanning; they may occur on floodplains on large rivers where the main channel is too large for damming; dams may fill in quickly with sediment in areas with high sediment delivery, or persist as deep ponds where background sediment delivery is low; they may breach over short time-scales where annual high peak flows are of sufficient stream power to breach or blow dams out, or they may persist for decades where peak flows are limited. Furthermore, the residence time of beaver at a particular location is driven both by these factors as well as other biological drivers such as the availability of food and forage (itself intertwined in feedback loops with hydrological and geomorphic processes) as well as other factors such as predation, disease, and forest health and succession.

The objective of this discussion is to help identify the drivers of beaver dam activity and therefore their hydrologic and geomorphic results in a way that does not prescribe a certain end target condition for streams on Six Forks Ranch, but rather acknowledges the dynamism inherent in beaver-influenced streams. Below we present a number of stream evolution trajectories that aid in understanding how beaver influenced streams evolve and the timeframes over which they evolve.

Cluer and Thorne (2014) present a stream evolution model (SEM) that describes how streams may change from multi-threaded (e.g., anabranching) to single-thread and/or incised and widened conditions in response to disturbance. While they do not make their model specific to beaver, they highlight that streams may adjust to different disturbances to move from one natural condition to another.

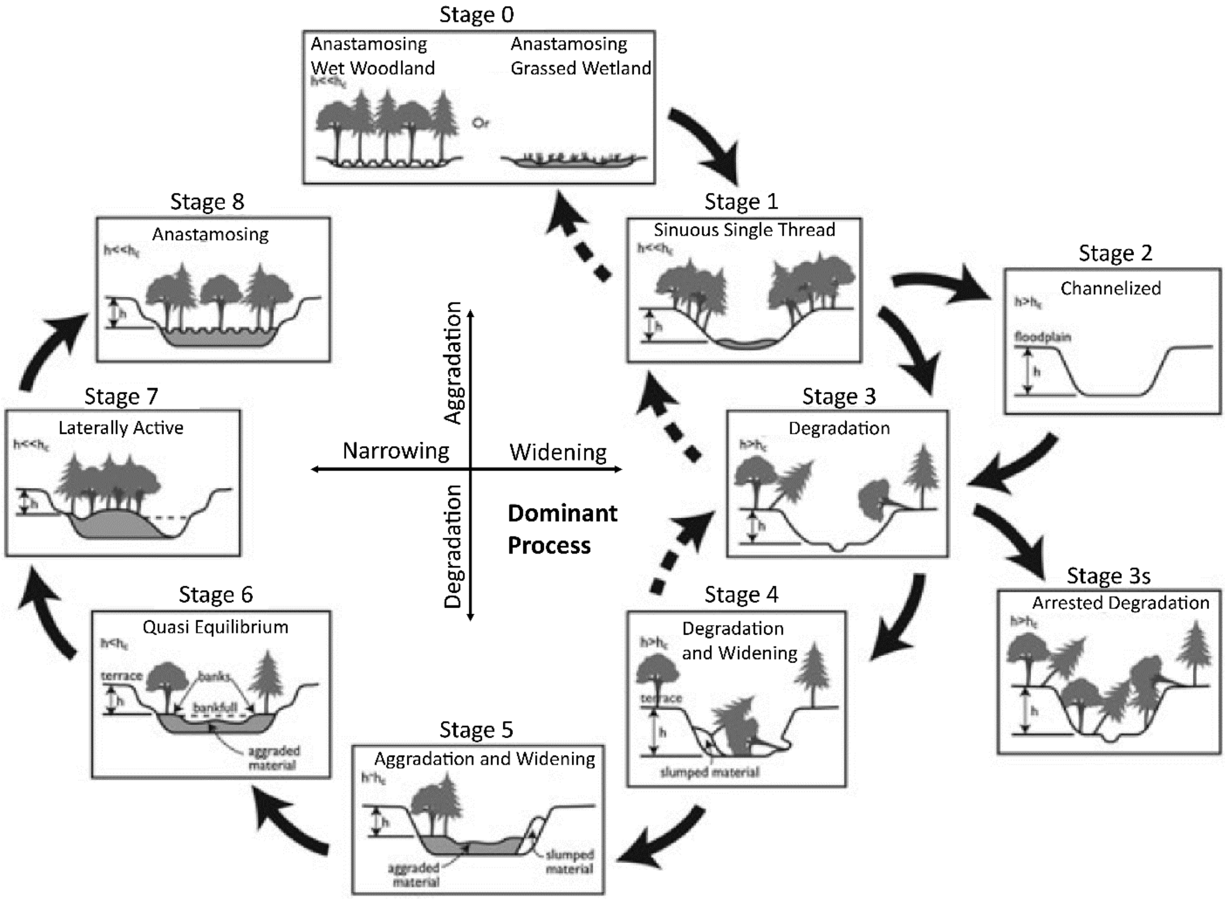

Figure 29 – Stream evolution model presented by Cluer and Thorne (2014). In response to varying levels of beaver activity streams on Six Forks Ranch are generally characterized by Stages 0 – 3, and as illustrated above can transition between stages as beaver dams are built and breached throughout the watershed.

Similar to the approach taken by Cluer and Thorne (2014), but with specific attention to beavers' ability to modify headwater streams, Polvi and Wohl (2013) describe the natural sequences by which streams may transition from anabranching to single-thread incised or meandering types in response to the level of disturbance and beaver dam activity.

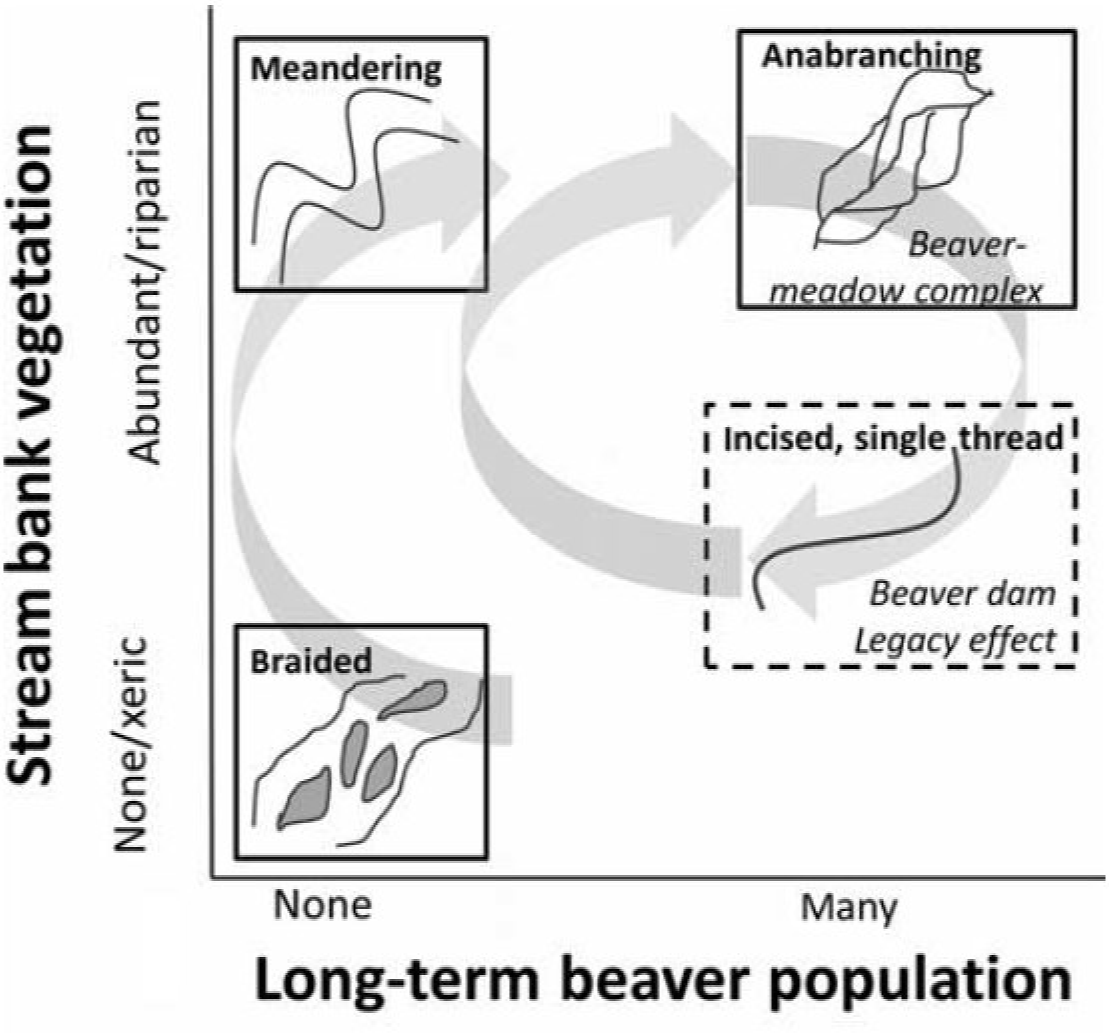

Figure 30 – Reproduced from (Polvi and Wohl, 2013). Six Forks Ranch vegetation fits the 'abundant/riparian' category while the long-term beaver population though difficult to characterize is clearly present in sufficient abundance to build persistent dams. As such we can expect the stream channel to move from an anabranching beaver-meadow complex to incised, single thread or meandering states as the beaver population fluctuates and streambank vegetation responds to both hydrologic and geomorphic processes.

These two studies aid our understanding of how beaver influenced streams may manifest. In short, there may be multiple natural reference conditions, rather than a single condition. However, these studies do not help us understand what a 'natural' amount of beaver dams across a watershed may be. Macfarlane, et al. (2014) developed the Beaver Restoration Assessment Tool (BRAT) in order to predict the maximum capacity of a landscape to support beaver dams based on hydrologic attributes and vegetation characteristics. Across the state of Utah, they predicted maximum beaver dam capacities as high as 40 dams per km (65 dams per mile). Importantly they caution that 'historically (pre-European settlement) the realized percent of capacity was…likely 30% - 50%.' In summary, it is unlikely that all sites that can support beaver dams will support beaver dams at a given point in time.

OPPORTUNITIES LOW-TECH PROCESS-BASED RESTORATION

EF Calf Creek, MF Calf Creek, WF Calf Creek, and Shingle Creek are currently characterized by a combination of active beaver dam complexes and recently abandoned beaver dam complexes, all of which are creating a mosaic of habitats to support complex instream and floodplain habitats. Mainstem (lower) Calf Creek, supports fewer active beaver dams and has less sign of historic beaver dam activity, and is characterized by a less complex valley bottom, and is the natural candidate for LTPBR that seeks to increase ponded area and flow complexity, raise water tables and support a multi-threaded channel.

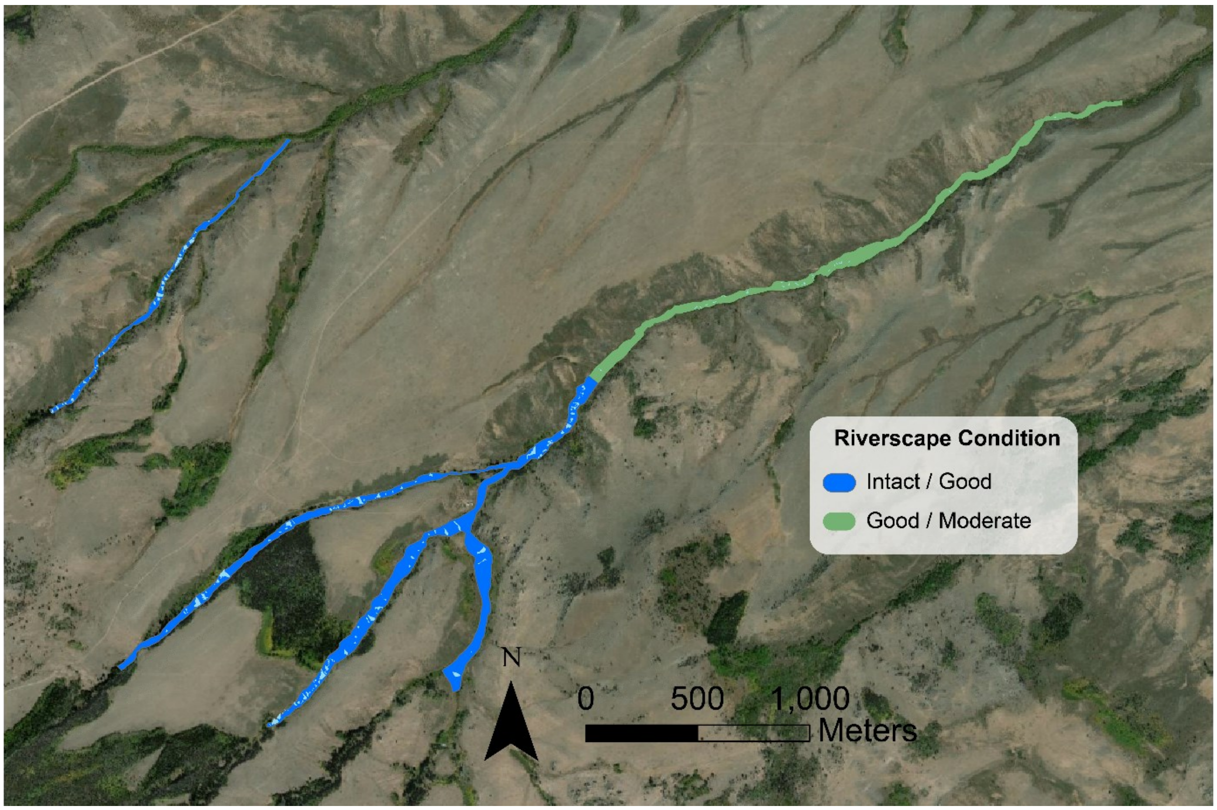

Figure 31 – Riverscape condition at Six Forks Ranch. We recommend using LTPBR on the lower portion of Calf Creek, and monitoring within an adaptive management framework on EF Calf Creek, MF Calf Creek, WF Calf Creek, Shingle Creek, and the portion of lower Calf Creek immediately below the confluence with the WF.

Low-tech process-based restoration (LTPBR) aims to improve riverscape health by simple, cost-effective methods that initiate or accelerate processes that create and maintain aquatic and terrestrial habitats. Unlike restoration that attempts to create specific forms, and to emphasize the stability and persistence of those forms, LTPBR acknowledges that healthy riverscapes are characterized by dynamism, not static features.

In the next section we outline specific opportunities for restoration in each of the perennial streams on Six Forks Ranch. Our recommendations are based on our condition assessment (Figure 31) and therefore fall into two categories. The first is lower Calf Creek, which is the only section of stream characterized as in good/moderate condition. The second category, includes EF, WF, and MF Calf Creek as well as Shingle

Creek. We group these streams together due to the broad similarities with respect to the restoration actions to be taken, and their good/intact conditions. Note that we provide overall specifications for additional structures along each stream but do not identify precise locations. We do not identify precise locations for three main reasons. First, given the dynamic nature of natural beaver dam activity along all streams in Six Forks Ranch, it is possible that natural beaver activity will expand in include areas marked for restoration, rendering precisely identified locations irrelevant. Second, we believe that the specific locations for individual structures are best identified in the field based on specific field conditions, and third, the highly precise location of individual structures is less important than the broader scale considerations outlined earlier in this report.

While we provide specific recommendations for all streams on Six Fork Ranch, we strongly suggest that only lower Calf Creek is an obvious, immediate site for restoration. Each of the other four streams is currently characterized by conditions that range from good to intact, and provide many of the hydrologic and ecological benefits characteristic of streams that are heavily influenced by beaver activity. While we do not advise against restoration actions in these areas, we suggest that they are currently intact ecologically and do not require restoration.

LOWER CALF CREEK

We recommend building beaver dam analogues (BDAs) and patching existing breached beaver dams along the mainstem Calf Creek, below the currently maintained beaver dams which are found in the 400 m downstream of the confluence with the WF. BDAs are built manually (i.e., with hand tools) without the need for heavy and invasive machinery, and should mimic natural beaver dam activity by using locally available materials (i.e., wood and sediment) and should be expected to have lifespans similar to natural beaver dams. The only material not available on-site is untreated wooden posts that can be used to increase temporary stability of BDAs when they are constructed in narrow, incised channels where they are more likely to experience breaching. Untreated wood posts typically cost $3-7 per post, and a single BDA may use between 6 – 30 posts depending on the structure location and specifications. We estimate that in the lower section of Calf Creek most BDAs would require 8 – 15 posts.

The lower section of Calf Creek (identified in green in Figure 29) spans 2.8 km and drops roughly 100 m. We suggest that up to 75 BDAs could be built in lower portion of Calf Creek. This corresponds to a density of approximately 25 BDAs/km which is consistent with the density of beaver dams built in similar streams as well as found elsewhere on Six Forks Ranch.

Specific restoration design and structure locations depend on site-specific considerations (e.g. channel geometry, channel substrate) as well as logistic and resource considerations (e.g. funding, labor) and therefore require additional discussion with the Six Forks Ranch owners. However, we contend that specific structure locations, while necessary for implementation, are far less important than the overall number of structures. Furthermore, there is no single correct restoration design. Like natural beaver dam complexes, restoration designs are better understood not on an individual structure basis, but over the length of the entire project. Lastly, BDAs can easily be designed in the field, and the large amount of available woody material in lower Calf Creek limits the need for extensive logistic planning.

EF CALF CREEK, MF CALF CREEK, WF CALF CREEK, AND SHINGLE CREEK

In general, each of these streams is currently in good or intact conditions. Specific recommendations in this section are therefore of a lesser importance than those provided for lower Calf Creek.

The significant historic beaver dam building along each of these streams leads to an opportunity to patch existing dams that may have breached, rather than the construction of wholly new dams. When determining what dams to repair there are a several factors to consider.

The first consideration in determining whether or not to repair a particular dam it its location with respect to other dams and beaver activity. We assume that abandoned or breached dams that are adjacent to currently maintained beaver dams are more likely to be reoccupied naturally and that the free-flowing habitats they currently support are important in the context of a large mosaic of both free-flowing and ponded habitats. As such, we recommend patching dams in areas that are currently characterized by longer sections (> 50 m) of free-flowing stream.

Second, what is the current condition of the dam? Is there an obvious breach through which channelized water is flowing? Is dam abandoned, but still intact though not ponding water? Has the upstream area experienced significant sedimentation? In general, it will be easiest to patch dams that have a discrete and obvious breach, rather than an abandoned dam that is no longer ponding but lacks an obvious breach. Furthermore, dams that are no longer ponding, but lack an obvious breach may provide important temporary ponds during spring runoff, while free-flowing sections do not. Another factor to consider is the current geomorphic characteristics upstream of the breached dam. Has the channel incised through previously deposited sediments in a manner that leaves it disconnected from its current floodplain? In areas where incision through previously deposited sediments is significant (> 1m) patching the dam may reestablish hydrologic connectivity to the previously inundated surface and be capable of supporting wetland vegetation.

Lastly, what is the likely impact of repairing the existing dam? In other words, what will the pond footprint be? In general, locating dams where repairing a breach forces the greatest upstream ponding extent will have the greatest hydrologic impact and be most effective at providing the greatest amount of habitat for beaver, which will hopefully lead to their adoption and maintenance of any given dam.

BEAVER TRANSLOCATION

The most important factor in the current and future conditions of streams on Six Forks Ranch is natural beaver dam activity. While potentially impactful in the short-term, man-made restoration structures, unless maintained in perpetuity or occupied by beaver are unlikely to promote continued riverscape health characterized by spatial and temporal dynamism that results in a perpetually shifting mosaic of habitats within the valley bottom that include, freshwater ponds, free-flowing stream, shallow overbank flows, and different wetland types (e.g. emergent wetlands, submerged wetlands).

Significant alteration of Calf Creek and Cow Creek, downstream of Six Forks Ranch by conversion to agriculture and water withdrawals for irrigation have led to decreased stream and riparian health and a major reduction in the capacity of those reaches to support beaver. As such, beaver populations downstream of Six Forks Ranch are almost certainly reduced relative to historic conditions. Furthermore, the degraded nature of Calf Creek and Cow Creek, including low flows, a single-thread channel, and low-to-absent riparian vegetation mean that beaver migration from the North Platte upstream to the Six Forks Ranch is likely reduced. We suggest that beaver translocation to the Six Forks Ranch be considered as a long-term strategy to support healthy riverscapes that can aid in mimicking natural beaver dispersion that would likely have been present historically. Restoring natural beaver dispersion would likely require the restoration of downstream sections of Calf and Cow Creeks and coordination with multiple additional landowners, and is currently beyond the scope of this assessment. BDAs can be built to provide immediate deep-water habitat to encourage successful translocation.

MONITORING AND ADAPTIVE MANAGEMENT

In order to ensure the long-term health of streams on the Six Forks Ranch, we recommend developing an adaptive management plan to guide future stream restoration efforts. LTPBR is not a ‘one-and-done’ approach to restoration, but rather an ongoing commitment, where future actions are based on the identification of deterioration in condition that warrant interventions. Adaptive management identifies specific thresholds or responses that trigger specific management actions. On Six Forks Ranch, an example of an adaptive management threshold may be: *If the proportion of the valley bottom occupied by ponded water on Calf Creek drops below 5%, we will construct and/or maintain BDAs.*

Development of an adaptive management plan is necessarily a collaborative process that requires inputs from the owners of Six Forks Ranch.

NEXT STEPS

Anabranch Solutions will work to secure relevant permits for restoration on lower Calf Creek for 2022 implementation. Anabranch Solutions will keep Six Forks Ranch updated on all correspondence with the US Army Corps of Engineers, Wyoming Game and Fish Department, and the Wyoming State Engineers Office.

CONCLUSION

Streams on Six Forks Ranch generally range from good to intact condition. The dominant factor influencing hydrologic and geomorphic processes as well as associated valley bottom riparian communities has historically been, and currently is beaver dam activity. Because the long-term health of streams on Six Forks Ranch depends on continual beaver dam building and maintenance, downstream restoration efforts, or increasing beaver populations through beaver translocation, may be the most cost-effective long-term strategy to ensuring the continued health of streams on Six Forks Ranch. BDAs can be used in the short-term to increase the likelihood of success of beaver translocation, as well as immediately influence hydrologic and geomorphic processes that will result in improved instream and floodplain habitats.

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