After the flood: Investigations of impacts to archaeological resources from the 2013 flood in southern Alberta

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Post-2013 flood historic resource assessments of the Sheep, Highwood, and Bow rivers and their contribution to a regional understanding of the precontact landscape

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ABSTRACT

Between 2013 and 2015, Lifeways of Canada Limited completed historic resources assessments of the impacts the 2013 flood on palaeontological and archaeological resources adjacent to the Bow, Sheep, and upper Highwood rivers in southern Alberta. These studies visually assessed erosional exposures on these rivers and documented historic resources. Analysis of the location and character of these finds has shed light on the types of landforms present and the nature of human occupations in the Bow River watershed, and highlights how significant the impact of flood-related erosion has been on historic resources. Here, we discuss these finds in a regional context to integrate them into the larger geological and precontact landscape contexts of southern Alberta. We present an idealized model of river zones, developed following observations of the flood impact studies in this system, and discuss how this model applies to each individual river studied and their associated archaeological sites.

KEYWORDS

Bow River, Sheep River, Highwood River, 2013 Bow River flood, Bighill Creek Formation, terraces, Precontact, landscape

1. Introduction

In June 2013, rivers and tributaries in the Bow River basin experienced devastating floods as a result of a slow-moving, heavy rainstorm in the upper drainages at the same time as the snowmelt peak. To the people affected, the flooding seemed to be an unprecedented event. However, historical and geological records show that the floods were a rare but predictable event. This has happened before and it will happen again (Osborn 1987; Wilson 1987; Pomeroy et al. 2015), the only thing not predictable is precisely when it will occur. By, once again, demonstrating the flood potential of the Bow basin, the 2013 floods provided further analogues for reconstruction of past events as well as an impetus for planning initiatives based on the measured impacts. These floods provide archaeologists and palaeontologists with a unique opportunity to undertake multidisciplinary studies of the historic resources present along several rivers in the Bow River system, in order to identify how much these resources have been impacted by the flood and to arrive at a better understanding of the geological contexts of these finds.

In the aftermath of the 2013 flood, archaeological and palaeontological surveys along the Bow, Sheep, and Highwood rivers in 2013, 2014, and 2015 have allowed us to compile an inventory of the rich cultural and historic resources associated with these watercourses. Results of these inventory surveys have been described in a series of detailed scientific reports providing descriptions of the archaeological and palaeontological finds observed in the context of flood impacts. Here, these results are discussed in a regional perspective to illustrate how these river systems were shaped and, in turn, how human populations used these riparian and nearby landscapes through time.

The floods had both negative and positive impacts: while devastating in terms of physical and financial impacts to property, the floods also reminded people that worse floods are possible. This was not the worst summer flood event of the historic record and it falls far short of what is possible in this drainage basin (Osborn 1987; Wilson 1987; Pomeroy et al. 2015). While many archaeological and palaeontological deposits were damaged by erosion, important new discoveries were also made at previously unknown sites and new exposures helped to clarify the depositional settings of known sites.

2. The Bow River basin and the 2013 flood

From its headwaters between the Main and Front Ranges of the Rocky Mountains, to where it joins the South Saskatchewan River, the Bow River is over 587 kilometres in length and drains an area of 26,200 square kilometres. The geographic reach of the Bow watershed covers all of the major physiographic regions present in the southern part of the province, from the high peaks of the Main Ranges, through the Front Ranges and dry Eastern Slopes of the Rocky Mountains, to the lower ridges and rolling topography of the Foothills, and finally, to the undulating lands of the Great Plains. The greater Bow River Basin, including major tributaries such as the Kananaskis River, the Elbow River, and further downstream, the Highwood River, covers almost a quarter of southern Alberta and contributes over 40% of all the water that flows through the South Saskatchewan River system (Figure 1). Currently, almost half of the province's population resides within the Bow River watershed or relies on its water for sustenance.

In June 2013, high waters from spring runoff combined with torrential rainfall from a slow-moving weather system, created catastrophic flooding throughout the Bow River watershed. Affected rivers included the Bow River itself, as well as the Highwood, Sheep, Elbow, and Kananaskis rivers and numerous smaller tributary streams and creeks along the Front Ranges of the Rocky Mountains. At the peak of

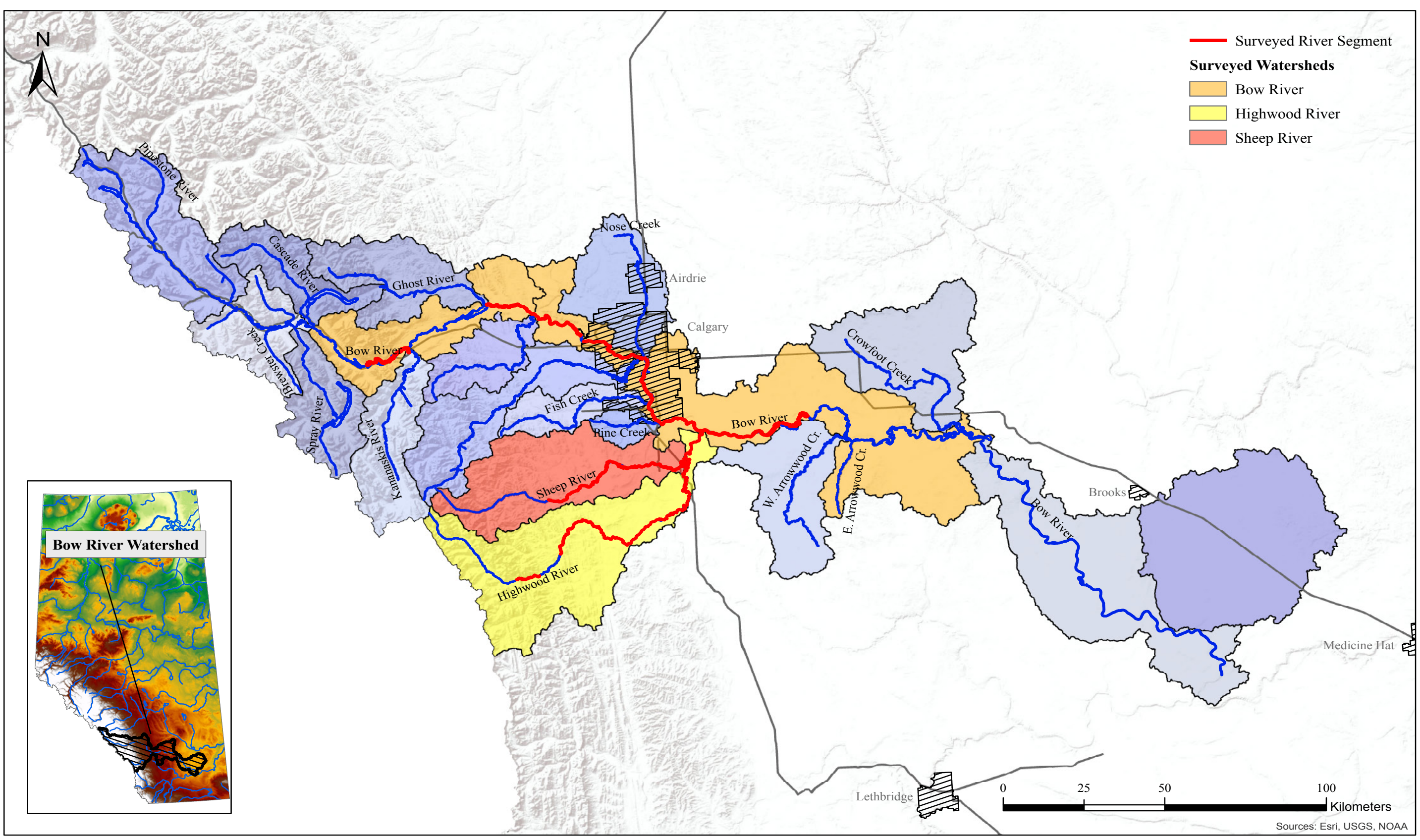

Figure 1. The Bow River watershed.

the flood event, water levels were the highest seen in the last 60 years, nearly comparable to historic flood events of the late 1800s and early 1900s (Pomeroy et al. 2015). The Bow, Highwood, and Elbow rivers were all flowing at volumes three times the level of the already noteworthy 2005 floods (Morris at al. 2014).

The Bow, Sheep, and Highwood rivers all reached their high watermarks on June 21, 2013, after which floodwaters slowly subsided. At its height, records indicate that the Bow River reached a maximum discharge of 1,740 cubic metres per second (Instantaneous Maximum Discharge or IMD). Quantified another way, Environment Canada records indicate that the river spiked over 4 metres in elevation, or nearly 3 metres above normal flows of the last two years (WaterSMART Solutions Ltd. 2013). Similar spikes were seen on the Highwood River, which reached a maximum discharge of 734 cubic metres per second (IMD) below the Little Bow Canal. On the Sheep River, the flood saw an estimated peak flow of over 1,000 cubic metres per second (IMD) in Okotoks and 720 cubic metres per second (IMD) in Black Diamond. This compares to peak flows of 769 cubic metres per second (IMD) in Okotoks and 380 cubic metres per second (IMD) in Black Diamond during the 2005 floods (Government of Alberta 2015). These floodwaters had dramatic impacts on human infrastructure in the Bow watershed, and accelerated the natural processes of erosion and deposition, significantly altering these river systems. However, flood impacts varied throughout the Bow watershed. In some areas, erosion was minimized by thick vegetation that held and protected the banks; in others, bedrock walls served as restraints. Elsewhere, extensive areas of land were washed away and entire new channels were formed by the floodwaters. In still other areas, fluvial processes deposited thick sand and gravel bars, deflecting river flows.

Impacts of the June 2013 flood were evident as soon as high water began to recede, especially the degree of erosion that occurred throughout the Bow watershed. In the ensuing weeks, an increase in observations and public reports of bones washing out along riverbanks indicated the flood's great impact upon historic resources (both archaeological and palaeontological). In response to these reports and with an eye to developing long-term plans for predication and mitigation of flood impacts on historic resources, Alberta Culture and Tourism initiated a series of historic resource surveys along watercourses within the Bow watershed. Since 2013, a team of archaeologists and geoscientists from Lifeways of Canada Limited (Lifeways), working under contract to Alberta Culture and Tourism, has surveyed banks of the Bow, Sheep, and Upper Highwood rivers to find and document such occurrences, to measure the impact of the 2013 flood on historic resources, and to provide recommendations for their long-term preservation and management (Vivian 2014; Vivian and Amundsen-Meyer 2015, 2016a, 2016b; Wilson 2015, 2016a, 2016b). Surveys have now been completed along most of the Bow River from Exshaw downstream to the Siksiká First Nation, along the Sheep River from Bluerock Wildland Provincial Park downstream to its confluence with the Highwood River, and on the Upper Highwood from Stony Creek (upstream from the Eden Valley First Nation) to Longview (Figure 1). Through these studies, we have gained a greater understanding of these river systems, the character of landforms present, the potential for erosional impact to these landscapes, the ages of human occupations present, and the potential for erosional and other flood impacts upon historic resources associated with these occupations.

3. Previous studies of the Bow River watershed

The Bow River and its environs have long caught the attention of researchers interested in the post-glacial history of landforms of southern Alberta and the region's precontact inhabitants. Over a century ago, James Hector (1861; Spry 1968) and then George Dawson (1875, 1884, 1891, 1897; Dawson and McConnell 1895) speculated about the origins of the terraces of the Bow valley, and first reasoned them to represent shorelines of a former glacial lake or incursion of a sea associated with the last great Ice Age. Panton (1884) was first to link the Bow River terraces to the action of a river different from that of today, but his opinion was ignored and was not shared by others until the early 1900s. Studies of Quaternary deposits were then effectively interrupted by two World Wars and the Great Depression, with geological attention in Alberta turning toward two great "rushes"—one for dinosaurs and the other for oil. In the post-war years, an increasing interest in Quaternary studies introduced new analytical techniques and brought a renewed focus on the Bow and other southern Alberta rivers. Researchers from the Geological Survey of Canada, the Alberta Research Council, University of Calgary, and elsewhere classified sediments and associated landforms, collected bone samples for radiocarbon dating, and formulated hypotheses as to how drainages throughout southern Alberta had been impacted by the glacial and post-glacial events that shaped this landscape. Analysts documented the role of receding ice fronts in deflecting rivers, which caused the sharp changes in direction that typify Alberta Plains' rivers, despite the absence of bedrock control. The presence of Late Pleistocene vertebrate megafauna was documented and the role and timing of an "Ice-free Corridor" were debated. The earth sciences that contributed to these studies continue to be a rich field of endeavour as investigations evolve to ask new research questions, revisit old ones, and contribute, in many ways, to management and planning processes.

The importance of these riverine environments to human populations in southern Alberta has not been lost on archaeologists. In the late 1930s, Junius Bird (American Museum of Natural History) and Wesley Bliss (American Philosophical Society) conducted surveys within the Ice-free Corridor in the hope of finding sites with evidence of early human occupation. Bird found only crude artifacts on high terraces but Bliss reported "Folsom and Yuma artifacts" in collections "made in the vicinity of Calgary" (Bird 1939; Bliss 1939:366). Again, war brought these studies to a halt. The formative years of Alberta archaeology in the 1950s and 1960s saw Dr. Richard Forbis record many important sites along southern Alberta's major waterways. These included the Ross Site, Kenny Site, and Junction Site on the Oldman River; and the FM Site and Sweet Site on the Bow River, among many others. As archaeological studies became increasingly systematic and regulated through the 1970s, valleys in the Bow River watershed remained a focus for investigations. A University of Calgary field school inventoried archaeological sites between Calgary and Cochrane, and in 1972, a team of its graduate students completed a more expansive survey of the Bow River from Fish Creek to the Highwood River confluence (Rogers and McIntyre 1972). Building on this survey's success, Rogers followed up with an inventory of archaeological sites along the Sheep River and another along the lower Highwood. This work found numerous archaeological sites which were documented with site forms, but full survey reports were never produced. The lack of survey reports has limited the overall utility of these inventories and has left many questions unanswered as to the contexts of the recorded sites and even the extent of the areas studied. Rarely, was detail provided as to the nature of exposed sediments or the age and character of observed landforms.

A departure from the earlier Bow River surveys was the study completed by Michael Wilson, which formed the basis of his dissertation defended in 1981 (Wilson 1983). Wilson took advantage of Calgary's building boom in the 1970s to locate and record archaeological and Quaternary palaeontological sites and to document their geological contexts and associated landforms. The resulting study remains one of the few to provide an integrated inventory of such finds in their geographic and geological contexts, using sites found along the Bow River. This approach seeks a more comprehensive understanding of archaeological and paleontological occurrences, both in temporal and landscape contexts, while attempting to determine where, when, and how they were deposited. Wilson sought not only a taphonomic perspective as to how these archaeological sites (and the patterned behaviour that they represent) came to be preserved, but also an understanding as to how past and modern landscape processes have selectively influenced our ability to find them. Wilson (1983) began to reconstruct the environments in which these sites were created *and* revealed, with the goal of producing stronger predictive models as to where similar sites may be found in the future. Our archaeological and Quaternary palaeontological surveys completed as part of the 2013 flood impact assessment program, as described here, build on this geoarchaeological approach to the Calgary area (Wilson 1983), applying these theories to much of the Bow River from Exshaw to the Siksiká First Nation boundary east of Carseland. We then consider how this same model applies to our finds on the Sheep and Highwood River.

4. Paleo-environmental background and results

The 2013 flood impact survey allowed us to conduct palaeontological and palaeoenvironmental examinations of a large stretch of the Bow River, building on Wilson's (1983) earlier studies of this watercourse and adjacent landforms in the Calgary area. Visually observing such a large stretch of the Bow Valley from river level brought a new and different awareness of the landscape, and challenged previous notions of the valley's limitations and potential. For example, we had expected to encounter paleo-environmental sites where the floodwaters had exposed slack-water deposits with in-place gastropods and peat sequences that could be sampled (these deposits are typically associated with flood plains). It soon became apparent that such settings have a very limited distribution in the study area, outside of the Bow River's broad floodplain in the City of Calgary. Within Calgary, near the mouth of Fish Creek, lateral cutting did expose a small area of Late Holocene, peaty, back-swamp deposits with gastropods. Bison bones from overlying overbank silts in this exposure were dated to ~2450 ^{14}C yr BP (radiocarbon years before present; Vivian and Amundsen-Meyer 2015; Wilson 2015). This occurrence illustrates the rarity of such deposits in the study area, and this, in turn, relates to our findings about river zonation, described below.

The same section near Fish Creek yielded a geological find of great interest: Bridge River tephra (volcanic ash; Wilson 2015). This tephra, from an eruption about 2350 ^{14}C yr BP at Mount Meager in the Pemberton area of southwestern British Columbia, had been recorded from west-central Alberta but not from this far south (e.g., Zoltai 1989). The dated bison bones were closely associated with the tephra band. By indicating that the downwind ash-fall distribution fan was larger than previously thought, the discovery informs reconstructions of the magnitude of the eruption itself, which was associated with a Mt.-St.-Helens-like flank collapse and lateral blast (Hickson et al. 1999; Simpson et al. 2006). Given the thinness of this tephra (a few millimetres), it may not have been observed at all were it not in a freshly cut exposure and in slackwater sediments, and for Wilson's prior experience with several Cascade Range tephras.

4.1 The Bighill Creek Formation and its implications

This new awareness of landscape also led to a greater understanding of the Late Pleistocene Bighill Creek Formation (BCF). Following earlier studies of the Bow valley, it was expected that this gravel and sand unit would form a relatively continuous high-terrace "ribbon" along the Bow valley from at least Cochrane to Carseland. This understanding was based on a mental "connecting of the dots" from one previously recorded occurrence to the next (e.g., Stalker 1968; Jackson et al. 1982; Wilson 1983, 1987). In fact, much of what might once have been relatively continuous had been profoundly affected by Holocene erosion and historic gravel mining, leaving what is now a critically endangered geological and palaeontological resource in need of urgent study (Wilson 2015).

What is the importance of the BCF for palaeontology and archaeology? First, it has yielded an important collection of vertebrate megafauna including mammoth, horse, camel, bison, bighorn sheep, and caribou (Churcher 1968, 1975; Wilson and Churcher 1978, 1984; Wilson et al. 2008). A large bison skull was an important find made after the flood at Calgary cut into BCF gravels at Montgomery (Figure 2; Vivian 2014). Dates on vertebrate megafauna recovered within the BCF, including now-extinct species, range from about 11,400 to 10,000 ^{4}C yr BP. Closer study of the BCF dates on the Bow and other drainages revealed that they fell into two clusters, ~11,400 to 10,700 and ~10,200 to 10,000 (or 9800) ^{14}C yr BP, essentially bracketing the Younger Dryas (Wilson et al. 2008). We now know that these animals lived in a warming, not periglacial, environment, and that they represented a fauna moving northward into the "ice-free corridor" from the Great Plains, not coming southward from Beringia. The early cluster of BCF dates coincides with the time of Clovis peoples on the Plains and it is likely that these people were part of that northward movement (Wilson 1996; Wilson et al. 2008). The now-extinct fauna seem to belong to the early BCF date cluster, with only the giant bison surviving to the late BCF cluster, so the extinction events seem to have happened during Younger Dryas times and in the presence of human hunters.

Flood impact studies in the Bow watershed indicate that some reaches of these rivers have cut down about 10 metres since BCF times, becoming entrenched in, or resting upon, bedrock to varying degrees. During Clovis times, the valleys were less entrenched and their floors broad, with a much different appearance from that of today. The survey work and literature review associated with the flood studies have also reopened another issue—that of the relationship between the Highwood and Sheep rivers. A very low divide separates the Highwood River from the headwaters of the Little Bow River, constituting a low area within the Town of High River. That area was inundated during the 2013 flood and ponded waters lingered long after the flood crest had passed. It has long been suspected that the Highwood River originally flowed southeastward via the Little Bow River into the Oldman drainage, and that it was captured at some undefined time by a headward-cutting tributary of the Sheep River, a tributary that was also separated from the Highwood by a relatively low divide. Avulsion of the Highwood River to a new channel, itself, likely involved a flood event, with over-spilling waters contributing their erosive force across the low divide into the Sheep tributary. After one or more such events, the main body of the Highwood River shifted to the northward path, taking over as the trunk stream for the Sheep River, and largely abandoned the Little Bow val-

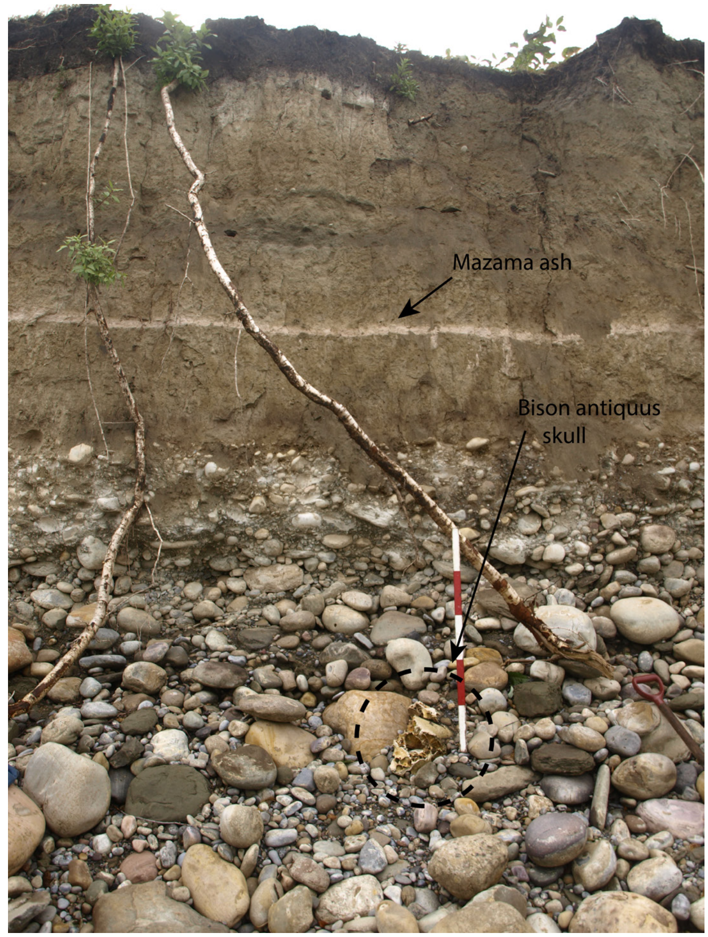

Figure 2. Freshly exposed *Bison antiqus* skull at EgPn-762.

ley. Our finding of BCF-like gravels and sands on the Sheep and Highwood rivers, and especially the pre-1930 find of mammoth teeth in terrace gravels on the Highwood River east of Aldersyde (between High River and the confluence with the Sheep), would indicate that the avulsion event and river capture occurred before BCF deposition. In other words, this event occurred before Clovis times. That would mean, in turn, that broad surfaces along the Little Bow valley have been conserved with minimal lateral erosion since before Clovis times, and that their mantle of slope-derived sediments (colluvium) and occasional overbank sediments from the Little Bow could preserve significant Late Pleistocene vertebrate fossils and archaeological remains. Such a scenario has obvious planning implications for the conservation of historic resources. Gravel-mining operations and other impacts on both the Lower Highwood River and the upper Little Bow valley should be monitored closely.

4.2 The formation processes of terraces, point bars, and scroll bars

The downcutting of these river valleys that has occurred since BCF times has important implications for the types of landforms present along waterways in the Bow drainage, and for their potential to contain archaeological sites of varying time depths. It is well known that, while rivers are downcutting, they can leave behind bench-like terraces as remnants of former floodplains. Obviously, terraces require downcutting to be produced and cannot occur along rivers that are aggradational (raising their bed levels); however, there are other requirements, too. Terraces will be rare and of limited extent where rivers are entrenched in bedrock and undergo little lateral migration and, hence, geological settings are important. In areas where lateral erosion is more common, rivers can develop broad floodplains with meanders of varying amplitude, leaving behind terraces as downcutting occurs (Wilson 2015, 2016a, 2016b).

It is important to distinguish "terraces" (erosional remnants) from "terrace fills" (the alluvial deposits associated with them). In some cases, it is possible to correlate (trace, laterally) the actual terrace surfaces, provided they have not been differentially eroded in the process of abandonment by the river. It is also possible to correlate terrace fills on the basis of their character and age, even though they might vary in level above the river by, for example, dropping in level as one moves upstream or downstream, indicating a change in river gradient. A third possibility is to correlate the levels of laterally planed bedrock or other deposits that underlie a given terrace fill. Any correlations based upon level must have highly accurate elevation information to be valid (the interpolated contours of a National Topographic System [NTS] topographic map are approximations of no value in such a study). The presence of upstream-migrating knickpoints, as are well represented along the rivers in the Bow watershed, further bedevils any attempts at long-distance correlation based on terrace levels. Mistakes can be made in other ways as well. For example, the presence or absence of Mazama tephra in terrace deposits has been used to distinguish older and younger terraces (e.g., Pennock and Vreeken [1986] for the Highwood River). This approach can be valid, provided that the tephra is demonstrably in overbank sediments of an alluvial fill (the "terrace fill") and not simply in a capping colluvial drape or aeolian sheet, as are common on terrace surfaces along these rivers. Tephra layers in non-alluvial strata can only be limiting dates for the terrace fills atop which they lie and, more importantly, do not provide limiting dates for river incision from that terrace level. This is because they could have continued to grow atop the fill long after the river had abandoned the surface.

Not all terraces are alike, and the character of a terrace has important implications for palaeoenvironmental studies and the ages of archaeological sites associated with these landforms. "Paired terraces" result when aggradation leads to deposition of an alluvial fill, then degradation (incision) by the river occurs. This leaves the top of the alluvial fill (filltop) as a floodplain remnant that is much the same elevation on both sides of the river, allowing for some local surface erosion as the river abandons its former plain. The key here is that, with paired terraces, there has been a clear reversal in river behaviour from aggradation to degradation which probably would have required some sort of environmental change. There is still a problem of equifinality, in that several different inputs might have produced the same result. The environmental change may have involved upstream factors (such as changes in river discharge or sediment input) or downstream factors (such as a change in base level, with a tributary responding to downcutting on the trunk river). The causes of these changes need to be clarified; thus additional lines of evidence are needed to narrow down the range of possibilities.

"Unpaired terraces" result from gradual downcutting with migration of meanders. The greatest erosional force directed by the river at a meander is located somewhat downstream from the mid-point of the meander, on the outside of the meander bend. This is why the meanders tend to migrate both laterally and in a downstream direction. On the low-energy "inside" of the meander bend is a point bar, which also grows laterally and in a downstream direction (Figure 3). Its surface (the point-bar slip-off surface) is gently sloping toward the river, and its deposits are laterally

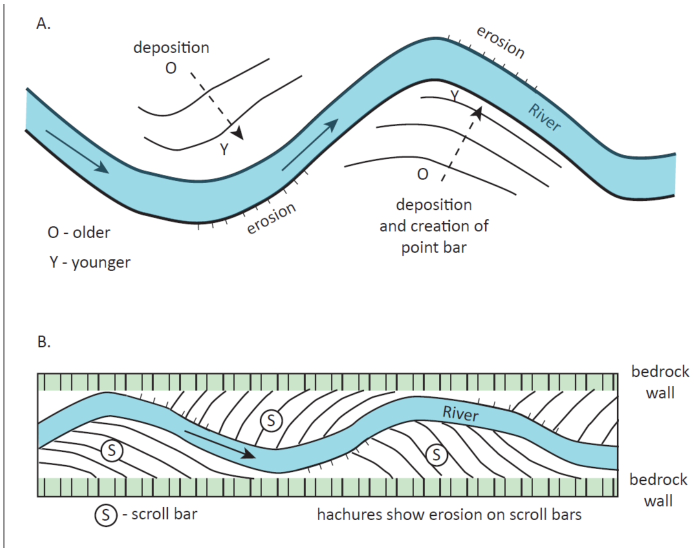

Figure 3. Schematic showing models of point bar and scroll bar deposition.

time-transgressive—i.e., they are younger near the river and older away from the river. If lateral migration continued in only one direction, there would be no terracing, only enormous slip-off surfaces. But with downstream migration as well, the meander direction at a given locality will eventually "reverse"—that is, alternate right and left meanders will "pass through" the locality. As a result, the direction of erosion will change and the river will cut laterally into an old slip-off surface while continuing to produce a new one. The result is a series of stepped surfaces that might, at first, resemble paired terraces, but the surface slope is different. More importantly, unpaired terraces require no reversal of river behaviour to be produced, and hence they do not have much inherent value for palaeoenvironmental reconstruction other than to indicate that there has been steady downcutting. Because of shared meander behaviour, it may be possible to trace unpaired terraces over very short distances, in which case they are useful locally (e.g., within the City of Calgary). However, lateral variations in age resulting from their lateral growth make these correlations more complex that they would, at first, seem.

Finally, "scroll bars" are temporary depositional features along confined reaches of the river, alternating from one side to the other, as the river swings back and forth across its channel (Figure 3). Like point bars, these features grow in a lateral and downstream direction and are eroded away at their upstream end. Channel confinement restricts lateral growth, so the result is that they move through the system rapidly and have little or no potential for long-term storage of archaeological and palaeontological materials.

Post-2013 flood impact investigations along the Bow, Sheep, and Highwood rivers revealed that paired terraces could only be demonstrated for high surfaces of known or probably Late Pleistocene age, possibly all associated with the Bighill Creek Formation terrace fill. As in Calgary, there is also a possible early- to mid-Holocene, post-BCF fill typified by finer-grained deposits and containing a Mazama tephra band. However, careful study is needed to confirm that the tephra is in overbank alluvium and not capping colluvium. All younger, mid- to late-Holocene terraces are unpaired slip-offs. In bedrock-incised reaches we saw only unpaired terraces at levels lower than that with the BCF fill.

4.3 A landscape model of river zonation

Based on these observations of river formation processes, an idealized model of the Bow, Sheep, and Highwood rivers with three longitudinal zones was developed. Each zone has its own geomorphic characteristics and dominant processes (Figure 4). Importantly, the zones differ in terms of their likelihood for preservation of archaeological or palaeontological remains, as well as in terms of their vulnerability to flood damage (Vivian and Amundsen-Meyer 2016a, 2016b; Wilson 2016a, 2016b). In its simplest form, the model does not perfectly describe any one drainage. However, the purpose of a model is to simplify comparison and to serve as a heuristic device against which to measure each example.

Zone one is an upstream, largely intermontane reach in which cross-valley growth of paraglacial debris-flow fans (Figures 4 and 5) has introduced huge amounts of sediment,

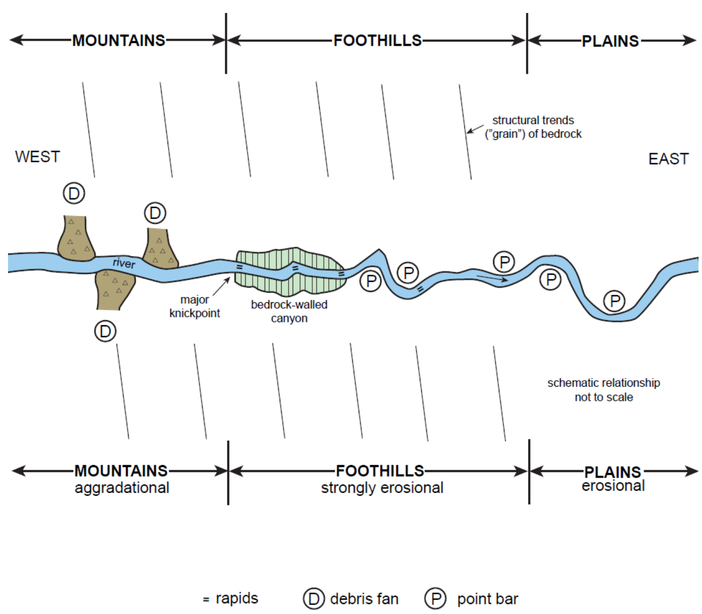

Figure 4. Schematic model of zonation in river form and valley processes for the Bow, Sheep, and Highwood Rivers.

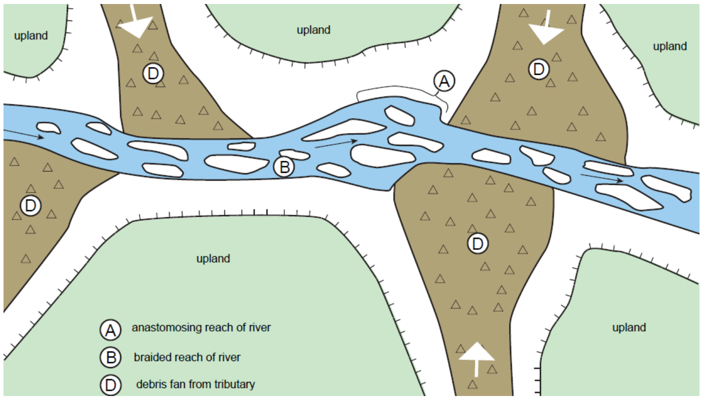

Figure 5. Model of relationships along debris-fan-dominated zone of upper drainage in mountainous areas.

and has caused the main river to be deflected and to back up with local ponding (e.g., Lac des Arcs and Vermilion Lakes on the Bow). Here, the river is aggradational (raising its bed) or relatively steady in level, and there is little or no development of terraces. In Zone one, preservation of ancient material is possible; but given aggradational conditions, their exposure is unlikely, except on the debris-flow fans, the toes of which may be cut by the river. Back-swamps are present along the river, but their potentially valuable palaeoenvironmental information must be obtained through coring.

Zone two is a Foothills reach where the river cuts across deformed (folded and steeply dipping) bedrock (Figure 4). Erosion by headward-migrating knickpoints has left the river increasingly entrenched in bedrock and increasingly unable to migrate laterally, although it may have done so in its early postglacial initiation. In essence, this reach is largely entrenchedin a bedrock canyon. Benches are often present, mostly as unpaired, bedrock-cut surfaces capped by channel gravels. Paired, Late Pleistocene terraces may be present, especially if the river flows along former glacial meltwater channels, but would be well above the modern, bedrock-entrenched river. River bends in this zone are typically not meanders from lateral cutting but, instead, are deflections caused by changes in resistance of steeply dipping bedrock strata to erosion. Throughput of sediment is typically in the form of channel-margin scroll bars that migrate rapidly downstream. Correspondingly, in the absence of floodplains, there is minimal opportunity for backswamp development, and palaeoenvironmental information is limited. Zone two has the least potential for preservation of palaeontological remains, except locally on the high terrace remnants. This zone also has the most limited potential for archaeological sites to be exposed immediately adjacent to the river. In this section, sites are most likely to be present on top of bedrock benches high above the river. Notably, damage from the 2013 floods in this zone was limited because the valley and its landforms had already been streamlined by previous flood events, and the bedrock benches commonly found adjacent to the river are resistant to erosion.

Zone three is a Plains reach in which the river dominantly flows in a broader valley, usually cut in Quaternary deposits (till, glacial lake deposits, and alluvium), although now it has reached bedrock and is beginning to be entrenched (Figure 4). Here, the river can develop meanders and can exhibit a broad floodplain with terraces representing former, abandoned floodplain surfaces. The underlying bedrock is undulating as a result of glacial scour, so some reaches in this zone may show moderate entrenchment into bedrock and characteristics similar to Zone two. Where entrenchment has begun, there may be incised meanders that developed before incision and became fixed in place during downcutting. Overall, this zone has high potential for preservation of palaeontological and archaeological materials in alluvial and colluvial sediments, as well as high potential for their exposure by erosion along river meanders. Backswamps (as oxbow channels) are present and those of old floodplains can be exposed by lateral cutting, exposing deposits with valuable palaeoenvironmental information.

5. Archaeological resources documented

With our description of the geology of the Bow watershed and the idealized model of these rivers outlined, we turn our discussion to a review of archaeological sites documented during post-2013 flood impact assessment studies and the contexts in which these sites are found. Comparison of site locations with the idealized model of river zones allows us to gain a greater understanding of the distribution and type of archaeological sites present, and the archaeological potential of different types of river-marginal landforms. Further, this allows us to develop a stronger predictive model for the location of, as yet unrecorded, archaeological sites along these watercourses.

5.1 Bow River finds

On the Bow River, archaeological surveys have now been completed along almost the entire length of the river from near Exshaw to the western boundary of the Siksiká First Nation (Figure 1). This study has resulted in the documentation of over 50 archaeological sites exposed by flood action on the river, approximately half of which were previously unrecorded (Vivian 2014; Vivian and Amundsen-Meyer 2015, 2016a). Review of these sites, in the context of the palaeoenvironmental data collected, facilitates the definition of four separate reaches along the river where temporally distinct sites occur in environmentally different settings.

The first of these is that portion upstream of the Seebe (Kananaskis) Dam and Reservoir, where the Bow River is dominated by large, cross-valley debris-flow fans emanating from tributaries (corresponding to Zone one of the idealized model). Where these fans have flowed across the valley, and in places where they partially dammed the river, erosional exposures have typically cut off the toes of these landforms to create cutbank exposures 2 to 5 metres in height. The sediments exposed in these cutbanks are typified by thick layers of aeolian (wind-blown) silts and fine sands overlying massive debris-flow-dominated deposits of sand and gravels from pebbles to boulders, often angular. Mazama tephra often occurs just above the base of the aeolian cap, indicating that debris-flow activity had largely waned by the early Holocene (Roed and Wasylyk 1973; Jackson et al. 1982). Previous archaeological assessments along the Bow River in the Canmore area, and extending up to Banff, demonstrated these debris flows to be excellent locales for deeply buried archaeological sites, several dating back to the Late Pleistocene over 10,000 years ago, as at Vermilion Lakes (Fedje and White 1988; Fedje et al. 1995). Other examples include the Second Lake Site just outside of Banff, and downstream of Canmore, EgPt-28 on the Pigeon Creek Fan, and EgPs-46, EgPs-47, and EgPs-48 on the Heart Creek Fan (Newton 1991; Balcom et al. 1995; Clarke et al. 1996).

During the 2015 survey, these debris-flow fans were found to be heavily impacted by erosion, and two sites were documented in cutbank exposures, one of which was newly discovered and the other, previously documented (Figure 6). While neither of these appears to include occupations as early as that at the Vermilion Lakes Site, the exposed stratigraphy did include buried paleosols in aeolian sediments that date back to early Holocene times, some below Mazama tephra.

Figure 6. Debris-flow fan on the Upper Bow River (EgPs-47).

These paleosols, indicative of ancient land surfaces, demonstrate the elevated potential for finding Early Precontact occupations in these settings and illustrate why deeply buried and stratified sites are found in this region. A third site along this reach was found in a dune, but this environmental setting reflects a continuing process and the temporal associations of archaeological finds in such a setting have less predictive value. Dunes and aeolian sheets are widespread in the area just downstream from Lac des Arcs, with the sediments derived in the past (as still continues today) from wind erosion of the exposed flats with the river at low stages (Rutter 1972).

From the Seebe Dam downstream to Cochrane (and beyond), the river becomes increasingly entrenched within the variably resistant bedrock formations of the Foothills, corresponding to Zone two of the idealized model. The bedrock-cut benches, with only thin, capping channel-gravels typically found in this stretch, were not greatly affected by the 2013 flood and limited erosional impacts were observed. Few sites were found in this context because the survey was focused on erosional impacts along the river. While, undoubtedly, there are archaeological sites to be found on benches and higher land surfaces along this stretch, it is likely that these will be smaller, less complex, and not deeply buried sites (given the typical absence of a thick sediment cap and only thin channel gravels over bedrock). The deeper canyon formations, which hinder direct access to the river and make it much more difficult to cross, were likely also key factors that influenced the strategic location of sites within this entrenched portion.

Downstream of the Bearspaw Reservoir, the third distinct segment of the Bow River is characterized by well-developed sequences of paired terraces and slip-off surfaces (Zone three of the idealized model). Within the Calgary city limits, Wilson's dissertation studies (1983) documented the development of the unpaired T1 and T2 terraces (and probably paired T3 terrace) in considerable detail. Now, with the surveys downstream, these landforms can be demonstrated to extend to the mouth of the Highwood River (Figure 7). Archaeologically, few of the examined land surfaces are old enough to include Paleoindian sites and it is generally believed that sites from this early time do not occur in the river valley bottomlands.

While this may, admittedly, be a function of site visibility, it is certainly true that we see an explosion of sites along the river dating between about 3,000 and 2,000 years ago. Most often these sites are associated with the T2 landform, which stands 3 to 4 metres above present river level (Figure 7). Vickers and Peck (2004) suggested that wood used for fuel was a critical resource that attracted people to these val-

Figure 7. Cutbank on T2 terrace at EfPm-37, facing south.

ley-bottom settings. Elsewhere, Reeves et al. (2001) have suggested the larger valley-bottom sites are winter camps associated with a marked shift in land-use that occurred during this period. The Bow Bottom Site (EfPm-104) is cited as the type site for this land-use pattern (Ronaghan and Landals 1982; Van Dyke 1982), but other sites that fit this pattern include the Quarry Park Site (Vivian 2006a), the Safeways Site (Vivian et al. 2009), the buried ring at EgPm-124 (Wilson 1983), and most recently, a buried ring at EfPm-37 (Meyer et al. 2016). Increased use of the valley bottom after this time period is marked by a myriad of small artifact scatters, buried hearths, and ring sites found on lower surfaces adjacent to the river (Vivian 2014; Vivian and Amundsen-Meyer 2015). The continued use of favoured locations, such as the FM Site, attests to the long-term resilience of this land-use pattern, which persisted until the Fur Trade Period when cultural and economic adaptations transformed across the West.

Downstream from the Highwood River confluence, the Bow River again becomes entrenched in a deep canyon with steep valley side walls, where it is superposed across a bedrock rise, a second expression of Zone two in the idealized model. The narrow valley bottom allows little room for landforms to develop adjacent to the river, and any evidence of higher terraces appears to have been washed away over time. The margins of the river are lined with a series of migrating scroll bars—low landforms created from sediment deposited and subsequently re-entrained—moving downstream, almost as if it were a rolling wave of sand and gravel. Several archaeological sites were found in the context of these low-lying scroll bars; but, true to their geological context, they appear to be associated with relatively recent Late Precontact Period occupations.

5.2 Sheep River finds

In a general sense, the Sheep River shares many similarities with the Bow River. It too is deeply entrenched in a steep-walled canyon through the Foothills (Zone two of the idealized model) before opening out into the wide valley downstream of Turner Valley (Zone three of the idealized model). As with the Bow River, erosional impacts along the upper reach of the Sheep River were limited, because the valley was already streamlined from earlier events. No archaeological sites were recorded in this canyon context (Vivian and Amundsen-Meyer 2016b). Downstream from Turner Valley, the well-formed terrace landforms that become more common appear to hold good potential for archaeological resources, although these landforms are typically located well away from the river itself. EePn-87, a bison kill and processing site affiliated with Pelican Lake and McKean occupations (ca. 3,500–2,000 yr BP), hints at the temporal potential these landforms may hold. The Brown Site (EePn-97), a newly discovered site on a remnant terrace adjacent to the Sheep River, immediately downstream of Black Diamond, indicates that cultural use of some landforms along the river is even older, extending back to the formative stages of the Middle Precontact Period (Figure 8). Here, flood impact assessment survey in 2015 recorded evidence for bison kill and processing activities dating as early as ca. 5,900 yr BP (Vivian and Amundsen-Meyer 2016a).

Downstream from Black Diamond to Okotoks, the river valley widens and older terrace levels recede from the river's margin. Adding to the complexity of the river system is the fact that, in this reach, the river is also flowing along an old, glacial meltwater channel, so the form of the valley

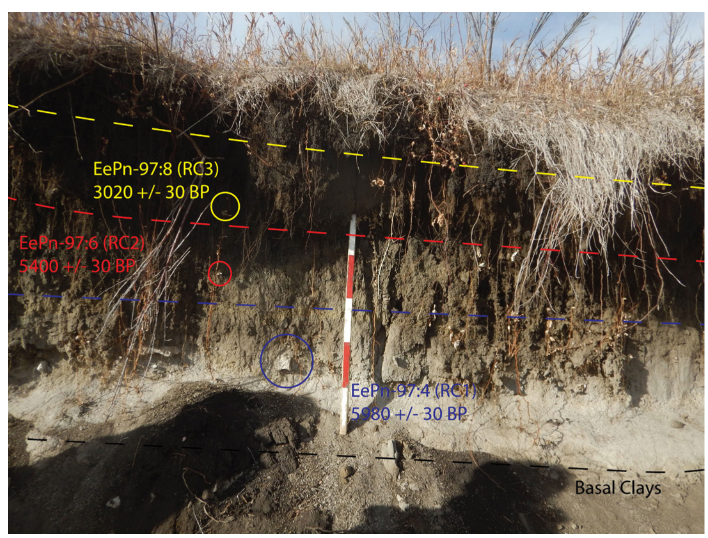

Figure 8. Multiple components exposed in erosional exposure on Sheep River at EePn-97.

is not the work of the modern river. Erosional impacts from the 2013 flood in this reach were significant. However, they were largely confined to erosion and reworking of sediments along the newer landforms that characterize low-lying lands adjacent to the river (Figure 9). Following assessment of 2013 flood impacts, the patterned distribution of previously recorded sites, which tend to be well away from the river on the margins of the valley, is now understood to result from the greater time-depth of these landforms further from the river. The limited number of archaeological sites that were found to have been impacted by erosion immediately adjacent to the Sheep River are considered to be relatively recent. This is a stark contrast to the large number of sites observed along the Bow River, and the higher terraces present on this latter waterway.

Figure 9. Low, young landforms in the Sheep River valley between Okotoks and Black Diamond, facing west.

The Late Pleistocene (pre-BCF and hence pre-Clovis) capture of the Highwood brought changes in streamflow and downcutting, leaving numerous high benches (mostly unpaired) on the Sheep River where it becomes entrenched downstream of Okotoks. Archaeological finds observed in these settings include scatters of bone and fire-broken rock from campsite activities. Overall, none of the sites recorded here appear to be multicomponent or to have a large density of cultural materials. Although no clearly temporally diagnostic artifacts were recovered, the common occurrence of fire-broken rock within these sites suggests that most postdate the Paleoindian Period. Here again, the bedrock base of these landforms protected many of the sites in these settings from significant erosional impacts.

5.3 Highwood River finds

Archaeological surveys on the Highwood River include Lifeways' 2015 study of the upper Highwood above Longview (Vivian and Amundsen-Meyer 2016b), in addition to the 2014 Stantec survey of the portion of the river between Longview and the Bow River confluence (Frampton and Bohach 2015; Porter et al. 2015). As with the Bow River, large, cross-valley debris flows occur along the margins of the upper Highwood (above the Eden Valley Reserve; Zone one of the idealized model). Only a small number of these debris flows have been cut into by the Highwood River. Landforms observed here are complicated further by the inclusion of fluvial terraces graded to a glacial lake that ponded in the valley (Zone one of the idealized model). Entrenchment cut headward from the Foothills zone into this reach, which was beginning to flow on bedrock. Hanging tributaries provide terrace-like surfaces, while unpaired alluvial terraces are common immediately adjacent to the river (Figure 10). Erosional impacts on this section of the Highwood River were as great as those seen on the Bow River downstream of Calgary, and had a significant impact on archaeological sites. Precontact sites along this reach most typically occur on unpaired alluvial terraces, and include campsites consisting of relatively dense concentrations of cultural materials. At least one of these sites, EcPp-30, is multicomponent (Vivian and Amundsen-Meyer 2016b).

Figure 10. Alluvial terrace typical of the Upper Highwood River (EcPp-30), facing west.

Downstream of Eden Valley, the Highwood River becomes deeply entrenched in a bedrock canyon characterized by steep, vertical bedrock walls (Figure 11) that continue almost to Longview (Zone two of the idealized model). The Highwood River canyon is even more deeply entrenched than those on the Sheep and Bow rivers, and no fluvial terraces are present along this stretch, except at the very top of the valley walls. Erosional impacts of the 2013 flood along this reach of the Highwood River were not great, and only one site was recorded (a small Precontact campsite

Figure 11. Highwood River canyon, facing east.

[EdPn-62]; Vivian and Amundsen-Meyer 2016b). As with the Bow River, it is likely that archaeological sites do occur on the high benches and valley rim above the canyon walls, but these are unlikely to be large campsite locations to which people returned year after year.

Below Longview, the Highwood passes through bedrock-controlled ridges before spilling out into a wider valley characterized by a wide, low floodplain with many back-channels and oxbows (Zone three of the idealized model). Some of the capping sediments on these landforms are fine-grained colluvium derived from nearby glacial lake sediments. Similar to the Bow River, the sequence of well-developed terraces seen at different elevations results in deep stratigraphic exposures of thick sediments, paleosols, and (in select locales) multiple cultural occupations. Scatters of bone and stone artifacts and pieces of fire-broken rock, indicative of campsite activities, were common on both the north and south banks of the Highwood through this reach (Porter et al. 2015).

At High River, we reach the point where the Highwood was cut off from its original course in the Late Pleistocene and, continuing downstream from a point not far to the northeast, the riverbanks become abrupt and steeply cut into the surrounding Quaternary deposits and bedrock. Landforms adjacent to the river include benches and terraces characterized by deep sedimentation, once again including colluvium above alluvium. Porter et al. (2015) document numerous finds and archaeological sites along this stretch, but few appear to predate the Mazama Tephra fall and it is debatable whether any Paleoindian sites will be found in this context. The early find of mammoth teeth at a gravel pit along the river, east of Aldersyde, is consistent with the view that Bighill Creek Gravels are present (fed by debris carried from the paraglacial fans upstream). This would suggest braided river conditions between ~11,400 and 10,000 yr BP and little possibility for archaeological site preservation along the river itself. During subsequent entrenchment, early, unpaired slip-offs might have potential for later Paleoindian materials. Past the Sheep River confluence, the Highwood continues to remain entrenched in a valley of the same character as that of the lower Sheep River. The documentation of numerous archaeological sites in this region demonstrates the importance of this riverine landscape to First Nations inhabitants (Porter et al. 2015), although it is unclear whether or not these sites fit within the pattern of winter campsites identified on the Bow River.

5.4 Discussion

In summary, archaeological surveys on the Bow, Sheep, and Highwood rivers have been successful in documenting a rich archaeological record associated with precontact occupation and use of these riverine environments, which extends back thousands of years. The multi-disciplinary approach followed in these investigations has facilitated the documentation of these archaeological sites within the context of the age and character of the landforms on which they are located. Stepping back further, we can now define segments of the river where specific landforms and certain types of sites are found or are more likely to occur. Clusters or concentrations of sites identified along the rivers highlight key locations that were favoured for winter camps or served as fords where these rivers could be easily crossed. Historic source materials, including known trail routes and Blackfoot names for specific landscape features, can be used to provide a more nuanced context for these archaeological finds, helping analysts to integrate the geographic distribution of sites found along the rivers into a cultural framework with regional implications.

One of the best examples in which these multiple threads are drawn together is along the canyon of the Bow River below the Highwood River confluence (Figure 12). The steep, north-facing slopes through this canyon mark the most easterly occurrence of fir, pine, and spruce seen on the Bow River, a fact that was well known to the Blackfoot, whose name for this reach downstream of the Highwood was translated on early maps as “Pine Cañon” (Dawson 1884). The few sites found in the valley bottom are indicative of Late Period camps where, coincidentally, grooved stone mauls have been recovered from EePk-256 and from EePk-286 (Vivian 2006b ; Vivian and Amundsen 2015). Furthermore, conifer residues have now been identified on the EePk-286 maul (Malainey and Figol 2010). Residue analysis indicates

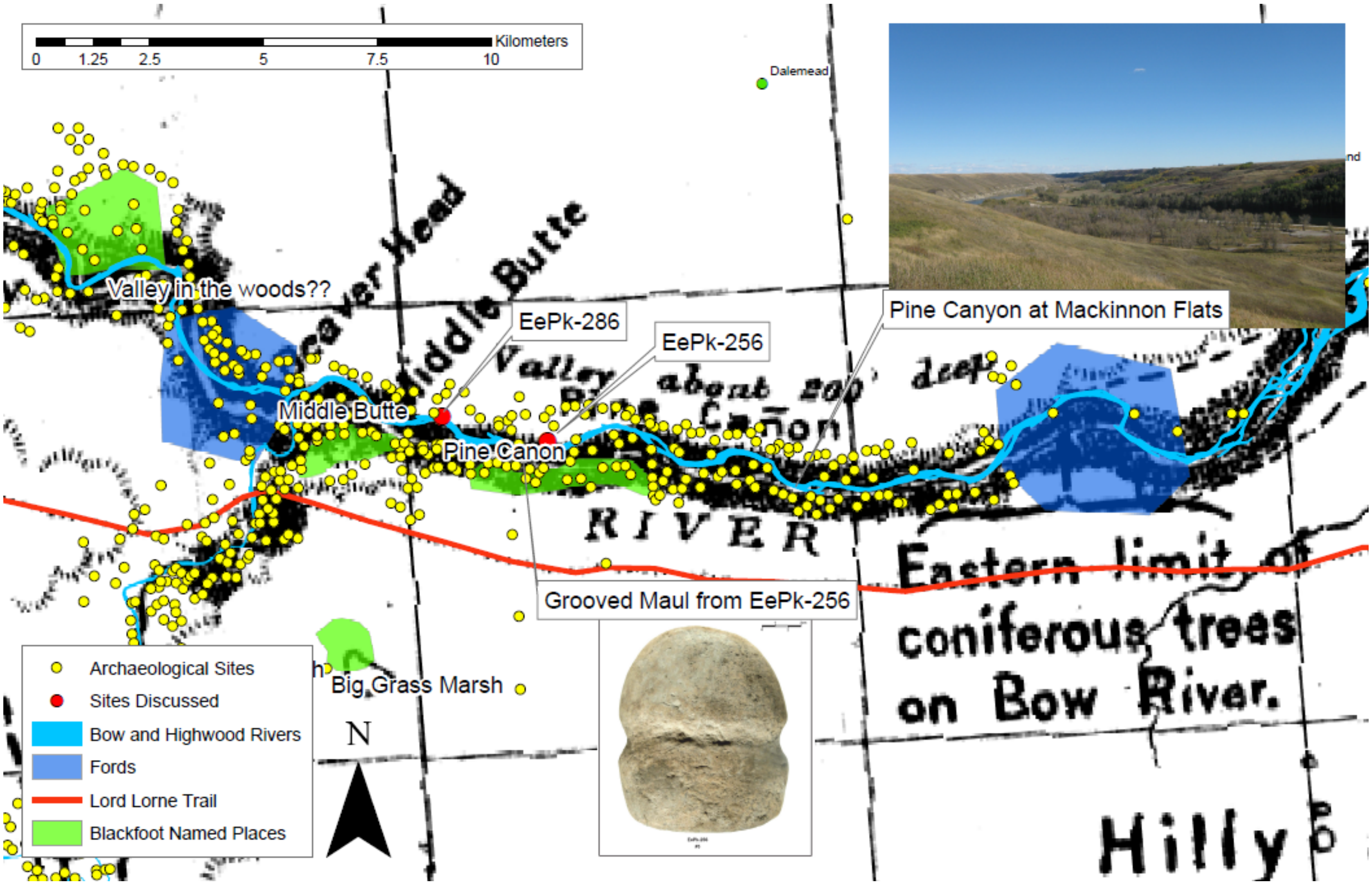

Figure 12. Trails, fords, Blackfoot named places, and archaeological sites in the Pine Cañon area

the maul from EePk-256 was also primarily used to process low-fat-content plant material, although conifer was not specified (Malainey and Figol 2016). In this way, the multiple lines of evidence all point to this as an important locale where First Nations inhabitants focused on the significant and unique conifer resources that could be gathered here. Elsewhere, a lack of Blackfoot place names appears to correspond with areas where low site densities or other data gaps exist, hinting at geographic regions that likely remained more peripheral to seasonal land-use patterns (Vivian and Amundsen-Meyer 2015, 2016a, 2016b). This line of reasoning may lead to an explanation for the seemingly lower number of sites associated with upper valley settings along the Bow and Highwood Rivers: regions that we know, in general, were frequented by members of the Stoney and Kutenai Nations, as well as the Blackfoot.

6. Conclusion

Results of the flood impact assessment surveys of the Bow, Sheep, and Highwood rivers have made a substantial contribution to the understanding of both the precontact land-use in the Bow watershed, and the diversity, locations, and geological contexts, of archaeological sites recorded along watercourses within it. It is telling that few sites of any great age are found on the lowest levels above the river, and that sites older than 4,000 years in age are rare in the river valleys. In part, this is due to the lack of riverside exposures of older land surfaces, which typically occur at slightly higher elevations above and back from the river. This pattern is also thought, in part, to represent a cultural change which saw people shift toward a greater use of the river valley through time.

The results of these studies have not only contributed greatly toward our understanding of the natural history and human use of the Bow River watershed, they have also served to highlight the fragility of these non-renewable historic resources. We have been reminded that these rivers are significantly flood-prone. The impact of the 2013 flood and associated erosion to historic resources throughout the Bow River watershed has been demonstrated to be real and highly significant, although variable, throughout each segment of the various rivers. In places, remnants of campsites and buffalo kill sites that have remained relatively intact for as much as 3,000 or 4,000 years are being washed away by changes in the flow of the Sheep, Highwood, and Bow rivers. Erosional forces of the flood-exposed sediments, fossils, and archaeological finds that had been buried for thousands of years, and the resulting survey and assessment studies have led to the recording of many previously-unknown sites. Although the impacts of specific erosional events are localized, on a regional scale the 2013 flood demonstrates how susceptible historic resources are to being destroyed. In this light, the idea that archaeological and palaeontological sites can be given long-term protection along the river simply by "storage" (prevention of development impacts) is open to challenge. The flood has had real value, then, in making scientists, planners, and the general public think about these important issues that will persist.

To conclude, these post-2013 flood impact assessment studies have been an important first step in dealing with flood-affected areas in the Bow River watershed and the cultural resources that are threatened along its watercourses. It is certain that erosional forces will continue to impact known sites and those yet to be discovered, and these studies have demonstrated that even the daily flow of the rivers and associated erosion have high potential to impact historic resources. Erosion was particularly hazardous to historic resources on alluvial terraces in these river systems, and it appears that meandering river systems dominated by these landforms are particularly susceptible to flood-related impacts. Greater attention should be paid to the Red Deer, North Saskatchewan, Battle, Athabasca, and Peace Rivers, most or all of which are likely to be similarly susceptible to catastrophic flood events.

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