UTILIZING GEOMORPHIC INFORMATION AS A GUIDE FOR REHABILITATING SALMONID HABITAT ALONG THE MIDDLE FORK JOHN DAY RIVER, OREGON

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Abstract

Anthropogenic activities over the last 150 years including vegetation clearing, logging, dredge mining, and the construction of a railroad have profoundly impacted large portions of the available salmonid habitat along the Middle Fork John Day River. Various types of geomorphic information were integrated into the current study to provide a better understanding of the physical setting and processes affecting a river system that has been highly altered historically and to provide a valuable tool in guiding salmonid habitat rehabilitation efforts.

Several aspects of the geomorphology are important to physical processes that influence this river system and are largely responsible for the formation of specific salmonid habitat. The bedrock along the river is comprised of mildly folded volcanic rocks. Structural and lithological characteristics of these rocks are directly responsible for the alternating valley and canyon morphology and for the position of the river regionally as it flows along the axis of a syncline. The valley reaches are relatively wide, contain a thick sequence of alluvium, and have low gradients. Canyon reaches are narrow, alluvium-deficient, with steep slopes. Landslides are common in the basin, exert control on the channel position and form, create local grade control, and represent a source of sediment input. Alluvial fans along the margins of the valley have formed at the mouths of the tributaries to the river. These fans create local constrictions that also control the position of the river, aspects of the channel geometry, local grade control, and contribute stream flow and sediment to the main channel. The geologic structure also influences the groundwater system and numerous springs and seeps along the valley margins play an important role in the base flow and thermal characteristics of the river.

Stratigraphic studies of the alluvium were undertaken to better understand the history of the river and place current physical processes into their long-term context. This is important to understanding factors that have influenced the presence of salmonid species and the development of their habitat in this basin. Results indicate an overall trend of incision over the last 7,600 years followed by a period of lateral channel migration. Preserved meander scars and abandoned channels indicate that the areal extent of the floodplain was much greater prehistorically than at present. Little is known about the native vegetation as historical accounts are limited and commonly general in nature. Therefore, pollen and charcoal samples were collected from older deposits to evaluate the type and distribution of the prehistoric vegetation. Analyzes of these samples suggest an ecosystem dominated by conifers, grasses and sedges. A significantly reduced presence of riparian species was also recognized. In addition, several species found in the paleobotanical record are not found in the immediate area today. Based the sedimentological characteristics of undisturbed alluvial deposits and the prehistoric vegetation records, it appears that areas of the Middle Fork John Day River supported relatively extensive wet meadow complexes that are largely absence today.

INTRODUCTION

The John Day River is a tributary to the Columbia River that drains nearly 8,000 square miles in north-central Oregon. The Middle Fork subbasin originates in the Blue Mountains of the Malheur National Forest and flows 75 miles to its confluence with the North Fork John Day River north of Monument, Oregon. Within the upper Middle Fork John Day River (MFJDR) subbasin, substantial changes to channel processes have occurred over the last 150 years that has resulted in substantial losses in salmonid habitat and markedly decreased populations of important species including spring Chinook (*Oncorhynchus tshawytscha*), summer steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). Notable human disturbances started in the middle 1800's with extensive valley clearing for farming and grazing activities, which led to the development of irrigation diversions, possible draining of the floodplain through the excavation of drainage ditches. Any riparian vegetation present along the channel banks and throughout the floodplain was removed, beaver were extensively trapped, and their ponds filled. This was followed by widespread logging, dredge mining, railroad construction, and channelization of the river. The straightening of the river alone resulted in a dramatic reduction in the area of floodplain, disconnection of side channels, a change in channel pattern and form, likely lowering of the water table locally, and destruction of the wet meadow ecosystem.

In response to the loss of habitat and decreased populations of ESA-listed and other culturally important fish species, the Bureau of Reclamation (Reclamation) initiated a variety of assessments in tributaries to the Columbia River (e.g., Reclamation, 2008). The goal for these assessments was to produce information that could be used collectively as supporting documents and planning tools by partners within a basin to focus their resources in identifying and prioritizing habitat rehabilitation and protection projects. The primary objective of these assessments was to develop an improved understanding of the processes acting on the watershed and to better identify limiting physical factors responsible for the development and sustainability of salmonid habitat. This objective was met through characterization of the current conditions including the fisheries and vegetation ecosystems, the geologic setting and geomorphic processes, basin hydrology, hydraulic and sediment transport characteristics, and anthropogenic impacts and constraints. This paper reports on one part of these studies that focused on the hydraulic characteristics, sediment transport capabilities, and geomorphic properties that was undertaken to define the spatial and temporal context of river processes and offer a predictive tool to assess proposed habitat rehabilitation actions.

METHODS

Fine-scale (1:12.000 scale) surficial geologic mapping was undertaken first to gain a better understanding of the spatial relationships of the various geomorphic features controlling the morphology of the MFJDR, the history of channel development, and river evolution over the last several thousand years (an example is illustrated in Figure 1). Mapping was completed on the 2005 color aerial photographs in conjunction with LiDAR data, existing topographic maps (USGS 7 ½' quadrangles), and the published geologic literature (Brown and Thayer, 1966; Jett, 1998; Bandow, 2003). In areas that had been highly modified by human activities (e.g., dredge mining), the mapping was supplemented with information derived from aerial photography flown in 1939, 1956, and 1976.

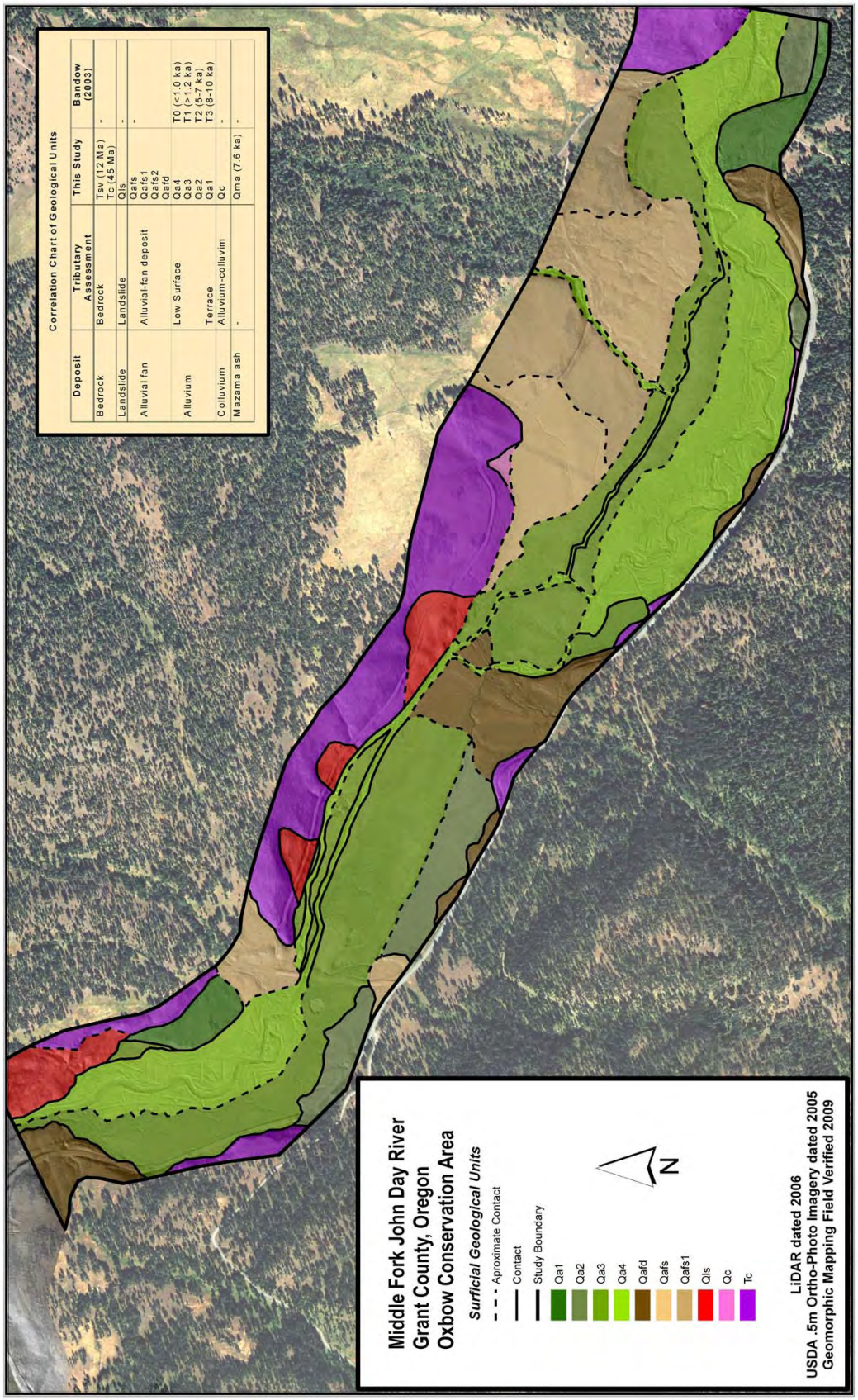

Figure 1. Surficial geologic map of the Oxbow Conservation Area on the Middle Fork John Day River. Mapping is draped over LiDAR data on a 2005 aerial photograph base.

One problem that exists in part of the study area was that much of the alluvium in the valley had been disturbed by dredge mining. Therefore, whenever possible, the location of specific units were mapped based on their position prior to the dredge mining. This information was considered important to better understanding the physical processes that might influence any restoration alternatives that would be proposed extent and to understand the spatial relationship of the deposits historically.

Major map units defined in the tributary assessment (Reclamation, 2008; see correlation chart on Figure 1) included four alluvial units in addition to the underlying bedrock. These alluvial units included landslides and colluvial deposits, alluvial fans, and alluvial deposits. The mapping of the alluvial fans and alluvial units associated with the river were further refined in this study based on physical characteristics such as surface morphology, relative age, and elevation above the active channel as represented on aerial photography, topographic maps, and in LiDAR data (see Figure 1). These physical characteristics or the appearance of a specific are generally related directly to the mode of deposition or process responsible for its formation. The map unit contacts were then checked in the field.

In addition to the surficial mapping, stratigraphic and sedimentological studies are undertaken to characterize the physical properties of the various map units. Shallow soil pits were excavated on each of the units and the characteristics of the deposits were documented. This included documenting physical properties of sediment comprising the deposits, the extent of soil formation, and sampling of detrital charcoal and pollen samples. The age (both relative and numerical) of these deposits is critical to understanding the history of the landscape and formation of specific landforms. In this study, ages of the various units was defined based on chronologies established by previous work (Brown and Thayer, 1966; Jett, 1998; Bandow, 2003; see correlation chart in Figure 1).

GEOMORPHOLOGY OF THE MIDDLE FORK JOHN DAY RIVER

The general geomorphic character of the MFJDR based on an analysis of historical aerial photography was that of a meandering multi-thread channel flowing across broad, flat valley reaches with low, wide floodplains alternating with short, steep sections of straight, narrow channels flanked by narrow, high terraces. That character was dramatically modified by various human-caused disturbances starting in the middle 1800’s with extensive clearing of the valley floor for farming and grazing activities, followed by extensive logging, dredge mining, and railroad construction. The character of the river before these changes was in part the result of constraints imposed on the river by the underlying bedrock formations and geologic structure in the area. The general course of the MFJDR is dictated by the geologic structure as it follows the axis of the Middle Fork Syncline for most of its length (Brown and Thayer, 1966). The poorly consolidated, less resistant sedimentary units within the bedrock are more readily erodible allowing the river to migrate laterally and form broad valleys while the more resistant volcanic rocks within these formations restrict the lateral migration and provide vertical control on the channel gradient thereby forming steep, narrow canyon reaches. In addition, some units within the bedrock formations are prone to landsliding due to lithologic characteristics of the rock, the general dip of the strata relative to the valley (syncline), and the overall geologic structure. These

landslides can influence the position of the river channel in the valley and some areas actually dictate its position.

Landslides and Colluvium

Landslides and shallow soil slumps are relatively widespread in this part of Oregon and play a large role in the regional geomorphology. Some of the landslides are quite extensive and have even altered the course of the river (Thayer, 1972). An example is provided by a very large landslide that extends for about a mile along the river between the Forrest and Oxbow Conversation Areas (FCA and OCA, respectively). This landslide also results in a dramatically narrower and steeper valley than both up- and downstream of the slide. Numerous smaller landslides are present throughout the study area, particularly along the northern valley margin of the OCA (see Figure 1).

Colluvium is similarly widespread and commonly forms the steeper deposits along the valley margins where material has been shed off of the adjacent hillslope. Excavations along the back margins of older stream terraces show the colluvium interfingering with alluvium along the valley margins. This can make it quite difficult to distinguish between the deposits without a clear exposure. In general, colluvium is limited to a narrow band along the margin of the valley and in outcrop is distinguished from the alluvial deposits by their more angular, poorly-sorted character and their generally steeper slope. In a few areas where the valley margins are quite steep, talus formed almost exclusively of angular rock has been deposited at or near the angle of repose. Colluvium and talus are both primarily the product of mass wasting and the downslope movement of material under the influence of gravity. The deposition of colluvium along the MFJDR generally has little influence on the character of the river other than providing a source of sediment in those cases where the river channel impinges on the valley margins.

Alluvial Fans

All of the alluvial fan deposits in the study area are located at the mouth of tributary streams and have been either shed onto the valley floor thereby impinging directly on the river channel or onto and across stream terraces. Two distinct types of alluvial fan deposits are recognized based primarily on the dominant mode of deposition responsible for their formation; stream-dominated and debris flow-dominated (Qafs and Qafd, respectively). The type of deposit is the result of two distinct processes; stream flow in wide, shallow channels and debris flows emanated from narrow, steep channels. The stream-laid alluvial fans are composed of moderately-sorted, subrounded and rounded gravel with coarse-grained sand matrix. The morphology of the alluvial fan surface on stream-laid alluvial fans is generally much smoother, generally has a gentler slope, and commonly is much broader in its areal extent and volume. The debris-flow dominated alluvial fan deposits have very rough fan surfaces, more often much steeper slopes, and are smaller volumetrically and in their areal extent. Jett (1998) outlined specific basin variables in the MFJDR basin that support this distinction between stream-laid and debris-flow dominated alluvial fans. On the OCA, the areal extent of stream-laid alluvial fans is about eight times greater than the debris flow dominated alluvial fans (see Figure 1).

Alluvial Deposits

For this analysis, four distinct alluvial deposits (see correlation chart on Figure 1) that could be attributed directly to deposition or reworking by the river including floodplain deposits and three

stream terraces were mapped. The four units can be easily differentiated in the field on the basis of their elevation relative to the active channel and on surface characteristics. The floodplain (Qa4) includes those deposits that are inundated and reworked regularly. This unit equates to unit T0 of Bandow (2003; see correlation chart on Figure 1) and on the basis of three radiocarbon ages is reported to have formed within the last 1000 years. Based on hydraulic modeling results, a majority of the floodplain is inundated by the 2-year peak discharge (see Gordon and Klinger, this volume). In addition to being located immediately adjacent to the active channel and side channels, the surface of the floodplain is formed by unweathered sediment and exhibits primary depositional forms (e.g., bars and swales) as well as exhibiting sedimentologic characteristics such as clast imbrication, bedding, and grading. The floodplain can also be delineated on the basis of the vegetation growing on the deposits (i.e., generally riparian species).

The floodplain deposits are inset into a slightly older but distinct terrace deposit (Qa3; see Figure 1). The terrace surface ranges from 3-5 feet above the active channel depending on its location and is marked by a much more planar surface than the active floodplain. It lacks clearly visible bar and swale morphology although it may exhibit narrow, shallow channels and/or scars of abandoned channel meanders (oxbows). In places these shallow channels may be maintained in part by flow emanating from springs along the valley margins. Quite often these channels are muted due to infilling by fine-grained sediment. The deposits underlying the surface are typically coarse-grained sandy gravel overlain by a thin layer of fine-grained silty sand that contains very little or no gravel. This thin layer of fine-grained sediment forms the medium for vegetative growth, which contributes to the initial stages of soil formation. This unit equates to the T1 deposit of Bandow (2003; see correlation chart on Figure 1) and based on a single radiocarbon age is reported as being abandoned by the river about 1000-1200 years ago.

The older terrace deposits (Qa2 and Qa1) are characterized by a noticeably smoother and planar surface that is 6-9 feet above the active channel. These deposits once supported extensive stands of conifers. Numerous stumps of old trees in growth position present on the Qa2 surface in the Forrest Conservation Area (FCA) were approaching 400 years old when they were cut and provide a minimum age for the age of the terrace surface. Detrital charcoal and pollen recovered from soil pits excavated on the surface of these terraces are predominately that of conifer species support this observation. Bandow (2003) reports the Mazama ash interbedded with overbank sediments in his unit T2 (Qa2 deposits of this study; Figure 1). No numerical ages have been developed for the Qa2 deposits along the MFJDR, but an age estimate of 5-7 ka for the abandonment of the terrace was made by Bandow (2003) based on the presence of the Mazama ash (~7,600 years old). At a location along the Powder River near Sumpter, Oregon (Klinger, 2003; unpublished data), the age of the terrace surface containing a 2-foot-thick bed of Mazama ash is estimated to be a minimum of 1800 years old based on radiocarbon analysis of detrital charcoal recovered from the overlying soil. In many areas of eastern Oregon, the Mazama ash present in terrace deposits is not primary air-fall and it was speculated that it may have been reworked from the landscape at a later date. The thickness and relative purity of the ash in the deposit may be the function of several factors including the abundance of the ash on the landscape or the tendency of the ash to become segregated in overbank sediments due to its lower density. Thick ash beds in terrace deposits are commonly recognized at numerous locations in eastern Oregon (Sarna-Wojcicki et al., 1991). Therefore, the presence of the

Mazama ash in fluvial deposits may not be a reliable indicator of age and must be carefully evaluated.

The oldest and highest terrace (Qa1) is relatively well-preserved in the OCA (Figure 1). It too displays a smooth planar surface that overlies a thin fine-grained sandy bed interpreted as overbank sediment and a thick sequence of sandy gravel. In a soil pit on the Qa1 deposit, the fine-grained overbank deposit is about 1 foot and interfingers with angular gravelly colluvium that prograded across the terrace surface from the nearby hillslope shortly after the terrace was abandoned. Again, no numerical ages have been developed for the Qa1 deposits along the MFJDR, but an age estimate of 8-10 ka for the abandonment of the terrace was made by Bandow (2003) based on a qualitative assessment of pedogenic development, which he ties loosely to variations in the climate. Soil properties on the Qa1 deposits described for this study are consistent with this interpretation.

POLLEN AND CHARCOAL ANALYSIS

Typically, organic material in the form of detrital charcoal, shell, and wood that is recovered during stratigraphic studies can be submitted for radiocarbon analysis to provide age estimates for the deposits from which the material was recovered. No geochronology was undertaken specifically for this study because radiocarbon analysis of material recovered from alluvium by Bandow (2003) provided the needed age information for the alluvial deposits along the MFJDR (see correlation chart; Figure 1). For this analysis, detrital charcoal and pollen samples were collected to make qualitative estimates of the vegetation present during various periods in the past. Bulk sediment samples were collected from stream terraces and alluvial fan deposits along the MFJDR. Each charcoal sample was identified to family and genus level if possible; pollen was identified to family, genus, and species when possible (Puseman et al., 2009).

The results of the charcoal and pollen analyzes indicate several trends in the type and distribution of paleobotanical material recovered (Table 1). The vast majority of charcoal and pollen identified was some type of conifer. This is understandable given the abundance of conifers in the area and the relative resilience of conifer pollen in particular. What was surprising was the relatively minor amount of charcoal and pollen representative of riparian arboreal species and the complete lack of evidence for cottonwood (*Populus*) given that most of the sample sites were in alluvial deposits that are directly associated with fluvial deposition (Table 1). Charcoal from alder (*Alnus*), and willow (*Salicaceae*) made up a minor percentage of the overall total, but was more common in younger alluvial deposits than in the older deposits. These species are common along the river in other areas of the basin, so their absence from the record in the study area is unclear. It may be that riparian species were only present in this area in limited numbers or isolated stands due to other ecological conditions. In general, samples recovered from the youngest deposits (in this case the Qa4 and Qa3 deposits) were relatively diverse including material representative of a wide distribution of species. This distribution included an abundance of pollen from flowering annuals, grass and sedge species commonly associated with wet meadow environments (Puseman et al., 2009). If the study areas supported wet meadows in the past, this would perhaps explain the decreased abundance of riparian arboreal species. Another interesting finding from charcoal and pollen analyzes is the presence of hemlock (*Tsuga*) charcoal in the oldest deposits (Qa1, Qa2, and Qafs). This species are not currently growing in

the area. Similarly, western red cedar (*Thuja plicata*) pollen is present in Qa3 and Qa2 samples, but does not appear to be growing in the area and is only present in the region in small isolated stands.

Table 1 Frequency Distribution of Arboreal Detrital Charcoal

Type of Material	Qa3	Qa2	Qa1	Qafs
Alnus (alder)	13,P	P	-	-
Abies (fir)	P	P	-	-
Arctostaphylos (manzanita)	1	-	-	-
Artemisa (sage)	P	1,P	-	-
Betula (birch)	P	-	-	-
Conifer, undifferentiated	47	35	41	21
Hardwood, unidentified	2	2	8	-
Larix occidentalis (larch)	62	97,P	7	-
Picea (spruce)	P	P	-	-
Pinus (pine)	58,P	62,P	1	4
Pseudotsuga (Douglas fir)	P	P	-	-
Salicaceae (willow)	2,P	P	-	-
Thuja plicata (cedar)	P	P	-	-
Tsuga (hemlock)	-	P	6	48

P, pollen present in sample.

A quantitative analysis of these results was not undertaken, and therefore, the trend indicated by these results is not considered statistically valid. Furthermore, anything other than a qualitative judgment from these data is not possible because the sampling methodology employed was random and did not follow a systematic procedure. The purpose of this analysis was undertaken solely to get an indication of the type and distribution of vegetation that may have been present prehistorically. These data can be used in conjunction with other information drawn from historical aerial photography and written accounts to get an idea of the probable conditions in the study area prehistorically. The condition of the riparian corridor in certain locations on the 1939 aerial photography appeared to be in much better condition than at present. However, it is not clear how the conditions in 1939 may varied from pre-1939 conditions. By 1939, the basin was likely suffering the from the widespread effects of human-induced change that even then may have been dramatically different than pre- European settlement.

DISCUSSION AND CONCLUSIONS

The principle source of sediment input to the MFJDR as well as control on the morphology of the river are the alluvial fans. This influence on the morphology is the result of not only the type of sediment delivered to the main channel, but the rate, volume, and the manner in which the sediment is delivered to the river. These factors formed the basis for thesis work completed by Jett (1998). Unfortunately, his work focused primarily on the various landscape characteristics that affect the formation of the alluvial fans, but did not address the history of alluvial fan deposition other than relating the influence that changes in climate have on their formation. For the most part, sediment is more or less delivered on a continuous basis to the mainstem by

tributaries, but that rate fluxuates through time given numerous variables including climate. The more important factors affecting the supply and delivery of sediment to the river from the tributaries on a time frame comparible to the life-cycle of salmonid species utilizing the basin will be fire and basin hydrology. Currently the supply of sediment to the river is at or slightly exceeds the ability of the river to transport this material downstream. This suggests the river is transport-limited in its ability to move sediment and based on the history of river incision and lateral migration, this has been the situation for perhaps the last several thousand years.

The most important geomorphic unit in regards to the fluvial system and salmonid habitat is the alluvium that forms floodplain and stream terraces (units Qa4-Qa1; see Figure 1). These deposits form in response to stream flow and the movement of sediment to the river and represent how sediment is transported downstream or stored in the channel and on the floodplain and terraces. The presence of multiple stream terraces, a wide floodplain marked by side channels and meander scars represents a complex and dynamic history of deposition, erosion, and lateral migration. Simply stated, this history is indicative of the processes required to develop a the channel complexity and diverse habitat that will be utilized by salmonids.

The most influential geomorphic unit on the MFJDR is the alluvial fans. Several important aspects of how they influence the evolution of the river and their impact on conditions in the river critical to habitat can be observed in their character and morphology. The largest tributary drainages not only supply coarse-grained sediment to the main channel, which is important for creating spawning habitat, but also contribute flow to the main channel. Thermal data suggest that this flow from large tributaries, and the character of the alluvial fans themselves, may play a critical role in maintaining base flows and moderating the stream temperatures (Figure 2). The Granite Boulder Creek alluvial fan (56.2 in Figure 2) is large in its areal extent and therefore exerts a lot of control not only on the position of the river in the valley and as a source of sediment to the system locally, but also in controlling stream temperature.

Several important aspects of the geomorphology, how it influences the valley and river geomorphology, and the processes controlling it can be observed along the MFJDR. In general, the character of the bedrock controls the alternating valley and canyon morphology and the position of the river regionally in the axis of a syncline. The position of the river within the valley reaches is controlled by the formation of alluvial fans build by the larger tributaries to the MFJDR. As a consequence, these alluvial fans directly influence the main channel gradient and channel form of the river immediately upstream of and adjacent to each of these tributary fans. Material shed onto the valley floor by the larger tributaries is in general coarse-grained, and the supply of sediment appears to greatly exceed the capacity of the river to transport it downstream. The coarse-grained character of the alluvial fans in combination with the flow from a large tributary basin also appears to have a significant influence on maintaining stream flow and moderating stream temperature.

Because vegetation on the valley floor was removed as a result of logging and agricultural activities and the alluvium was later disrupted by dredge mining, little is known about the type and extent of historical riparian vegetation. Pollen and charcoal samples collected from the stream terraces and alluvial fan deposits were analyzed to help provide insight to the prehistoric vegetation type and distribution. Results suggest that vegetation within the study area was

dominated by species indicative of wet meadow environments. These findings are consistent with wide, low gradient valley reaches observed on historical photography and physical evidence in the form geologic controls on gradient, groundwater and thermal characteristics, and sedimentologic properties of valley alluvium. Commonly represented riparian species such as cottonwood (*Populus*) and willow (*Salicaceae*) are missing or make up a relative minor percentage of the paleobotanical record. An interesting sideline finding was evidence for hemlock (Tsuga) and western red cedar (*Thuja plicata)* in the paleobotanical record, but it appears that neither species is growing in the immediate area today. Pollen analyses also indicate periods of landscape stability followed by periods of greater deposition which are interpreted to correlate directly to fires, floods, or other natural disturbances in the basin.

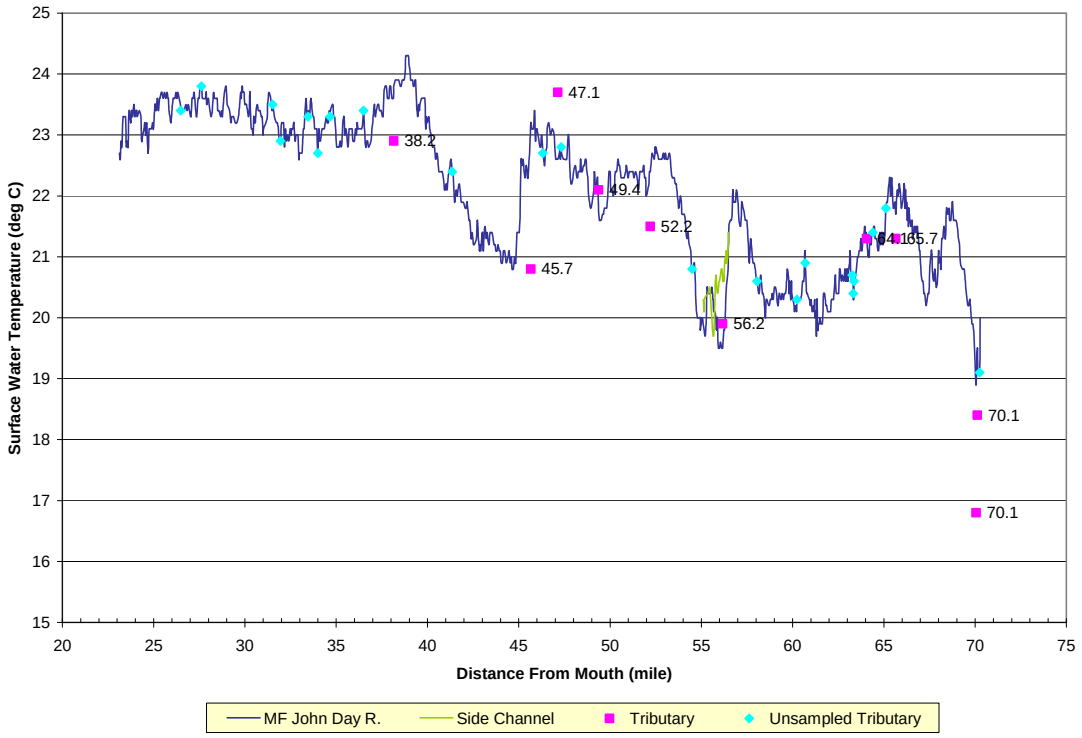

Figure 2. Median channel temperature profile for the Middle Fork John Day River measured on August 16, 2003. The area represented in Figure 1 is located from about river mile 54.5 to 57.

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