HUMAN IMPACTS AND RIVER CHANNEL ADJUSTMENT, NORTHEASTERN OREGON: IMPLICATIONS FOR RESTORATION

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ABSTRACT: Historical data were used to reconstruct channel change in the Middle Fork John Day River, a tributary of the Columbia River. Human impacts on the channel from the 1800s to present include: beaver trapping, early alluvial gold mining, dredge mining, livestock grazing, haying and irrigation, railroad-building, road-building, and placing of bank stabilization structures. 1881 land survey records, 1939 aerial photos, 1989 aerial photos, and a detailed 1996 channel habitat inventory were used identify the extent and location of channel change, and to compare direct human modification of the channel with channel self-adjustment by fluvial processes. Channel change and human impacts have been expressed differently in wide valley segments, which are inherently sinuous with abundant pools, compared to narrow valley segments, which are inherently less sinuous. The major effects of human activities include loss of sinuosity, loss of riparian woody vegetation, probably loss of large woody debris and pools, and reduced potential for adjustment because of bank stabilization structures. Wide-valley segments have more potential for fish habitat but also have been the most affected by human impacts. Implications for restoration are discussed.

KEY TERMS: fluvial geomorphology, human impacts, channel adjustment, riparian restoration

INTRODUCTION

In this paper, I will review historical channel changes on the Middle Fork John Day River and use historical evidence to identify limitations for future restoration efforts. Historical information on stream channel morphology at decades to centuries in the past can be used to define future desired conditions and to develop river channel reconstruction designs, although this approach may not be suitable for many restoration projects (Kondolf and Larson, 1995; Federal Interagency Stream Restoration Working Group, 1998). Alternative and valuable uses for historical information are demonstrated in this paper: a) to evaluate the degree to which current channel morphology is due to self-adjustment versus direct human manipulation, and b) to determine the channel’s potential for future self-adjustment. Passive restoration approaches, in particular, rely on the capability of the channel to adjust its planform, bar morphology, and bed morphology, and to build banks. Self-adjustment is also important in active restoration approaches.

DESCRIPTION OF THE STUDY AREA AND DATA

The study area is located in the Blue Mountains ecoregion of northeastern Oregon (Clarke and Bryce, 1997), at elevations of 1000 to 2500 m. Uplands are forested (dominantly ponderosa pine, Pinus ponderosa), and the riparian zone includes both forested and meadow reaches. The Middle Fork is used by steelhead (Oncorhynchus mykiss) and chinook salmon (O. tshawytscha). Chinook populations are very suppressed at present compared to historical levels, and habitat is poor (Li and others, 1995). Steelhead is presently listed as threatened under the Endangered Species Act (National Marine Fisheries Service, 1999; Busby and others, 1999). Numerous stream improvement projects have been done in the study area over the last two decades. Interest in river restoration is likely to increase in the near future as part of the Columbia River basin salmon restoration efforts.

This study focuses on a 30 km section of the main stem of the Middle Fork John Day River that is part of a more extensive study of ecological and physical influences on fish habitat (e.g., Torgerson and others, 1999). The study section runs from a point near Austin (drainage area 150 km²) downstream to the junction of Camp Creek with the Middle Fork (drainage area 660 km²). The channel is an alluvial channel throughout this section, but channel morphology is influenced by valley morphology. In narrower alluvial valleys, channels are partially constrained, and influences of mass movement from hillslopes and down tributary alluvial fans is likely to be higher. The study section has been divided on the basis of
valley morphology into seven segments labeled E (downstream end) to K (upstream end). Segment characteristics are summarized in Table 1.

Table 1. Channel characteristics averaged by segment.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Segment length, km</th>
<th>Segment type</th>
<th>Average valley width (m)</th>
<th>% area in pools¹</th>
<th>Average pool depth² (m)</th>
<th>Maximum pool depth³ (m)</th>
<th>1939 sinuosity</th>
<th>1989 sinuosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>8.0</td>
<td>Wide</td>
<td>350</td>
<td>22.8</td>
<td>0.38</td>
<td>0.77</td>
<td>1.48</td>
<td>1.11</td>
</tr>
<tr>
<td>F</td>
<td>3.1</td>
<td>Narrow</td>
<td>123</td>
<td>22.3</td>
<td>0.31</td>
<td>0.66</td>
<td>1.18</td>
<td>1.07</td>
</tr>
<tr>
<td>G</td>
<td>4.2</td>
<td>Wide</td>
<td>422</td>
<td>58.9</td>
<td>0.46</td>
<td>0.87</td>
<td>1.63</td>
<td>1.05</td>
</tr>
<tr>
<td>H</td>
<td>7.0</td>
<td>Narrow</td>
<td>126</td>
<td>29.6</td>
<td>0.38</td>
<td>0.71</td>
<td>1.46</td>
<td>1.26</td>
</tr>
<tr>
<td>I</td>
<td>5.2</td>
<td>Wide</td>
<td>304</td>
<td>53.2</td>
<td>0.44</td>
<td>0.91</td>
<td>1.44</td>
<td>1.05</td>
</tr>
<tr>
<td>J</td>
<td>1.3</td>
<td>Narrow</td>
<td>121</td>
<td>22.1</td>
<td>0.39</td>
<td>0.76</td>
<td>1.25</td>
<td>1.07</td>
</tr>
<tr>
<td>K</td>
<td>1.4</td>
<td>Wide</td>
<td>332</td>
<td>49.0</td>
<td>0.34</td>
<td>0.74</td>
<td>1.59</td>
<td>1.05</td>
</tr>
</tbody>
</table>

¹ Percentage of water surface area in pools. All pool characteristics were measured at summer flow conditions in 1996.  
² Segment-average of average depth of each pool.  
³ Segment-average of maximum depth of each pool.  

There is also a contrast in land ownership and land use among the segments. The valley floor in wide-valley segments is mainly privately owned. In recent years the land has been used primarily for summer cattle pasture. There is also a large Nature Conservancy preserve in segment E. In narrow-valley segments, the valley floor is mainly publicly owned (Malheur National Forest). Both narrow-valley and wide-valley segments have experienced multiple human impacts since the 1860s, but there has been more direct human modification of the channel and riparian zone in wide-valley segments than in narrow-valley segments.

Several data sources were used in this analysis. The original land survey records (U.S. General Land Office, var.), done in 1881 in the study area, provide information on the location of the channel and riparian vegetation. Aerial photos from 1939 and 1989 were scanned and geocorrected, and the river channel was digitized on each for overlays. A stream habitat inventory was conducted on foot in 1996, in general following the procedures of the U.S. Forest Service (1996). The stream inventory provided information on pool area, pool depth, channel improvement structures placed in the river, and other characteristics. This analysis is focused on channel morphology, rather than ecological and hydrologic characteristics of the aquatic habitat.

HISTORICAL HUMAN ACTIVITIES WITH IMPACTS ON THE CHANNEL

Beaver trapping in the early 1800s was the first extensive Euro-American impact on stream channels in northeastern Oregon. There is no direct data for the impact of beaver trapping in the study area, but loss of beaver dams probably changed channel morphology and sediment transport on Middle Fork tributaries and smaller side channels. The gold rush of the 1860s first brought Euro-American settlers to this area, and there has been a variety of human impacts on the channel and valley floor since then (Anonymous, 1983). Mining of alluvial gold deposits began during the 1860s. Significant impacts from mining were still evident almost a century after the initial gold rush. Between 1939 and 1942, a bucketline dredge that completely overturned valley floor deposits, creating a new artificial channel, was used in segment G (Brooks and Ramp, 1968). A small section of segment I was also affected by dredging. In addition to the direct effects of alluvial gold mining, the 1860s gold rush brought settlers who established ranches and began to modify riparian vegetation and channel conditions to support irrigation and cattle grazing. A railroad was built on the valley floor shortly before 1910 and operated until the 1930s (Anonymous, 1983). Railroad construction cut off channel meanders and constrained the channel in some places within segment I. Since 1950, there have been several new activities that have had direct effects on the channel: channel straightening and elimination of side channels, road building that has encroached on the channel in a few places, and placement of rip-rap and instream structures. Although vegetation change is not analyzed in this study, it is important to note that the 1881 survey notes show dense willow (Salix sp.) thickets, or riparian communities of willow, cottonwood (Populus sp.), and alders (Alnus sp.), in many places along the Middle Fork that today have little or no woody riparian vegetation. Loss of woody riparian vegetation probably led to reduction of large woody debris in the stream. Today there is almost no instream large woody debris in the study section.
There are inherent differences in channel morphology, present before Euro-American impacts, between the wide and narrow valley segments. Some differences are observable today, but human impacts over the last century have modified original channel morphology. The 1881 land survey records and the 1939 aerial photos were used to identify channel morphology prior to intensive human impacts. The 1881 survey records represent conditions after some initial Euro-American impacts (particularly beaver trapping and early placer mining), but with many aspects of the channel and riparian system relatively unmodified. The 1939 aerial photos represent a system affected by road building, railroad building, ranching, irrigation, and mining, but before the widespread direct channel modification that occurred after 1950.

Based on these data sources, wide valley segments originally had high sinuosity, while narrow valley segments generally had lower sinuosity (Table 1). Today the wide-valley segments retain some of that sinuosity. In some places in the wide segments, inactive channel scars are evident on aerial photos, and these channel scars are typically sinuous. Wide-valley segments (G, I) generally have meandering pool-riffle channels with relatively high pool area, while narrow segments (D, F, H) generally have low sinuosity plane-bed or pool-riffle channels with lower pool area. Segment E is a wide-valley segment with reduced sinuosity and pool area today because of direct human modifications, discussed below.

In the 1996 stream inventory, wide valley segments typically had higher pool area and deeper pools than the narrow valley segments. Historical analysis supports this model of channel morphology in wide valley segments. The 1881 survey notes show that anabranching reaches with two or three active meandering channels were present in at least two parts of segment E, and in the middle of segment G.

Channel locations noted in the 1881 survey were compared with channel locations and inactive channel scars visible in the 1939 and 1989 aerial photos. The 1881 data do not provide a channel map, only the locations of the channel at specific points where the section lines cross the channel (nineteen points in the study section). Relatively little channel change by self-adjustment occurred between 1881 and 1939. In most places, the location of the 1881 channel is consistent, within measurement error, with its location in 1939. Lateral migration and avulsion occurred at a total of five points out of nineteen, and the amount of lateral migration is small. In segment I, about 1 km of channel was cut-off by construction of the railroad between 1910 and 1939; this is the major human-caused change between 1881 and 1939 that can be identified.

Channel change is more evident between 1939 and 1989. Based on overlay of channel maps constructed from the 1939 and 1989 aerial photos, twenty-four active reaches (reaches displaying lateral movement greater than approximately two channel widths) were identified. The type of change (avulsion, lateral migration, or human construction of a new channel) and the cause (self-adjustment or direct human modification) were identified for each active reach. Table 2 summarizes the results.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Segment type</th>
<th>% length in active reaches</th>
<th>% length in human caused active reaches</th>
<th>% length in self-adjusted active reaches</th>
<th>% of total channel length with bank structures, 1996</th>
<th>% of inactive reach length with bank structures, 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Wide</td>
<td>38.6</td>
<td>35.0</td>
<td>3.6</td>
<td>51.3</td>
<td>56.1</td>
</tr>
<tr>
<td>F</td>
<td>Narrow</td>
<td>14.3</td>
<td>0</td>
<td>14.3</td>
<td>18.9</td>
<td>11.6</td>
</tr>
<tr>
<td>G</td>
<td>Wide</td>
<td>83.3</td>
<td>63.3</td>
<td>20.0</td>
<td>20.6</td>
<td>43.7</td>
</tr>
<tr>
<td>H</td>
<td>Narrow</td>
<td>57.4</td>
<td>6.7</td>
<td>50.7</td>
<td>7.3</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>Wide</td>
<td>51.0</td>
<td>12.6</td>
<td>38.4</td>
<td>54.9</td>
<td>63.9</td>
</tr>
<tr>
<td>J</td>
<td>Narrow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>K</td>
<td>Wide</td>
<td>77.1</td>
<td>0</td>
<td>77.1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The amount of channel change since 1939 is larger in wide-valley segments than in narrow-valley segments. In wide-valley segments E and G, most of the change was due to direct human actions. In wide-valley segment K, there was extensive self-adjustment related to direct human disturbance. A highly sinuous channel was artificially straightened...
shortly before 1939. Between 1939 and 1989, the straight artificial channel experienced lateral migration, resulting in new meanders of lower amplitude than those prior to straightening. Less channel change between 1939 and 1989 is evident in narrow-valley segments. The type of channel change in narrow valley segments is avulsion and modest lateral migration.

Between 1939 and 1989 sinuosity was reduced in every segment (Table 1), and most sinuosity reduction is human-caused. Wide-valley segments experienced the largest reductions in sinuosity. The cause of sinuosity reduction is somewhat different for each of the wide-valley segments. In segment E, the main cause has been cutting off of large meander loops, to allow unrestricted access to the floodplain from one side for grazing and irrigation. In addition, some individual meanders have been reshaped and bank-stabilization structures have been installed, resulting in minor reductions in sinuosity. In segment G, dredging of alluvial gold deposits created a new artificial channel that is the main channel today. In segment I, sinuosity has been lost through meander reshaping and installation of bank-stabilizing structures. In segment K, the sinuosity reduction actually occurred shortly before 1939 when an artificial straight channel was cut through the meanders of the highly sinuous channel. The 1939 channel length includes cut-off meanders that still carried flow. By 1989 these cut-off meanders were inactive, but new low amplitude meanders had been reestablished. Sinuosity reductions have been smaller in the narrow-valley segments, which originally had less sinuous channels.

The effects of dredge mining are different from other human-caused channel changes. About 15 percent of the total active-reach length of the study section was modified by dredge mining. Dredge mining completely overturned the floodplain deposits, bringing deep, coarse alluvial deposits to the surface and winnowing fines and finer gravels. The result today is channels with bed and banks formed of cobble-dominated alluvium. The river does not appear to be competent to adjust these channels today. In segment G, the mined channel is narrow and deep and has abundant, deep pool area (Table 1). The channel, however, is straight, lacks habitat complexity, and has essentially no riparian woody vegetation.

EFFECTS OF BANK STABILIZING STRUCTURES

Another significant change between 1939 and today is the extensive installation of bank-stabilizing structures that harden the banks and eliminate the possibility of future lateral migration by self-adjustment. Most of these structures probably were installed since 1980. All instream structures were recorded during stream inventory survey in 1996. Structures were recorded by habitat unit and structure type. Of all the structures, three types were intended to stabilize and harden banks, rip-rap and thumb jetties (short groins projecting into the channel) built of rock, and tree trunks cabled parallel to and along the bank. The data in the last two columns of Table 2 include these types. Percent length in bank structures in Table 2 was calculated by habitat unit length, even though the structures may not occupy both banks along the entire length of the habitat unit. This method may result in overestimation of hardened bank length. Field examination shows, however, that structures were preferentially placed at points where bank migration was most likely, so the length estimates probably represent the length of channel effectively hardened by structures.

Most bank-hardening structures are formed of rock (rip-rap and thumb jetties). Tree trunks represent a small portion of bank hardening structures. Bank-hardening structures are most abundant in the wide-valley segments, where sinuosity is higher and lateral migration is more common. Over fifty percent of segments E and I have bank-hardening structures. In 1881 and 1939, these segments both had sinuous, unconfined channels, with higher potential for lateral adjustment than most other segments. Segment G has fewer bank structures. Most of segment G consists of a straight channel constructed by dredge mining. The lack of bank hardening may be due to the fact that this channel has not been laterally active in recent decades. The bank-hardening structures in segment G are located in the parts that were not dredge mined. Segment K does not have bank-hardening structures, and some lateral adjustment back to its initial sinuous pattern has occurred since 1939. Segments F and J have relatively little of their length hardened, probably because they have not been very active. Segment H has been active, but mainly through avulsion, and relatively little of its length has bank-hardening structures. Bank-hardening structures, therefore, are most abundant and most limiting in wide segments with the highest potential for improvement of habitat conditions by lateral migration.

Segment E in particular has been strongly affected by the combined impacts of channel straightening, loss of sinuosity, and bank hardening. Segment E today has much lower pool area, and somewhat lower pool depths, than the other wide-valley segments (Table 1). It initially had a sinuous, and at least partially multi-thread, channel. The primary type of pool was likely lateral scour pools at meander bends. Today, lateral pools have been reduced in number, and perhaps in size, and bank hardening prevent re-establishment of meanders than could increase pool area.
DISCUSSION AND CONCLUSIONS

Direct human modification of channel morphology has been extensive in the Middle Fork John Day River – over twenty percent of the study section channel has been reshaped by direct human action. In reaches where there has not been direct human modification, channel self-adjustment may well have been triggered by human caused disturbance such as removal of riparian vegetation, mining upstream or other disturbances in the watershed. Human modification has almost universally led to reduced quality of aquatic habitat, by reducing sinuosity, pools, large woody debris and channel shade.

Improvement of stream habitat may require decreasing the width:depth ratio, adding pools, deepening pools, and changes in other ecological characteristics such as shade and large woody debris. Accomplishing these adjustments in a way that is consistent with natural channel morphology will require planform adjustment. In many segments in the Middle Fork, more than half the channel length shows no discernible planform change since 1939, and there is little evidence for planform change between 1881 and 1939. The Middle Fork John Day River’s inherent potential for self-adjustment of planform is only moderate. This low potential for self-adjustment will have to be considered in development of restoration strategies. One strategy for restoration that may increase potential for self-adjustment is increase of large woody debris loading. Large woody debris accumulations can stimulate bar development, pool scouring, avulsion, and increased sinuosity (Abbe and Montgomery, 1996, Bilby and Bisson, 1998).

The most adjustable reaches are the wide-valley segments, and they also have the highest potential for habitat, especially pool area. There is a link between wide valleys, sinuosity, and pool abundance. Wide-valley segments are good candidates for passive restoration. Bank-hardening, however, has limited the potential of wide-valley segments for passive restoration. Bank hardening is most common in those reaches that have greatest potential to be laterally active, and therefore achieve passive restoration. Future restoration strategies may require removal of bank stabilization structures. Narrow-valley reaches have been less modified by human action, and perhaps are closer to their initial conditions.

Wide-valley reaches with channels constructed by dredge mining present a special set of challenges for restoration. At present the Middle Fork does not appear to be competent to move the bed and bank material in these reaches, to reshape its channel. Active channel reconstruction may be necessary in these reaches.

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REFERENCE LIST


