



Riparian Condition Assessment for the Pawnee River (Version 2.0)

Fort Larned National Historic Site, Kansas

Natural Resource Report NPS/NRSS/WRD/NRR—2016/1246



ON THE COVER

Army bridge built in 1868 across the Pawnee River at Fort Larned
Source: Fort Larned National Historic Site archives

Riparian Condition Assessment for the Pawnee River (Version 2.0)

Fort Larned National Historic Site, Kansas

Natural Resource Report NPS/NRSS/WRD/NRR—2016/1246

Michael Martin
National Park Service
Water Resources Division
1201 Oakridge Drive, Suite 250
Fort Collins, Colorado 80525

Joel Wagner
National Park Service
Water Resources Division
P.O. Box 25287
Denver, Colorado 80225

July 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Martin, M. and J. Wagner. 2016. Riparian condition assessment for the Pawnee River (Version 2.0), Fort Larned National Historic Site, Kansas. Natural Resource Report NPS/NRSS/WRD/NRR—2016/1246. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Executive Summary	v
Acknowledgments.....	vi
Introduction and Setting.....	1
Pawnee River Channel Characteristics	3
Recent Geomorphic History of the Pawnee River	9
Hydrology of the Pawnee River.....	10
Groundwater and Riparian Resources.....	12
Functional Condition of Riparian Systems	14
Assessment Results and Discussion.....	16
Hydrology.....	16
Vegetation	17
Erosion/Deposition.....	18
Conclusions/Recommendations	20
References.....	22
Appendix: PFC Checklist for Riparian Condition Assessment	23

Figures

	Page
Figure 1. Location of Fort Larned along the Santa Fe Trail.	1
Figure 2. A typical view of the Pawnee River channel at FOLS (NPS, 2013).	3
Figure 3. Topographic overview of the Pawnee River Valley and some of the adjacent uplands.	5
Figure 4. Google Earth image of the Pawnee River at FOLS.	6
Figure 5. Oblique aerial Google Earth image of the check dam that spans the channel of the Pawnee River about 500 feet downstream of the park boundary	7
Figure 6. Concrete check dam located just downstream from FOLS.	8
Figure 7. Photo of first army bridge built in 1868 across the Pawnee River at FOLS.....	9
Figure 8. Annual peak flow record from USGS gage #07141200, Pawnee River at Rozel, KS.	10

Executive Summary

The National Park Service (NPS) is preparing a Natural Resource Condition Assessment for Fort Larned National Historic Site. To inform this assessment, the NPS Water Resources Division was asked to evaluate the functional condition of the Pawnee River riparian area within and adjacent to the park. We performed our assessment during a June 2013 site visit. Using methods described in “A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas” (U.S. Department of the Interior, 1998), we determined that the entire reach of the Pawnee River at Fort Larned is in a “nonfunctional” condition (lowest of three possible ratings). This rating is given to riparian areas that lack adequate vegetation or channel/floodplain forms necessary to dissipate energy during flood flows. As a result, they may become unstable during flood events and exhibit excessive erosion or sedimentation, with resulting loss of many of the beneficial functions and values provided by healthy riparian ecosystems.

The nonfunctional rating assigned to the Pawnee River riparian area at FOLS is primarily due to a lack of connection between the stream channel and the local water table for any appreciable amount of time during the growing season. This is most likely related to a regional drop in the water table due to decades of groundwater withdrawal. Groundwater levels in the vicinity of FOLS have declined anywhere from about 10 to 20 feet since the mid – 20th century, and while they have apparently stabilized, they are still well below pre-development levels (Balleau Groundwater, Inc., 2006).

In addition to the water table decline, the channel has aggraded about 10 feet above its base level due to a concrete check dam just downstream of the park boundary. The sediment that has deposited upstream of the dam since it was constructed exacerbates the problem of disconnection between the channel and the water table. The most dramatic effect of this disconnection is the almost complete lack of perennial riparian-wetland vegetation in the channel bed and on its lower banks.

Despite the nonfunctional rating, we don’t believe that the Pawnee River is likely to become destabilized by low to moderate-frequency floods in the near-term because the check dam provides substantial, albeit artificial, grade control. However, if the dam does fail in the future, or it is removed without careful sediment management, the channel bed would incise to obtain a new, stable grade and a great deal of sediment would be discharged downstream. Additionally, the channel banks at FOLS could become de-stabilized if the channel adjusts laterally to the new hydraulic conditions, possibly threatening park infrastructure. Ultimately, such channel adjustments could result in a more functional riparian system, especially if they reestablish a connection between the channel bed/lower banks and the water table. But, the time it would take the river to “re-stabilize” is not predictable, and the degree of potential improvement in riparian condition is uncertain. A focused study of water table conditions in the Pawnee River riparian area at FOLS would help the NPS understand the potential for river restoration and achievement of a properly functioning riparian ecosystem.

Note: This report was originally published as Natural Resource Report NPS/NRSS/WRD/NRR—2015/912. This Version 2.0 corrects the positions of labels and arrows in Figure 4.

Acknowledgments

We thank FOLS Superintendent Kevin McMurry and Chief Ranger George Elmore for logistical support, guidance and context during our assessment. They provided information on land ownership, land use history, recent flood history and other factors that may be influencing Pawnee River channel and floodplain characteristics. We also thank Rob Bennetts (Program Manager, NPS Southern Plains I&M Network) for requesting and facilitating this assessment. Special thanks go to Tomye Folts-Zettner (NPS Southern Plains I&M Network) for her excellent and always good-natured assistance with plant identification during our assessment.

We thank Gary Smillie (Hydrologist, NPS Water Resources Division) and Rebecca Weissinger (Ecologist, Northern Colorado Plateau Network) for providing peer review for this report. Their comments gave a broader perspective on local and regional hydrology, geomorphology and riparian vegetation ecology, which helped us improve this final version. Finally, we thank Heidi Sosinski (Data Manager, NPS Southern Plains I&M Network) for providing editorial and formatting support for this report.

Introduction and Setting

Fort Larned National Historic Site (FOLS) is a 718-acre unit of the National Park System located in Pawnee County, Kansas. It is situated along the Pawnee River approximately 14 miles upstream of its confluence with the Arkansas River near the town of Larned. The park was authorized by Congress on August 31, 1964 to commemorate Fort Larned's significant role in guarding the Santa Fe Trail during the 1860's and 1870's, a period of westward expansion for the United States (Figure 1). Other park purposes include preserving and interpreting the historic structures and grounds, preserving areas of archeological and ethnological interest, and protecting other scenic, scientific, natural and historic values.

The National Park Service (NPS) is preparing a Natural Resource Condition Assessment for the National Historic Site. To inform this assessment, the NPS Water Resources Division was asked to evaluate the functional condition of the Pawnee River riparian area within and adjacent to the park. This report documents our findings and provides some resource management recommendations for this historically important and culturally significant riparian ecosystem.

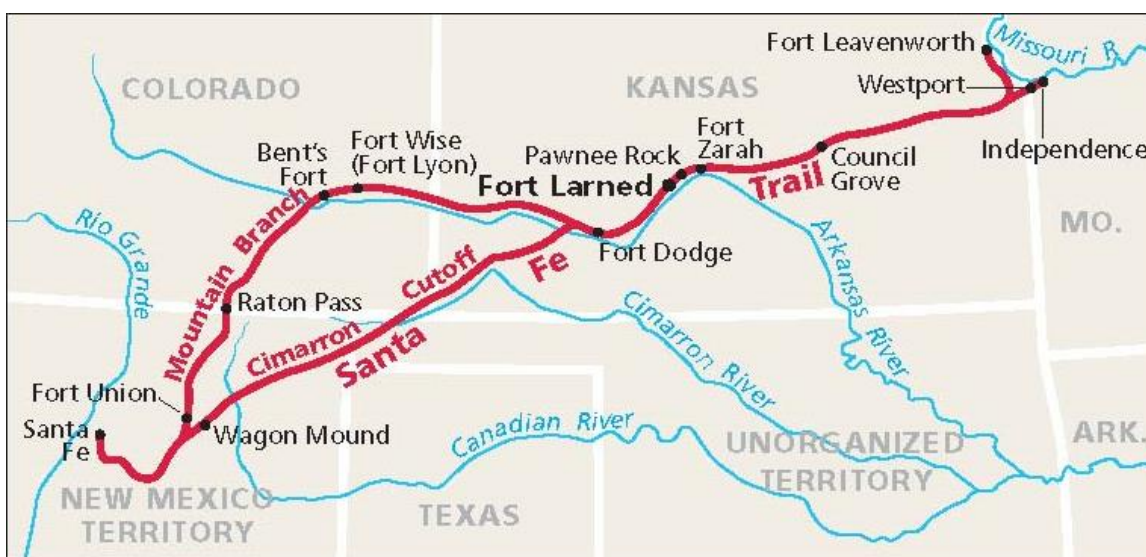


Figure 1. Location of Fort Larned along the Santa Fe Trail. The Pawnee River (not shown) passes through Fort Larned and then forms a confluence with the Arkansas River. (NPS graphic obtained from www.nps.gov/fols)

The Pawnee River watershed is located in the High Plains Section of the Great Plains Geomorphic Province. This area is characterized by gently rolling, upland plains and broad, low-relief valleys containing relatively flat floodplains and terraces. The Pawnee River, sometimes referred to as the Pawnee Fork or Pawnee Creek, begins in Gray County in western Kansas and runs predominantly east for about 200 miles before joining the Arkansas River. Larger tributaries within the 2700 square-mile watershed include Buckner Creek, which joins the Pawnee near Burdett, Kansas upstream of the park, and Sawmill Creek which enters the Pawnee about seven river miles

downstream of the park. At FOLS, the Pawnee River Valley is about 1000 feet wide and slopes gently from west to east.

The climate in Pawnee County and the rest of the western third of the state is similar to other parts of the High Plains Section, with relatively low precipitation, high evaporation rates, and a wide range of temperatures. Referred to as a steppe climate, summers are hot and are generally less humid than the other seasons. Winter temperatures can fluctuate quickly between warm and very cold. Blizzards are common, but on occasion Chinook winds can warm western Kansas into the 80 °F range. The long-term average annual precipitation for the region is about 22 inches/year, with the greatest amount occurring during late spring and summer and the least during the winter months (Kansas Department of Agriculture, 2010). In recent history the entire region has had periods of prolonged (multi-year) drought and it is currently experiencing severe to extreme drought conditions (NOAA, 2013). Overall, the climate and local meteorological conditions are highly variable, which in turn causes a great deal of variability in local hydrologic conditions.

Pawnee River Channel Characteristics

The Pawnee River is a relatively sinuous, meandering stream incised into its gently sloping valley (average valley gradient is approximately 2 feet per mile). The gradient of the river is much less than the valley gradient due to the sinuosity of the channel. Furthermore, inspection of aerial imagery indicates that there are a number of grade control structures in the river channel, including one only about 500 feet downstream from the park boundary. These structures can locally reduce the channel slope even further by retaining sediment.

The river is alluvial, which means that its bed and banks are composed of sediment recently transported (in a geologic sense) by the watercourse. This sediment is mostly fine-grained sand with some silts and clays (Fishel, 1953). The channel itself is deeply incised into the landscape, varying in depth from about 15 to 25 feet below the valley surface. Top width, the distance between the tops of the banks, ranges from about 100 to 200 feet. The overall shape of the channel is somewhat trapezoidal with steep banks and a broad, relatively flat bottom about 50 to 80 feet wide (Figure 2).



Figure 2. A typical view of the Pawnee River channel at FOLS (NPS, 2013).

The watershed of the river does not extend to the high mountains so snowmelt runoff is local and minor at best. Furthermore, most of the watershed soils have high infiltration rates and readily absorb small to moderate precipitation events. Consequently, sustained periods of flow in this reach of the river are rare, usually only driven by intense summer thunderstorms. Park staff report that seasonal flow only occurs in about three out of four years, and then only lasts for a short time. Some reaches of the Pawnee River are likely perennial due to a connection with the water table. But nowhere along the reach within FOLS is there perennial flow, nor is there any evidence of a persistent, shallow water table. There are historical accounts that suggest that the Pawnee near the Fort had supported perennial flow, but currently the river is intermittent and only flows seasonally in response to rainfall and snowmelt.

The portion of the river within FOLS is about 2.5 river-miles long and includes about five prominent meander loops (Figure 3). Additionally, there is at least one relatively recently abandoned meander bend adjacent to the active channel and an oxbow just east of the Fort grounds (Figure 4). Numerous remnant meander scrolls exist about 200 to 500 feet south of the current channel (Figure 3). Based on their position and sinuosity, these abandoned channel features appear to be a former alignment of the Pawnee River.

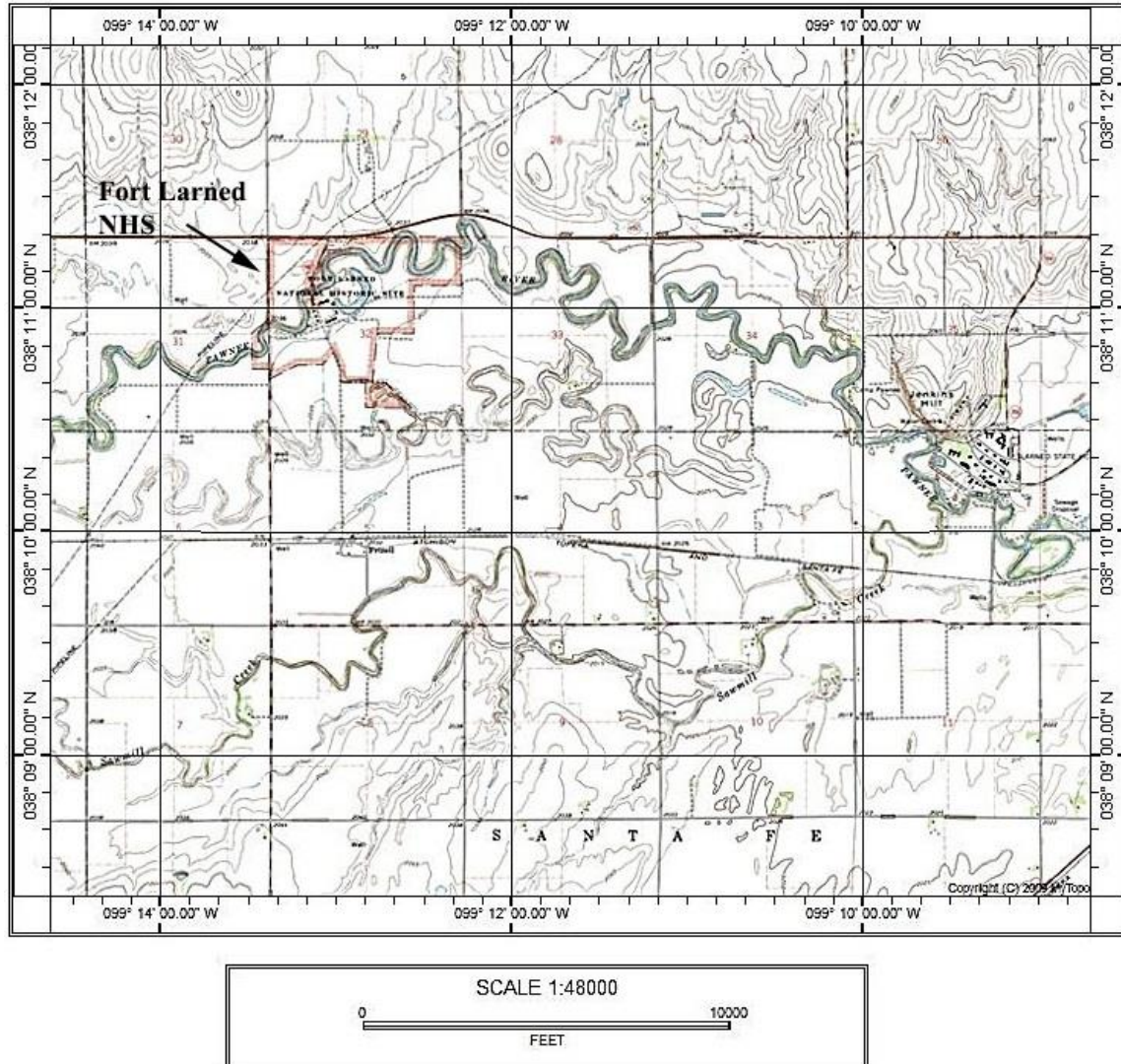


Figure 3. Topographic overview of the Pawnee River Valley and some of the adjacent uplands. Note the remnant meander scrolls just south of the present-day Pawnee River channel. Also note the prominent tributary, Sawmill Creek, along the southern margin of the Pawnee River Valley. Image acquired from USGS quadrangle, Fort Larned, Kansas (1970).



Figure 4. Google Earth image of the Pawnee River at FOLS. Note the prominent oxbow near the center of the image and the continuous lines of riparian vegetation along both sides of the channel and oxbow.

At some time in the early 20th century, a large concrete check dam was installed about 500 feet downstream from the current park boundary (Figure 4). This dam is about 15 feet high and completely spans the channel (Figures 5 and 6). Its presence has had a dramatic effect on the gradient and elevation of the river channel as well as on channel forming processes. The apparent purpose of the structure was grade control, as there are no appurtenant features associated with the dam. No type of spillway is present and there is no indication that the structure was ever used to capture and redirect water for irrigation. Therefore, it was most likely placed to arrest channel incision and retain sediment, rebuilding the grade of the channel. Currently, there is about 10 feet of sediment and debris that has accumulated on the upstream side of the dam (Figure 6), and this “wedge” of sediment continues upstream through the entire park reach. There is still about six feet of freeboard on the check dam, so some sediment that enters the river upstream will probably be retained and the aggradation will continue.

In terms of river function, not only has natural sediment transport been disrupted by the dam, but natural river flow, channel morphology, riparian vegetation and aquatic habitat characteristics have been greatly altered as described later in this report. When large flows do occur, the dam creates a backwater pool or “lake” that extends a substantial distance upstream. A topographic survey

conducted by WRD in 1992 measured a high water mark on the bridge pier, an indication of a somewhat persistent flow level that was only about half a foot higher than the top of the check dam 1.7 river miles downstream.



Figure 5. Oblique aerial Google Earth image of the check dam that spans the channel of the Pawnee River about 500 feet downstream of the park boundary. Note the pool of open water downstream of the dam, which suggests a connection to the local water table at that elevation.



Figure 6. Concrete check dam located just downstream from FOLS. Note the height of the riverbed on the right (upstream) side of the dam due to sediment accumulation compared to the downstream riverbed height on the left (bed elevation difference of approximately 10 feet). Also note the presence of surface water in the riverbed on the downstream side, possibly indicating a connection between the channel and the water table there.

Recent Geomorphic History of the Pawnee River

Several studies during the last few decades have hypothesized dramatic geomorphic changes of high plains streams throughout the region over the last couple hundred years. For example, the Arkansas River is believed to have evolved from a wide, braided stream and floodplain system with sparse riparian vegetation to a relatively narrow, single-thread channel with heavily vegetated floodplains (Dunne and Leopold, 1978; Nadler and Schumm, 1981). This channelization and encroachment of vegetation was probably accompanied by some degree of incision. These changes have been attributed to the effects of river regulation and associated irrigation followed by changes in water table elevations in the early part of the 20th century. However, based on geomorphic evidence and several historic accounts, the Pawnee River channel appears to have been a single-thread, meandering stream with some degree of incision prior to the time of the Fort's establishment in 1860.

Fort Larned was purposefully sited along the banks of the Pawnee River, indicating that its current alignment existed in the mid-1800's. We know that the channel was at least somewhat incised at that time because a photo of the Fort Larned Army Bridge, which was built soon after the Fort's establishment, shows a relatively deep channel (Figure 7).



Figure 7. Photo of first army bridge built in 1868 across the Pawnee River at FOLS.

Also, there are anecdotal reports from the early 1800's of the channel being incised and having a prominent corridor of timber on its upper banks. In September of 1825, George C. Sibley, a contractor with the U.S. Army, noted he "could distinctly trace the course of the Pawnee River for a great distance by the fringe of trees along its banks" (Gregg, 1995). In 1844 James Josiah Webb, an early trader along the Santa Fe Trail, observed that "The east bank must be from twenty to thirty feet above the water and very steep" (Webb, 1995). Consequently, we believe that while the Pawnee River channel may have undergone some 20th century incision, channel characteristics including some degree of entrenchment were well established by the mid-1800's.

Hydrology of the Pawnee River

To evaluate flow conditions of the Pawnee River, we used the long-term record from the USGS gage at Rozel, KS (#07141200). This gage has been operated since 1926 and has a continuous record of 87 years, with only one year (1991) missing. The gage is located about 10 miles upstream of FOLS, it has a datum of 2,040.24 feet (NGVD29) and it drains an area of about 2000 square miles.

Flow in the Pawnee River is highly variable, both within years and between years. Annual-mean flow, a rough measure of the relative “wetness” between years, has varied between 5-6 cubic feet per second (cfs) in dry years to over 100 cfs in wet years. The highest recorded annual-mean flow was about 550 cfs in 1951. Annual peak flows are also quite variable, ranging from lows less than 100 cfs to extreme flows that approach and sometimes exceed 10,000 cfs (Figure 8). The flood of record for the gage at Rozel occurred on July 28, 1958 with a flow of 16,300 cfs. The second largest flood took place on May 28, 1935, reaching a peak of 14,000 cfs. About 55 percent of the annual peaks were between 1000 and 2000 cfs, and 85 percent were between 1000 and 5000 cfs. Eighteen percent were below the relatively modest flow magnitude of 1000 cfs (Figure 8).

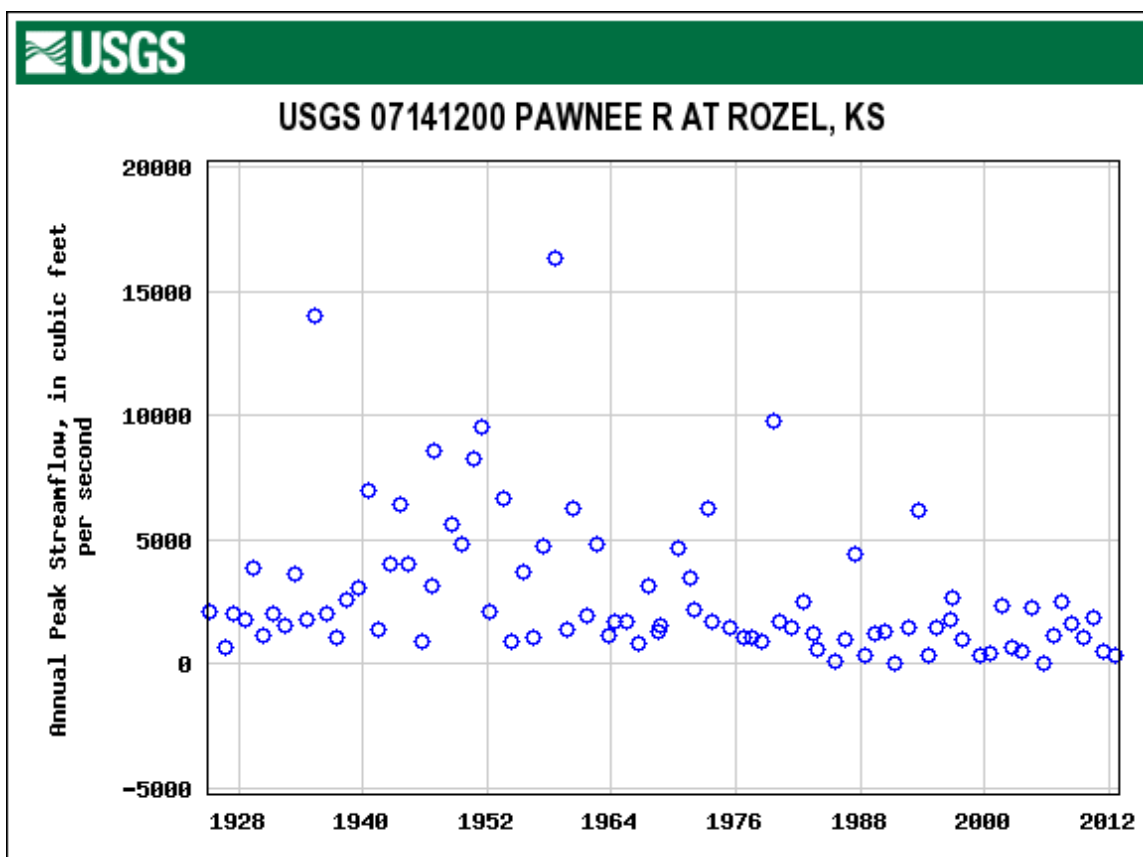


Figure 8. Annual peak flow record from USGS gage #07141200, Pawnee River at Rozel, KS. Note the high variability in magnitude between near zero and over 15,000 cfs.

While this reach of the Pawnee River is generally dry, runoff events (usually short-term seasonal flow) do occur periodically, and occasionally there are very large, out-of-channel floods. Park staff report that there is seasonal flow present in the channel in about three out of four years, and there have been at least seven flood events that have reached the Fort grounds in the last 36 years (about once every five years). We do not have specific dates for these events, but review of the gage record indicates that there have been about five annual peaks that approached or exceeded 5000 cfs in the last 40 years or so (Figure 8).

The flood frequency distribution calculated from a gage record provides a good view of prevailing flow magnitudes for that reach of the stream. The 2-year event is generally accepted as being in the range of bankfull discharge, a flow level that helps drive channel formation and maintenance processes. A USGS analysis from the gage record at Rozel calculated 2250 cfs for the 2-year flow event (Rasmussen and Perry, 2000). This is a sizable flow for a relatively frequent event, suggesting that this watershed is (or was) capable of regularly producing substantial flows under the prevailing climate. During the first 36 years of records for the Rozel gage (1927 -1962), discharge nearly equaled or exceeded the calculated 2-year flow at least every other year, which is very consistent with the Rasmussen and Perry (2000) analysis. However, by the mid-1960's, it appears that the frequency of the annual peak discharge approaching the calculated 2-year flow began to diminish. In the last 40 years the annual peak discharge has exceeded 2000 cfs only eight times, meaning that the calculated 2-year flow only occurred about once every five years during this period (i.e., bankfull flows occurred less frequently than expected). This trend may be related to changing precipitation patterns, but it also could be related to a drop in the water table (see following section) and a corresponding reduction or loss of base flow contributions. The record also suggests there may have been a downward trend in the magnitude of annual peak flows over the last 50 years or so. Prior to the mid-1960's, there were eight annual peaks that exceeded 5000 cfs, while after that time there were only three (Figure 8).

Rasmussen and Perry (2000) calculated the 100-year flood for this gage to be 15,400 cfs, and the two highest discharge events recorded at the gage, 16,300 cfs in 1958 and 14,000 cfs in 1935, were both in that range. The FEMA map that covers this area, Pawnee County Kansas, 1977 (revised 1990), depicts the entire National Historic Site as being within the 100-year floodplain, and these two events almost certainly reached the Fort grounds.

There are historical accounts that the Pawnee River may have had a more perennial character during the 19th century, and these accounts have been supported by a flow duration analysis of the USGS gage record at Rozel (Figure 8). Flow duration curves developed by Balleau Groundwater, Inc. (2006) from 87 years of gage records indicate that discharge has progressively decreased over the period of record. There have been wet periods when flow has recovered somewhat, but for the most part there is less water in the river system now than in the past.

Groundwater and Riparian Resources

In the vicinity of FOLS, the primary aquifer is the alluvial aquifer (Sophocleous, 1980). This water table aquifer fills the extensive Pawnee River valley and is recharged by direct precipitation (including occasional snowmelt), storm runoff, streamflow or any combination of these. Since the amount of water that enters the alluvial aquifer is directly related to atmospheric trends, water levels may be greatly affected by prevailing meteorological conditions. On the other side of the equation, groundwater withdrawals may dramatically lower water levels in an alluvial aquifer, and this has occurred within the immediate area of the National Historic Site. In addition to the alluvial groundwater system, there are other formations that may serve as aquifers in the area, but because they have no known connection to the Pawnee River or Fort Larned, they are not included in this discussion.

The alluvium in the Pawnee River Valley was deposited in channels cut into Cretaceous, Tertiary, and Pleistocene sediments, the latter of which remain in places as terrace deposits on the outer margins of the river valley (McLaughlin, 1949). The age of the alluvium, therefore, is late Pleistocene and Holocene. The thickness of the alluvium ranges from about 65 to 138 feet with an average of about 105 feet (Fishel, 1953).

The lithology and predominant grain size of the alluvial material is not uniform throughout the deposit, and therefore, water bearing properties also vary. The upper part of the alluvium in the Pawnee Valley consists primarily of silt with some clay and sand. Beneath this upper layer there is, in most places, a thick zone with a greater proportion of sand and gravel. The overlying zone, which has an average thickness of about 30 feet, is much less permeable than the lower, coarser-grained layer, which yields large quantities of water to wells in the valley. Most of the domestic and stock wells and all of the irrigation wells in the area obtain water from this lower layer in the alluvial fill (McLaughlin, 1949). The three wells present on the Fort Larned grounds range in depth from about 55 to 85 feet and are likely finished in this lower, more permeable layer.

The elevation of the water table relative to the land surface is determined by a balance between inflows and outflows of the local groundwater system. When the water table is maintained at a high enough elevation, or rises seasonally and intersects local stream channels, perennial or seasonal stream flow occurs. Even if a stream channel rarely supports flow, proximity to a local water table may produce moist conditions in the alluvial soil and support riparian-wetland habitats. Conversely, when an alluvial river such as the Pawnee is dry for most of the year and only flows in response to substantial precipitation events, it is likely disconnected from the water table.

Topographic data collected from a stream channel survey by WRD in 1992 indicated that the channel bed elevation of the Pawnee River through FOLS was about nine feet above the local water table elevation measured in three park wells at that time (Martin, 1992). This elevation difference between the channel and the local water table likely persists today as evidenced by rare and short-lived flow events through the channel. Additionally, recent groundwater analyses completed for the local groundwater management district have mapped the local water table at up to about 30 feet below the valley surface (Balleau Groundwater, Inc., 2006). This lack of a regular connection to the water

table has had a pronounced effect on the type of vegetation that dominates the channel, as described later in this report.

Declining groundwater levels have been a concern throughout the Western U.S. for some time. The invention of high capacity pumps in the 1950's and 1960's allowed the expansion of irrigated agriculture throughout the Great Plains and enormous quantities of water were removed from local aquifers. Water levels in the alluvium in the vicinity of FOLS have declined anywhere from 10 to 20 feet below historic levels, with the overall average decline about 19 feet from 1947 to 1997.

Currently, under the sustainable yield policy adopted by the local groundwater management district (GMD#5), additional water appropriations since 2002 have been curtailed and the entire basin is expected to stabilize. While new groundwater withdrawals have stopped, water levels still fluctuate about plus-or-minus 10 feet from year to year, depending on other hydrologic factors (Balleau Groundwater, Inc., 2006).

Functional Condition of Riparian Systems

The purpose of our assessment was to determine the functional condition of the Pawnee River channel and its associated riparian corridor within FOLS. To perform this assessment, we used “A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas” (U.S. Department of the Interior, 1998). For this method, an interdisciplinary team of technical experts evaluates 17 hydrology, vegetation, and erosion/deposition elements for each assessment reach (see PFC Checklist Items in the Appendix). Based on this evaluation, the team assigns one of three ratings to the reach: Proper Functioning Condition, Functional At-Risk, or Non-Functional.

“Proper Functioning Condition” (PFC): For this method, PFC is the highest rating that can be given to a stream reach and its associated riparian area. In general, riparian areas function properly when adequate vegetation, land form or large woody debris are present to:

1. dissipate stream energy associated with high water flows, thereby reducing erosion and improving water quality;
2. filter sediment, capture bedload, and aid floodplain development;
3. improve floodwater retention and groundwater recharge;
4. develop root masses that stabilize stream banks against cutting action;
5. develop diverse ponding and channel characteristics to provide habitat and the water depths, durations, temperature regimes, and substrates necessary for fish production, waterfowl breeding, and other uses; and
6. support greater biodiversity.

A riparian area in PFC is in dynamic equilibrium with its streamflow forces and channel processes. The system adjusts to handle moderately large flood events with limited change in channel characteristics and associated riparian-wetland plant communities. This limited change is within the context of natural stream evolution for the channel type, such as gradual cutbank erosion and point bar expansion for meandering, low-gradient alluvial channels. Because of this resiliency and stability, riparian areas in PFC can maintain aquatic habitat, water quality enhancement, and other important ecosystem functions, even after moderately large runoff events. In contrast, nonfunctional systems subjected to the same flows might exhibit excessive erosion and sediment loading, loss of aquatic and wetland habitat, and so on.

“Functional-At Risk”: These riparian areas are in proper functioning condition, but an existing soil, water, vegetation, or related attribute makes them susceptible to instability and degradation. For example, a stream reach may exhibit attributes of a properly functioning riparian system, but it may be poised to suffer severe erosion during a moderate flood event in the future due to likely migration of a headcut or increased runoff associated with recent urbanization in the watershed. When this rating is assigned to a stream reach, then its “trend” toward or away from PFC is assessed.

“Nonfunctional”: These are riparian areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with flood flows, and thus are not reducing erosion, improving water quality, sustaining desirable channel form and riparian habitat characteristics, and so on as described in the PFC definition. The absence of certain physical attributes, such as a floodplain where one should exist, is an indicator of nonfunctional conditions.

Assessment Results and Discussion

To accurately complete a Properly Functioning Condition assessment, the stream or river segment of interest may be divided into shorter assessment reaches based on changes in geomorphology, vegetation, or other factors. After careful consideration of the Pawnee River riparian ecosystem at FOLS, we decided to evaluate the river as a single reach due to an apparent consistency of geomorphic and vegetation characteristics throughout the site. The following discussion is organized according to the three major topics that are evaluated by the PFC method: Hydrology, Vegetation and Erosion/Deposition.

Hydrology

The hydrology section of the PFC assessment asks the team to determine if the observed channel morphology is stable and in balance with the landscape setting, given prevailing hydrologic and sediment inputs. This is done by determining the frequency of floodplain inundation, evaluating several channel morphology parameters (sinuosity, slope, and width-to-depth ratio), determining the width and trend (widening or narrowing) of the riparian-wetland area, evaluating the influence of upland watershed conditions on hydrologic and sediment characteristics, and other factors.

Our determination of whether the Pawnee River floodplain at FOLS is inundated in “relatively frequent” flow events (Item #1 on the PFC Checklist in the Appendix) was somewhat problematic due to the unconventional nature of the channel form. For channel/floodplain forms normally expected in this landscape and climate setting, flows would likely overtop stream banks and spread onto the adjacent floodplain about every two years or so. But, as explained previously, the channel at FOLS has incised deeply in the past. When an incising channel reaches a new (lower) base level, a new channel and floodplain and associated riparian-wetland community often establishes at this lower level, over time. At FOLS, however, the hydraulics and channel forming processes have been so affected by the check dam that we did not observe the formation of any substantial channel features (e.g., point bars or cutbanks) or a new floodplain at the lower base level. Only in one short reach (about 300 feet) were we able to identify a distinct thalweg (deepest part of the channel) at all. We concluded that the geomorphic floodplain at FOLS is at the level of the top of the river banks, and that floodplain inundation is very infrequent, about once in six to 10 years, on average. Therefore, our answer to this checklist item was “no.”

For the landscape setting and climate in this region, in-balance channel forms (PFC Checklist Item #3) would be expected to have sinuosities greater than 1.2, gradients less than two percent and width-to-depth ratios greater than 12 (U.S. Department of the Interior, 1998). For the Pawnee River at FOLS, these channel parameters were split between stable and unstable characteristics. The sinuosity of the river, as measured from aerial imagery, is about 1.83. This is well above the expected value of 1.2, and in fact the meander pattern suggests a very robust sinuosity. However, this sinuosity alone does not indicate channel stability, and must be evaluated in the context of the other parameters. We obtained width-to-depth (W:D) ratios from channel cross section survey data collected previously by the NPS Water Resources Division (Martin, 1992). Four of the six cross sections surveyed had W:D ratios below or very close to 12, indicating an incised channel that is out of balance with the

landscape setting. This finding is consistent with our response to Checklist Item #1, where we concluded that the channel is incised and the floodplain is not inundated on a relatively frequent basis.

The overall channel gradient for this reach of the Pawnee River, taken from the Fort Larned, Kansas (1970) USGS quadrangle map, is about 0.03 percent. Values cited in various documents related to the Pawnee River report the gradient to be about 2 ft/mile, or again about 0.03 percent. This relatively gentle gradient is even flatter through FOLS because of the downstream check dam. Consequently, all indications are that the local channel gradient at FOLS is well within the reported “stable” value of less than two percent (U.S. Department of the Interior, 1998). However, the nearly flat channel gradient through the site should be considered temporary. If the check dam were to fail or be removed, the local channel slope would increase substantially through incision, at least for some time.

For Checklist Item #4, we determined that the riparian-wetland area is not widening, nor has it achieved its potential extent. As mentioned previously, channel formation at the current base level is practically non-existent, suggesting that post-incision channel and floodplain development processes (and associated riparian-wetland vegetation community establishment) have not occurred. In fact, we were unable to locate any perennial herbaceous wetland vegetation within the channel or on the lower banks, and the limited woody riparian vegetation present on the lower channel banks displayed low vigor.

For Checklist Item #5, we evaluated whether land use activities in the contributing watershed are degrading the quality of the riparian ecosystem by contributing excess water or sediment. The incised channel at FOLS appears capable of passing the water being delivered by the watershed under most flow conditions without creating excessive erosion or instability. Nowhere in the study reach did we observe isolated deposits of sediment that would suggest excessive upstream erosion and associated deposition along the channel or floodplain. The substantial channel aggradation (up to 10 feet) observed throughout the study reach appears to be the result of long-term trapping of almost the entire sediment load (with the exception of some suspended transport) behind the check dam, as described previously. In view of these findings, we concluded that the upland watershed is not contributing to riparian-wetland degradation.

Vegetation

An integral part of the PFC analysis is evaluation of riparian-wetland vegetation along the channel and floodplain. Checklist Items 6-12 (Appendix) are used to evaluate the species composition, percent cover, age structure, energy dissipation capability and other diagnostic vegetation characteristics for the study reach.

A critical finding was that we observed no perennial herbaceous wetland vegetation within the channel. Herbaceous cover was typically 90-100% on most channel bed locations and lower banks, but it was dominated by annual or biennial species including smartweed (*Persicaria pensylvanicum*), poison hemlock (*Conium maculatum*), mapleleaf goosefoot (*Chenopodium simplex*), lambs-quarters (*Chenopodium album*), Canadian horsetweed (*Conyza canadensis*), stickywilly (*Galium aparine*) and

Venus' looking glass (*Triodanis perfoliata*). Smartweed and poison hemlock are considered wetland plants, but the rest are more typical of uplands (Lichvar, 2013). Also represented in various locations (but not dominant) were annual upland species including cheatgrass (*Bromus tectorum*), common wheat (*Triticum aestivum*), little barley (*Hordeum pusillum*) and peppergrass (*Lepidium densiflorum*) and the wetland annual *Veronica peregrina* ssp. *xalapensis*. This annual/biennial herbaceous cover indicates repeated disturbance (e.g., ponding) and a relatively deep water table. The only perennial herbaceous species we observed in the channel (near the maintenance area) was clammy groundcherry (*Physalis heterophylla*), an upland plant.

Scattered mature cottonwoods (*Populus deltoides*) were observed in the forested corridors along the tops of the channel banks. We saw seedling/young sapling sized plants at some lower channel bank locations, but middle-aged cottonwood trees were absent. We couldn't estimate the ages of the seedling/sapling sized cottonwoods because they had re-sprouted from their bases multiple times, likely due to repeated ponding, herbivory or other stressors. Mature black willows (*Salix nigra*) were observed occasionally on the tops of the banks, but we saw only one sapling on a lower channel bank. Other woody riparian species in the forests along the upper banks (but not observed on mid to lower banks) include green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and slippery elm (*Ulmus rubra*).

Based on: 1) the complete absence of perennial herbaceous wetland vegetation in the channel bed or on the lower banks; 2) the general lack of diverse age-class distributions for woody or herbaceous riparian-wetland species; 3) the absence of species with root masses capable of stabilizing streambanks during high flow events; and 4) the poor vigor of the cottonwood seedlings/saplings that have managed to survive in some locations, we answered "no" to PFC Checklist Items 6 - 11 (Appendix). The extensive corridor of riparian trees on the upper banks appears healthy, but these trees do not contribute to the stability of the channel bed and lower banks. The check dam downstream and the resulting pool that forms throughout most of the channel within FOLS provide artificial physical stability to what otherwise would be an extremely unstable channel form during flood events.

Erosion/Deposition

The primary focus of this section of the assessment is to determine if there is an apparent balance between flow, sediment, and erosion/deposition processes in the river system. A key element of this balance is energy dissipation that results from resistance to flow from rocks, channel features, and large woody debris, for example.

For the Pawnee River at FOLS, channel roughness and channel form do not result in much energy dissipation during frequent to moderately large floods. Characteristics such as floodplains, point bars, or cutoff chutes have not formed within the incised channel to help diminish flow energy, nor are there substantial roughness elements like coarse alluvium or extensive woody debris that systemically reduce flow energy. For these reasons, we rated Checklist Item #13 as "no." There is also no apparent lateral stream movement within the overall channel, and no new channel formation or lateral movement at the new base level created by past incision, so Item #15 was rated "no."

Rather, the downstream dam creates backwater conditions that result in very low velocities and greatly decreased erosive energies.

Vertical stability is a very important element in evaluating conditions of erosion and deposition in riparian systems. This study reach does not exhibit typical attributes of a vertically unstable riparian system (e.g., v-shaped channel, steep eroding banks, headcuts). Although its U-shaped channel and stable banks suggest vertical stability, processes associated with an incised river that has reached a stable grade, such as an actively forming channel and floodplain morphology at the new base level, are completely absent. We concluded that the aspects of apparent vertical stability are artificially maintained by the check dam. If the structure were to fail catastrophically or be purposefully removed without management of the accumulated sediment, this reach of the Pawnee River would undergo dramatic incision and stream channel evolution, with the release of a great deal of sediment into aquatic habitats downstream.

Conclusions/Recommendations

While the Pawnee River at FOLS supports a nearly continuous corridor of riparian trees on its upper banks, we found the riparian system to be in “nonfunctional” condition as defined by the PFC method. We answered “no” to nearly every applicable Checklist Item for the study reach (Appendix), and supported these responses with Checklist “Remarks” and the preceding discussion. Critical findings supporting our rating include a channel/floodplain form that is out of balance with the landscape setting, absence of vegetation with root masses capable of stabilizing the lower channel banks during high flow events (e.g., no perennial wetland plants), almost no recruitment of woody riparian-wetland plants and absence of channel/floodplain formation at the new base level following past incision.

One of the primary conditions that led to the nonfunctional rating for this river reach is the lack of a connection between a persistent shallow water table and the stream channel. Because of this, the channel bed and lower banks fail to support perennial wetland-riparian vegetation, and the system is unable to develop diverse aquatic and wetland habitats, enhance channel stability or provide other beneficial functions of healthy riparian systems. The disconnect between the water table and the channel is likely caused, at least in part, by the regional decline in the alluvial aquifer. However, this condition has been exacerbated throughout the river reach within FOLS by channel aggradation (sediment accumulation) above the check dam located a few hundred feet downstream of the park boundary.

The downstream check dam has held the riparian ecosystem at FOLS in an artificially stable, very early successional state. If the structure were to fail catastrophically, the Pawnee River at FOLS would undergo dramatic incision and a great deal of sediment would likely be released into downstream aquatic habitats. A significant lowering of the channel bed would pose an immediate threat to bridge pier foundations and buried utilities. Significant bed lowering would also increase bank height and bank instability, which may trigger channel widening and further threaten infrastructure at FOLS.

Controlled dam removal with careful management of the accumulated sediment and re-establishment of a natural river grade through FOLS is probably the only possible means of restoring a more functional riparian system along this reach. Despite the regional decline in the water table and an apparent reduction in flow frequencies and magnitudes over the last few decades, we observed ponds in the channel immediately downstream of the dam (Figure 6). USGS records from the Pawnee River gage at Rozel show zero flow for more than 2 months prior to our assessment, so these ponds may be surface expressions of local groundwater conditions and evidence of a direct connection between the channel and the water table at this lower bed elevation. Therefore, reestablishment of the natural grade of the channel bed within FOLS could potentially restore at least some connectivity between the channel and the water table, perhaps enough to support perennial riparian-wetland vegetation.

Even with controlled dam removal and sediment management the threats associated with resulting bank instability described above would still exist to some degree. The time it would take the river to “re-stabilize” after dam and sediment removal is not predictable, and the degree of potential improvement in riparian condition is uncertain. However, a focused study of existing water table conditions in the riparian area at FOLS would help the NPS understand the potential for restoration of a properly functioning riparian ecosystem.

References

- Balleau Groundwater, Inc. 2006. Pawnee River Basin Water Accounting for Big Bend GMD#5 (Safford KS), Water-Management Planning. Albuquerque, NM.
- Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman & Co. pp. 687-693.
- Fishel, V. C. 1953. Ground-water Resources of Pawnee Valley, Kansas. State Geological Survey of Kansas, Bulletin 94. University of Kansas Publications.
- Gregg, K.L. (editor). 1995. The Road to Santa Fe: The Journals and Diaries of George Champlin Sibley. University of New Mexico Press. Albuquerque, NM.
- Kansas Department of Agriculture, Division of Water Resources. 2010. Pawnee-Buckner Sub-basin, 2009 Field Analyses Summary.
- Lichvar, R.W. 2013. The National Wetland Plant List: 2013 Wetland Ratings. Phytoneuron 2013-49: 1–241. Published 17 July 2013. ISSN 2153 733X
- Martin, M. 1992. Hydrologic analysis of the Pawnee River in the vicinity of Fort Larned National Historic Site, Kansas. Trip Report, National Park Service, Water Resources Division. 8p.
- McLaughlin, T.G. 1949. Geology and Ground-water Resources of Pawnee and Edwards Counties, Kansas, with Analyses by H.A. Stoltenberg. Kansas Geological Survey, Bulletin 80, 189 p.
- Nadler, C.T. and S.A. Schumm. 1981. Metamorphosis of South Platte and Arkansas Rivers, Eastern Colorado. Physical Geography: 2, 95-115.
- National Oceanic and Atmospheric Administration (NOAA). 2013. Southwest Kansas Drought Monitor. (<http://www.crh.noaa.gov/>)
- Rasmussen, P.P. and C.A. Perry. 2000. Estimation of Peak Streamflows for Unregulated Rural Streams in Kansas. U.S. Geological Survey, Water Resources Investigations Report 00-4079.
- Sophocleous, M.A. 1980. Hydrogeologic Investigations in the Pawnee Valley, Kansas. Kansas Geological Survey, Open-File Report 80-6.
- U.S. Department of the Interior. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. TR 1737-15. Bureau of Land Management National Applied Resource Sciences Center. Denver, CO.
- Webb, J.J. 1995. Adventures in the Santa Fe Trade, 1844-1847. University of Nebraska Press. Lincoln, NE.

Appendix: PFC Checklist for Riparian Condition Assessment

Name of Riparian Area: Fort Larned NHS – Pawnee River

Date: 6/5/2013 Segment/Reach ID: Entire reach within FOLS

Miles: 2.3 miles Acres:

ID Team Observers: Mike Martin & Joel Wagner (WRD); Tomye Folts-Zettner (SOPN Network)

Yes	No	N/A	HYDROLOGY
	X		1) Floodplain above bankfull is inundated in “relatively frequent” events
		X	2) Where beaver dams are present they are active and stable
	X		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
	X		4) Riparian-wetland area is widening or has achieved potential extent
X			5) Upland watershed is not contributing to riparian-wetland degradation

Yes	No	N/A	VEGETATION
	X		6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
	X		7) There is diverse composition of riparian-wetland vegetation for maintenance/recovery)
	X		8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
	X		9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events
	X		10) Riparian-wetland plants exhibit high vigor
	X		11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
		X	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Yes	No	N/A	EROSION/DEPOSITION
	X		13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
		X	14) Point bars are revegetating with riparian-wetland vegetation
	X		15) Lateral stream movement is associated with natural sinuosity
	X		16) System is vertically stable (with respect to incision only, not aggradation)
	X		17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

(Revised 1999)

Remarks (numbers correspond to checklist items)

1. Channel is deeply incised. W:D ratio calculated from four of six cross-sections surveyed in 1992 ranges from about 7 to 12.
3. Overall channel sinuosity is a relic of the pre-incision channel form. No lateral migration is taking place due to entrenchment. There is no evidence of new channel/floodplain formation or succession in the bottom of the incised channel as would be expected in a recovering system after an incision event. Instead the channel maintains a trapezoidal shape, likely influenced by pooling and sediment deposition behind the downstream dam.
4. As described in 3. above, the channel has maintained a trapezoidal shape after incision and the riparian zone is not widening either through lateral adjustment and aggradation or channel narrowing processes. We observed no perennial riparian-wetland vegetation in the incised channel other than a few cottonwood seedlings/saplings on some lower channel banks. Mature riparian trees persist on the tops of the channel banks.
5. Although we didn't see evidence of excessive sediment or water contributions from the uplands, the downstream dam has caused as much as 10 feet of sediment to accumulate in the channel bottom within FOLS. The water table may be so far below the accumulated sediment that there is no capability to support perennial herbaceous wetland and riparian species along the channel.
6. No perennial herbaceous wetland-riparian vegetation was observed within the channel. Channel beds and sides are dominated by annual or biennial herbaceous species including smartweed (*Persicaria pensylvanicum*), poison hemlock (*Conium maculatum*), mapleleaf goosefoot (*Chenopodium simplex*), lambs-quarters (*Chenopodium album*), Canadian horsetweed (*Conyza canadensis*), stickywilly (*Galium aparine*) and Venus' looking glass (*Triodanis perfoliata*). Smartweed and poison hemlock are considered wetland plants, but the rest are more typical of uplands. Also represented in various locations (but not dominant) were the upland annual species cheatgrass (*Bromus tectorum*), common wheat (*Triticum aestivum*), little barley (*Hordeum pusillum*) and peppergrass (*Lepidium densiflorum*) and the wetland annual *Veronica peregrina* ssp. *xalapensis*. This annual/biennial herbaceous cover indicates repeated disturbance (e.g., ponding) and a relatively deep water table. The only perennial herbaceous species we observed in the channel (near the maintenance area) was clammy groundcherry (*Physalis heterophylla*), an upland plant. Scattered mature cottonwoods (*Populus deltoides*) exist on some upper channel banks and we saw seedlings/young saplings in some lower channel bank locations, but middle-aged (replacement) cottonwoods were absent. Ages of seedling/sapling-size cottonwoods could not be estimated because they have been stressed by ponding, herbivory, sediment deposition, and/or erosion and have re-sprouted from their bases multiple times. Mature black willows (*Salix nigra*) were observed occasionally on upper channel banks, but we saw only one sapling-size plant on a channel bank.
7. Perennial herbaceous riparian-wetland vegetation is absent in the channel. Cover is annuals or biennials, many of which are upland species. For woody riparian vegetation, green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), slippery elm (*Ulmus rubra*), cottonwood and black willow are components of the woods lining the tops of the pre-incision channel banks. But,

they are not found on the banks or bottoms of the channel except for the stressed seedling/sapling cottonwoods and the single black willow sapling discussed in 6. above.

8. See 6. and 7. above.
9. Annuals and biennials dominating the channel banks and bed do not have root masses capable of withstanding high stream flow events. There are no rhizomatous wetland plant species in the channel.
10. Seedling/sapling-size cottonwoods on lower banks are stressed by ponding, herbivory or sediment deposition and have re-sprouted from their bases multiple times. Trees at the tops of channel banks show vigor, but they would only contribute to upper bank stability when flows reach that elevation.
13. The downstream dam pools water in the channel in most of the Pawnee River reach within FOLS, and this serves as a primary means of slowing flow and dissipating energy. Natural floodplain and channel characteristics such as overflow channels and riparian vegetation do not come into play for energy dissipation until flows are large enough to access the tops of the relic (pre-incision) channel banks and floodplain.
15. The pre-incision (relic) channel is no longer migrating laterally and there is no evidence of new channel/floodplain formation or succession in the bottom of the incised channel as would be expected in a recovering system.
16. For now the channel is vertically stable (not incising) due to pooling and sediment deposition behind the dam. However, the channel would be expected to incise quickly through the accumulated sediment if the dam fails or is removed without sediment management.
17. There is excessive sediment accumulation in the channel due to the downstream dam.

Functional Rating:

Proper Functioning Condition _____
 Functional – At Risk _____
 Nonfunctional X

Trend for Functional – At Risk:

Upward _____
 Downward _____
 Not Apparent _____

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes X No _____

If yes, what are those factors?

____ Flow regulations ____ Mining activities ____ Upstream channel conditions
 ____ Channelization ____ Road encroachment ____ Oil field water discharge
 ____ Augmented flows X Other (specify): check dam downstream of park

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 425/133457, July 2016

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

2016

NationalParkService.
CENTENNIAL

EXPERIENCE YOUR AMERICA™