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Riparian Condition Assessment for Big Sandy Creek

Sand Creek Massacre National Historic Site, Colorado

Natural Resource Technical Report NPS/WRD/NRR—2014/788

ON THE COVER:
Big Sandy Creek at flood stage, May 2007.
Photography by: NPS, 2007

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Executive Summary

This report presents results of a June 2012 riparian condition assessment conducted along Big Sandy Creek at Sand Creek Massacre National Historic Site. We used 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) to evaluate hydrology, vegetation, soil and geomorphology characteristics for five assessment reaches along the creek. Based on that information, we rated each reach as being in "Proper Functioning," "Functional At-Risk" or "Nonfunctional" condition. Riparian condition Checklists and supporting notes prepared for the assessment reaches are provided in the Appendixes.

We rated all five Big Sandy Creek reaches as being in "Proper Functioning Condition," the highest rating for this method. This means that the creek is in dynamic equilibrium with respect to streamflow forces and channel processes. As such, it can withstand moderately large flood events with only limited change in channel characteristics and plant communities, thereby preserving beneficial riparian functions, processes and values. Results presented in this report can be directly incorporated into the Natural Resource Condition Assessment being prepared for the park.

Management recommendations for the riparian corridor include: 1) continue eradication, monitoring and control of highly invasive, non-native plant species such as *Salsola tragus*, *Kochia scoparia*, *Elaeagnus angustifolia* and *Tamarix ramosissima*; and 2) install and monitor a network of shallow ground water wells in the riparian zone. The well data would establish a baseline for evaluating future water table conditions that may be affected by external development, ground water withdrawals, drought or other perturbations. The data would also be useful in understanding relationships between riparian water table conditions and the establishment and health of cottonwood trees and other riparian vegetation.

Acknowledgments

We thank Sand Creek Massacre NHS Superintendent Alexa Roberts and Park Operations Manager Karl Zimmerman for logistical support, guidance and context during our assessment. They provided information on land ownership and land use history, including dams and diversions, grazing practices and other factors that may be influencing the channel and floodplain characteristics of Big Sandy Creek. We thank Rob Bennetts (Program Manager, NPS Southern Plains I&M Network) for requesting and facilitating this assessment. We also thank Melanie Myers (NPS Intermountain Region) for assisting us in obtaining GPS coordinates for stream reach boundaries and special features and in preparing the aerial photos presented in this report.

We thank Dr. Bill Jackson (Hydrologist, former Chief, NPS Water Resources Division), Steve Monroe (Hydrologist, NPS Southern Colorado Plateau Network), and Mike Britten (Program Manager, NPS Rocky Mountain I&M Network) for providing peer review for this report. Their comments gave a broader perspective on local and regional hydrology, vegetation and geomorphology, which helped us improve this final version. Finally, we thank Heidi Sosinksi (Data Manager, Southern Plains Network) for providing editorial and formatting support for this document.

Introduction

Sand Creek Massacre National Historic Site (SAND) is a 12,583 acre unit of the National Park System located in Kiowa County in southeastern Colorado (Figure 1). On November 29, 1864, Colonel John M. Chivington led approximately 700 U.S. volunteer soldiers to a village of about 500 Cheyenne and Arapaho people camped at this location along Big Sandy Creek. Although the village inhabitants believed they were under the protection of the U.S. Army, Chivington's troops attacked and killed about 150 people, mainly women, children, and the elderly. SAND was established in recognition of the national significance of the massacre in American history and its ongoing significance to the Cheyenne and Arapaho people and massacre descendants.

The National Park Service is conducting a Natural Resource Condition Assessment for SAND. To inform this assessment, the NPS Water Resources Division was asked to evaluate the functional condition of the Big Sandy Creek riparian area within the park. This report documents our findings and provides some resource management recommendations for this historically important and culturally significant riparian ecosystem.

Setting/Background

The Big Sandy Creek watershed is located in the Colorado Piedmont area of the Great Plains Province. The headwaters of this long and relatively narrow drainage basin begin near Peyton, Colorado. From there, the watershed trends due east for about 10 miles, veers to the northeast for about 30 miles, and then trends eastward toward Limon, Colorado. The creek then angles to the south and southeast until forming a confluence with the Arkansas River about eight miles east of Lamar, Colorado. The U.S. Geological Survey (USGS) has operated a stream gage on Big Sandy Creek at Lamar (#07134100) for about 30 years. The drainage basin is reported to be about 3,400 square miles at this gage; however, the USGS has determined that only about 2,631 square miles contribute flow to the lower watershed (http://waterdata.usgs.gov/usa/nwis/uv?07134100). The highest elevations of the watershed are in the range of about 7000 feet, and the confluence with the Arkansas River is at about 3500 feet.

The major tributaries of Big Sandy Creek are Rush, Wild Horse, and Big Spring Creeks, the largest being Rush Creek. SAND encompasses about three miles of Big Sandy Creek along its lower reaches, several miles above the confluence with Rush Creek (Figure 1). Within the boundaries of SAND, there are no major tributaries. Several ephemeral drainages join the creek from the north, as does a small, unnamed perennial stream that is supported by spring discharge emanating in the uplands about one mile northeast of Big Sandy Creek.

The valley that Big Sandy Creek occupies has been carved out of Cretaceous bedrock formations, namely the Pierre Shale, the Niobrara formation, and the Carlile Shale. These predominantly marine deposits are very thick (upwards of 4000 feet) and are also relatively impermeable. Consequently, the bedrock formations underlying the valley-fill alluvium serve as confining layers, prohibiting downward movement of ground water and supporting water table conditions in the overlying Quaternary sediments. The unconsolidated sediments overlying the Cretaceous bedrock serve as the major water-bearing formations (aquifers) in the area, but for the most part these aquifers are isolated (Coffin and Horr, 1967). Some water may be present in thin limestone layers within the Cretaceous bedrock, but the actual occurrence of these water-bearing strata below SAND is unknown.

Water use in this area and in the watershed overall appears to be fairly limited based on inspection of aerial imagery. There are about ten center-pivot irrigation wells located roughly five miles to the west, but these wells are within the Rush Creek drainage and are most likely isolated from the Big Sandy Creek alluvial valley. Within the Big Sandy Creek watershed there are three obvious center pivot wells located six to seven miles upstream of the park boundary. The degree that withdrawals from these wells may affect the hydrology of the stream-aquifer system in SAND is unknown. There are a few other center pivot wells and water diversions evident in the upper portions of the watershed; however, it does not appear that overall water use in the catchment is extensive. The most notable agricultural diversion is the Ramah Reservoir, which is located in the upper watershed in El Paso County about seven miles upstream of Simla, Colorado. This 800 acre reservoir was constructed on the main channel of Big Sandy Creek, but it is generally dry and has only periodic influence on the creek's hydrology. The influence in the lower watershed near SAND is likely to be very small to negligible.

A recent publication from the State of Colorado indicates that ground water levels in the upper watershed do not follow a uniform trend. Overall, water levels in wells measured by the Division of Water Resources declined an average 0.64 feet between 2011 and 2012. Longer term (10-year) trends indicate that water levels have increased slightly (0.5 - 3.5 ft) around Limon and have remained fairly stable upstream of the Ramah Reservoir. Other reaches of the creek in the upper watershed between Ramah Reservoir and Limon have experienced groundwater declines ranging from 1-5 feet (Topper 2012). We were unable to locate any similar publications regarding water levels in the lower basin of Big Sandy Creek in the vicinity of SAND.

As the name implies, Big Sandy Creek, also known as Sand Creek, is an alluvial stream, meaning that its bed and banks are composed of sediment transported by the watercourse. The sediments associated with Big Sandy Creek are composed of various size particles ranging from clay to gravel, mostly deposited as alluvium but also with some eolian deposits, especially on the surface. The average thickness of the valley fill is about 23 to 30 feet with a range that varies from 0 to about 70

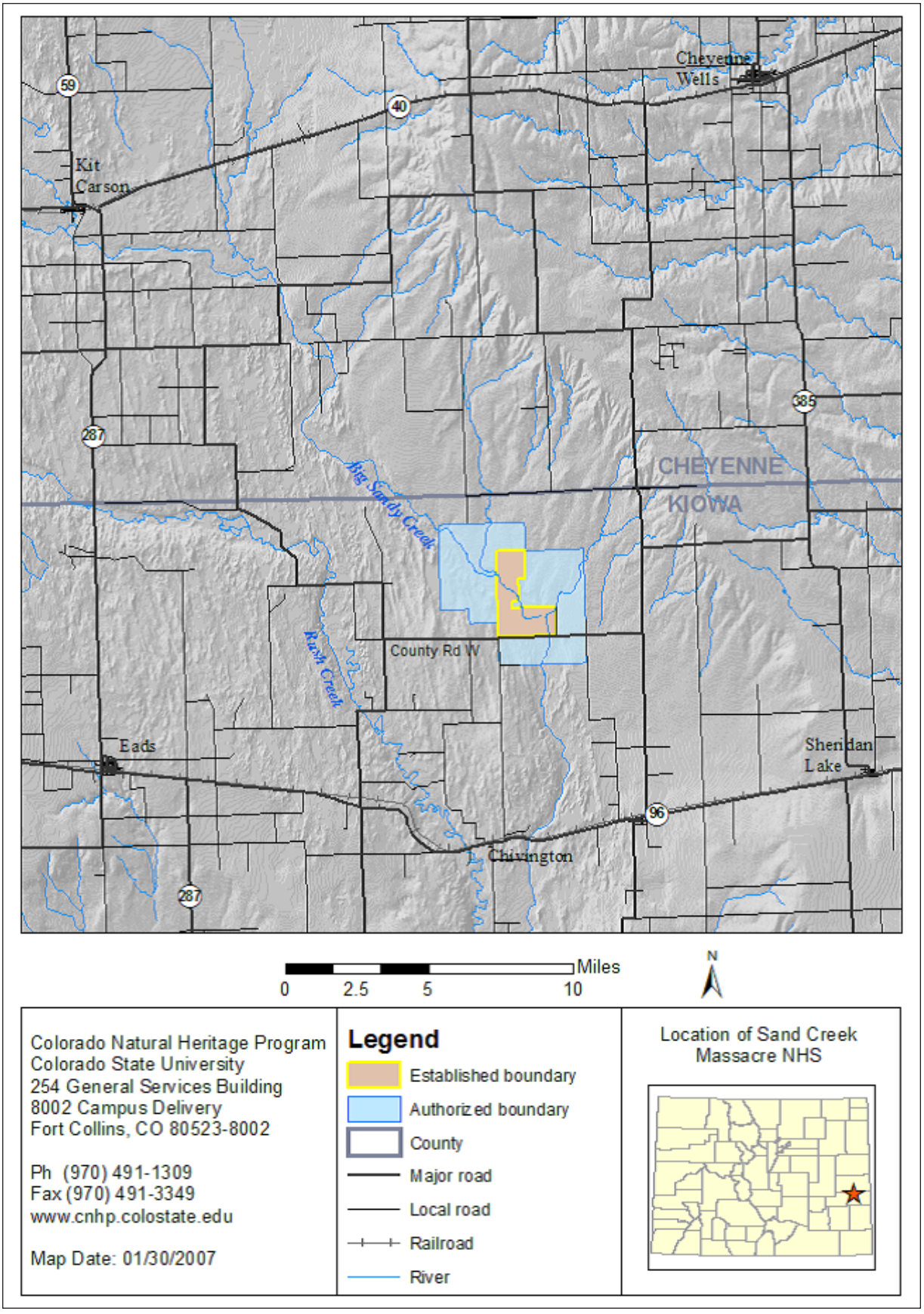

Figure 1 - Location of Sand Creek Massacre National Historic Site, Kiowa County, Colorado (reproduced from Neid et al. 2007)

feet. The areas of thickest deposition are generally in the approximate center of the valley.

Geomorphic History

The overall configuration of the creek is a slightly meandering alluvial channel within a broad alluvial valley. Competent flows, those capable of transporting sediment and re-working the channel, are infrequent. As a result of this infrequency of "channel forming flows," the Big Sandy Creek channel is poorly defined throughout most of the park. The geomorphic features that are generally associated with meandering streams, such as point bars, cutbanks, and overflow channels, are largely absent or poorly formed.

The present-day flood prone area, also called the "modern floodplain," lies very near the elevation of the active stream channel at places where a channel has formed. For the most part, it has a surface that is fairly smooth with some evidence of recent flow. The width of the modern floodplain varies from about 200 feet at its narrowest to less than 500 feet in the wider reaches. Throughout SAND the modern floodplain is bounded by fluvial terraces of older age sediments, thick eolian deposits, or bedrock at some locations. Very weak soil development on the floodplain surface implies a very young landform consistent with an active stream channel and floodplain system (Holmes and McFaul, 1999).

The next oldest fluvial landform has been referred to as the low terrace. This landform bounds the modern floodplain through most of the park, at least where it has not been removed by erosion. The surface of this terrace level is typically only about 1.5 feet above the modern floodplain level and is often difficult to distinguish. The surficial material is predominantly coarse-grained sand, but it may be covered with as much as 4 inches of medium-grained, well-sorted eolian sands. This mantle of wind-derived sediment is discontinuous, variable in thickness, and may obscure boundaries between older landforms. Although there are at least two higher and much older fluvial terrace levels within SAND (Holmes and Mcfaul 1999), this riparian assessment is only concerned with the modern floodplain and portions of the lowest fluvial terrace where it supports riparian vegetation.

Hydrology of Big Sandy Creek

The Big Sandy Creek watershed is located in a semi-arid portion of the country where annual evaporation greatly exceeds annual precipitation. Almost all of Big Sandy Creek flows only in response to substantial rainfall events; however, there are a few reaches that support perennial flow due to higher water table conditions. One such reach is near the downstream end of the creek within the park, where spring flow from the east helps to maintain a higher water table and perennial surface water. The rest of the creek at SAND is an ephemeral watercourse that only flows in response to precipitation.

About 30 miles downstream of the park at Lamar, Colorado, the USGS has operated a gage on a perennial reach of Big Sandy Creek for about 30 years (gage #07134100, Figure 2). The record starts in 1968 and continues to the present, with a number of missing years from 1983 - 1995. The range of annual peak flows recorded by this gage is typically about 100 - 500 cubic feet per second (cfs), with an occasional peak around 500 - 700 cfs. For comparison, regional flood frequency equations developed for Eastern Colorado suggest that an "average" watershed of this size should have an annual peak of about 1700 cfs (Ries and Crouse, 2002). Consequently, Big Sandy Creek appears to be much less active hydrologically than other streams in this region. Only twice in the 30-year record did peak flow at the gage exceed the modest discharge value of 700 cfs, once in 1976 and again in 1999. Both of these flow events were large, exceeding 2500 cfs.

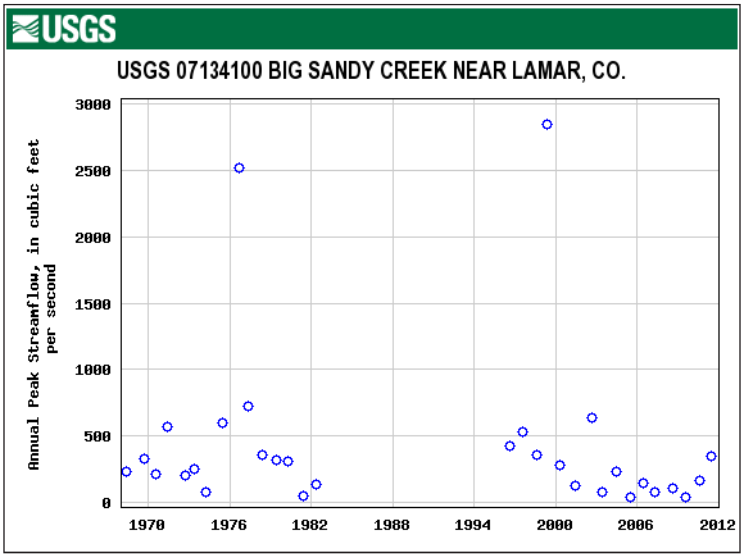

Figure 2 – Graphical representation of measured peak flows at the USGS gage located just upstream from the confluence with the Arkansas River near Lamar, CO.

Flood Frequency

The Colorado Water Conservation Board conducted a Log-Pearson III statistical analysis of the existing peak flow record for Big Sandy Creek (Lamar gage) to estimate flood recurrence intervals and associated magnitudes. The relatively short gage record of 23 years available at the time of the analysis produced an estimate for the 100-year flood of 2,577 cfs (Colorado Water Conservation Board, 1998). Other methods exist for estimating design flood discharges, however, even with the short record of 23 years, using drainage specific data is usually preferred over other indirect methods. Consequently, this value may serve as a reasonable estimate of the 100-year flood for this drainage. Interestingly, Big Sandy Creek has experienced two floods in the range of the 100-year recurrence interval since measurements began in 1968 (Figure 2). It is noteworthy that neither of these relatively extreme events, the most recent having occurred in 1999, resulted in any substantial erosion or channel re-working that is still evident today.

Riparian Vegetation

Neid et al. (2007) described the Big Sandy Creek riparian corridor at SAND as a mosaic of three vegetation associations: 1) plains cottonwood (*Populus deltoides*) woodland with a western wheatgrass (*Pascopyrum smithii*)/switchgrass (*Panicum virgatum*) understory; 2) alkali sacaton (*Sporobolus airoides*)/ inland saltgrass (*Distichlis spicata*) meadow on many lower terrace, modern floodplain and drier channel bank sites; and 3) bulrush (*Schoenoplectus pungens*) wet meadow in the wetter channel bottoms. Additional plant species observed within these associations are described in the Results and Discussion section below.

A proxy indicator that is very useful in assessing the recent history of the creek is the age class structure of the mature cottonwood stands present along the watercourse. In 2005, researchers from the Institute of Arctic and Alpine Research (U. of Colorado - Boulder) conducted detailed core samplings of cottonwoods along Big Sandy Creek within the park (Lukas and Woodhouse, 2006). They identified three distinct age classes: the oldest had an estimated germination date range of 1865-1885 and the two other age classes were 1908-1925 and 1949-1960. There has been little to no cottonwood establishment at SAND since 1960.

Also of interest to this assessment is the spatial distribution of these age classes. Almost all of the cottonwoods present in the drainage are within 300 feet of the active channel and the vast majority are within 100 feet. The most recent age class, 1949-1960, was predominantly associated with the active channel. The two older classes are mostly located farther from the channel but still along the same general alignment. This arrangement strongly suggests that the active channel of Big Sandy Creek may have undergone some degree of migration since 1865, but the present general alignment has been basically the same for at least the last 150 years or so. Lastly, the authors concluded that the establishment dates of the three age classes coincided well with probable extreme flood events based on review of historical meteorological and hydrologic data.

The positions of the three cottonwood age classes on the landscape at SAND are consistent with geomorphic and vegetative processes described by Friedman and Lee (2002) for ephemeral, sand-bed streams on the Eastern Colorado Plains. They found that cottonwoods establish along these channels after extreme floods that occur only once in a few decades, on average. During these extreme flood events, flows can be large enough and carry enough sediment that the channel widens substantially. As the flood flows recede, a relatively wide swathe of freshly deposited/reworked sediment is created, providing a bare, moist mineral substrate to support cottonwood seedling germination and establishment. With the return of lower flows in subsequent years, growth of riparian vegetation causes the channel to narrow again to a form such as that seen at SAND today. As this process is repeated over time, a relatively wide riparian forest composed of even-aged stands of trees originating from different extreme flow events can become established.

Functional Condition of Riparian Systems

The purpose of our assessment was to determine the functional condition of the Big Sandy Creek channel and its associated riparian corridor within SAND. 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). When applying this method, a stream may be evaluated as a single assessment reach if vegetation, hydrology, channel form or other defining characteristics are considered to be fairly uniform along its length. However, it may be appropriate to divide the stream into sub-reaches for separate assessments based on changes in these characteristics.

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 Appendixes). Based on this evaluation, the team assigns one of three ratings to a 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

After careful inspection of Big Sandy Creek throughout the site, we decided to separate it into five assessment reaches based primarily on degree of channelization, presence and structure of cottonwood stands, and perennial vs. ephemeral flow. Many of the assessment results were common across all five reaches. Rather than repeat these results, we summarize the commonalities here and highlight the differences in the following sections for the individual reaches.

In most largely unregulated watersheds, overbank flows occur about every two years or so. But for Big Sandy Creek at SAND, the natural frequency of such events is much less, more on the order of every five to ten years. When larger flow events occur, they likely inundate most of the modern floodplain up to and sometimes including the adjacent low terrace (see cover photo). We evaluated the fluvial system within the hydrologic context and capability of the Big Sandy Creek drainage and concluded that overbank flows occur on a "relatively frequent" basis in all reaches ("yes" responses for PFC Checklist Item #1).

For all five stream reaches, the geomorphic parameters evaluated in this assessment (channel sinuosity, slope and width-to-depth ratio) met or were close to the thresholds of stability provided in the PFC guidance. The guidance suggests that a stable stream in a wide alluvial valley should have a sinuosity greater than 1.2, a channel gradient less than two percent, and a width-to-depth ratio greater than 12 (U.S. Department of the Interior 1998). The variability of channel morphology, or more specifically the weak channel formation in some reaches and the lack of a defined channel through most of the site, made precise and consistent estimates of these quantitative parameters difficult. Channel sinuosity, estimated from LIDAR at about 1.15, was slightly below the suggested threshold of stability (sinuosity >1.2). The general lack of a defined channel through most of the stream course resulted in the low value. However the channel and floodplain morphology do not suggest instability from lack of sinuosity under this flow regime.

The overall slope of both the channel and the floodplain is about 0.2 percent, well below the suggested stability threshold of <2.0 percent. It is probably the combination of this very gentle slope and the prevailing flow regime that leads to overall geomorphic stability. There are likely short reaches of the creek that have a greater slope, possibly where some channel formation is occurring. But the gradient of the system overall is mild and not likely to support erosive flows, except under extreme flood conditions.

Width-to-depth ratio was probably the most variable geomorphic parameter, mostly due to the presence of an "inner channel" in some segments of the stream. Where an inner channel had formed or was forming, the depths were generally less than 1.0 -1.5 feet but sometimes were between 3 - 4 feet. Top width distances were usually less than about 10 or 12 feet. Therefore, the width-to-depth ratios of the inner channels were below the stable threshold value of >12. This suggests that some degree of channel evolution may be occurring, at least in these short reaches. Most of the stream course through SAND, however, is a vegetated swale that occupies the modern floodplain rather than a distinct channel. Through these reaches, width-to-depth ratios measured from LIDAR are more in the range of 20 - 30, well above the threshold of stability. Consequently, we responded "yes" to PFC Checklist Item #3 for all assessment reaches. Additionally, we concluded that the riparian corridor is approaching or has reached its potential width through all of the reaches (Checklist Item #4).

Nowhere within the study area did we observe any large, recent deposits of sediment to suggest extensive upstream erosion. Nor did we observe any areas of significant erosion within or adjacent to the channel. At one location in Reach 1, we observed an apparent channel scour hole roughly 10 yards long and a recently deposited sand bar immediately downstream, but this was not characteristic. Consequently, we concluded that the channel and floodplain are able to pass the water and sediment being delivered by the watershed under most flow conditions without excessive erosion or deposition. Stated another way, the watershed is not contributing to riparian area degradation in any of our assessment reaches, and we answered "yes" for all Checklist Item #5's.

An integral part of the PFC analysis is evaluation of the riparian vegetation present along the channel and floodplain (PFC Checklist Items 6 through 12). On the active floodplain and lowest terrace the only woody species of any significance within SAND is

plains cottonwood (*Populus deltoides*). Practically all of the individual cottonwood trees fall into one of two age classes: 1949-1960 or 1908-1925 (Lukas and Woodhouse, 2006). Additionally, there is a scattering of individuals from the 1865-1885 age class, mostly on the margins of the modern floodplain, but within about 100 yards of the channel and usually less than three feet higher in elevation. The potential at SAND for coyote willow (*Salix exigua*), a common woody riparian species on many eastern Colorado streams, is unknown (none observed at the time of our assessment).

Figure 3 – Orthophoto of Reach 1. Yellow dots mark the upstream (upper left) and downstream (lower right) boundaries of the reach. Note the extensive stand of cottonwood trees and the evidence of some channel development.

Throughout the site, the dominant herbaceous plant species on the floodplain, streambanks and channel bottoms include native species such as Chairmaker's bulrush, (*Schoenoplectus americanus* [1]), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*), alkali sacaton (*Sporobolus airoides*) and inland saltgrass (*Distichlis spicata*). The species distribution is largely related to water table depth. In the deeper channels (closer to the water table), bulrush is often dominant, with switchgrass found at slightly higher elevations. At these sites, western wheatgrass and saltgrass are typically dominant on the upper streambanks and floodplain. In areas where the channel is very shallow and vegetation is less influenced by the underlying water table, western wheatgrass and saltgrass may also cover the channel bottoms.

The riparian-wetland vegetation along all assessment reaches is indicative of sub-irrigated riparian soil (Checklist Item #8), and the rhizomatous species on the streambanks have root masses capable of withstanding frequent to moderately large flood flows, thus providing excellent bank stabilization (Checklist Item #9). The riparian-wetland vegetation along the corridor exhibits high vigor (PFC Checklist Item #10), with a couple of exceptions noted in following sections. The herbaceous species described above provide 90-100% cover on nearly all floodplain and streambank locations (Checklist Item #11). All of these native species support important riparian functions such as dissipation of flood energy, capture of sediment and habitat diversity. Therefore, we consider the vegetative elements of the assessment to be contributing to channel and floodplain stability and a Proper Functioning Condition rating throughout the riparian corridor.

Big Sandy Creek, Reach 1

Rating: Proper Functioning Condition

Reach 1 of Big Sandy Creek extends from the western boundary of SAND approximately 5000 feet southeastward to the end of a large cottonwood stand (Figure 3). There is some degree of channel formation in

1 Neid et al. 2007 referred to this species as *Schoenoplectus pungens*, which is very closely-related and morphologically similar to *S. americanus*. The two species also are known to hybridize. The park plant species list includes only *S. americanus*.

this reach and it is "on grade," with no evidence of vertical or lateral instability.

The PFC Checklist results for Reach 1 and the comments supporting our responses to the 17 riparian assessment elements are found in Appendix 1. The Checklist shows that almost all applicable items received "yes" responses, which is usually indicative of a properly functioning stream reach. The only "no" response was item #6, which asks if there is an adequately diverse age-class distribution of riparian vegetation for maintaining a healthy system into the future. We answered "no" because there has been no cottonwood recruitment here since the 1950's, and therefore no young trees exist to replace the older trees that will eventually die. But, given the nature of this site (cottonwood establishment events are on the order of several to many decades), this was not a reason to rate the site as anything lower than "Proper Functioning Condition."

Figure 4 – Orthophoto of Reach 2. Note the relatively sparse cottonwood stands and the trace of the Chivington Canal in the right center of the image.

Checklist Item #7 asks if there is a diverse composition of riparian-wetland vegetation on this stream reach. With the exception of one willow tree (likely peach-leaf willow, *Salix amygdaloides*), plains cottonwood is the only woody riparian species in this reach. Although coyote willow is known to exist several miles upstream, there are no records for this species in the park. Despite the lack of woody species diversity, the team felt that the diverse, native herbaceous plant community in the channel and on the banks/floodplains is likely to maintain channel stability during all but extreme floods. For this reason we answered "yes" for item #7.

Two highly invasive, non-native species, prickly Russian thistle (*Salsola tragus*) and burning bush (*Kochia scoparia*), were observed in the channel in this reach, but neither is dominant except in small patches. These annual weeds do not have the soil-binding characteristics of the native herbaceous species discussed above, and they are difficult to eradicate once well-established. We encourage park staff to continue to control these species in the riparian zone before they spread further and displace beneficial native species.

Big Sandy Creek, Reach 2

Rating: Proper Functioning Condition

Reach 2 begins at the downstream end of the riparian forest in Reach 1 and continues downstream for about 2100 feet (Figure 4). We considered this reach distinct from adjacent stream segments due to a somewhat greater degree of channel development and relatively few cottonwood trees. The channelization is not great, with only about 2-3 feet of depth relative to more common channel depths of less than 1.5 feet in other reaches. This reach also includes the site of the former diversion dam and the intake to the Chivington Canal. It is unclear whether these channel alterations caused the slight channel incision seen in parts of this reach, but even if so, the geomorphic effects are not great. There are also several small excavated ponds along the reach

that are part of the cultural landscape at SAND. We did not consider these ponds to be a threat to the stability or detrimental to the functional condition of this reach.

The slight channel incision may have been enough to inhibit cottonwood recruitment on much of this reach. As with the other reaches there is no recruitment age class (no seedlings, saplings, or young trees), and the only substantial cottonwood stands present (1949-1960 age class) are in the downstream one-third of this reach. This could be related to the channelization and associated water table effects, but past grazing practices or other factors may also have prevented establishment. Interestingly, the cottonwoods that are present in this reach appear to be healthy and do not show stress commonly associated with water table drawdowns. Installation and monitoring of observation wells in this reach would help us understand relationships between water table depth and cottonwood establishment and maintenance.

Figure 5 – Orthophoto of Reach 3. Note the presence of cottonwoods both as thick stands and individuals. The reaches immediately upstream and downstream have much less woody vegetation.

Within the slightly incised channel, sinuosity associated with channel meandering is establishing with formation of point bars and cutbanks, indicating vertical stability. Additionally, the formation of these fluvial features results in a widening riparian-wetland zone at this lower elevation. In spite of the slightly greater degree of channelization along this reach, there is substantial evidence of flood debris on the adjacent floodplain, indicating that flood flows are still able to spread onto the overbank areas.

The PFC Checklist results for Reach 2 and our supporting remarks are found in Appendix 2. As with Reach 1, the assessment team rated Item #6 as a "no" due to the lack of a recruitment age class of cottonwoods. Cottonwood was again the only woody riparian species, and stands in this reach were relatively sparse. A diverse, vigorous, soil-binding herbaceous plant community in the channel and on the streambanks and floodplain is likely to maintain channel stability in frequent to moderately large floods. The small ponds in the reach provide additional energy dissipation during flood flows. Therefore, the team did not feel that the "no" response to Checklist Item #6 or the lack of woody species diversity noted for item #7 is a threat to the stability of the riparian system in frequent to moderately large floods.

Big Sandy Creek, Reach 3

Rating: Proper Functioning Condition

Reach 3 was distinct from adjacent reaches because of a greater density and age distribution of cottonwoods (all three age classes identified by Lukas and Woodhouse (2006) are represented) and a variable degree of channel formation. This reach includes about 5100 feet of channel/floodplain from the downstream end of Reach 2 to where the cottonwood forest essentially ends (Figure 5).

The PFC Checklist results for Reach 3 and our supporting remarks are found in Appendix 3. As with Reaches 1 and 2, the lack of a recruitment age class for cottonwoods was the basis for a "no" response for Checklist Item #6 (our only "no" response for this reach). However, also as with Reaches 1 and 2, a diverse, native herbaceous riparian plant community in the channel and on the banks and floodplain provides superior soil stabilization. This is likely to maintain channel stability in frequent to moderately large floods. Buffalograss (*Buchloe dactyloides*) covers 70-100% of the channel bottom in a few small areas. This species does not have deep or massive roots capable of withstanding flood flows, but it is only a small component of the cover in this reach and it is not considered a threat to overall channel stability.

Figure 6 – Orthophoto of Reach 4.

Cottonwoods at the upstream and downstream ends of this reach appear to show more dead branches than in other riparian areas, likely indicating water stress (drought or flood) at some time. However, herbaceous communities maintain strong vigor, and upland species are not invading the riparian zone. Installation and monitoring of observation wells in these areas would allow the NPS to determine relationships between water table fluctuations and establishment and health of cottonwood trees.

Big Sandy Creek, Reach 4

Rating: Proper Functioning Condition

Reach 4 of Big Sandy Creek differed from adjacent reaches due to the almost complete absence of cottonwoods and a general lack of distinct channel development (Figure 6). The PFC Checklist results for this reach and our supporting remarks are found in Appendix 4. The channel in this reach is mostly "on grade" and is more of a wide, variable elevation, vegetated swale than a distinct channel/floodplain configuration. The floodplain is generally less than 1.5 feet above the top of the swale banks, and relatively recent flood debris above the banks indicates that the floodplain is inundated at its potential frequency (see cover photo).

Other than the few mature trees at the upstream end of the reach, cottonwoods are absent, and there is no recruitment age class. This led us to a "no" response for Checklist Item #6 (our only "no" response on the Checklist). There are no other woody riparian species present. As with previous reaches, the herbaceous plant communities of the channel bottom, banks and floodplain are dominated by Chairmaker's bulrush, switchgrass, Western wheatgrass and inland saltgrass, depending on the depth to the water table at a particular location. Overall the channel is somewhat wetter and herbaceous wetland-riparian vegetation is somewhat more diverse than in upstream reaches. Clustered field sedge (*Carex praegracilis*) and showy milkweed (*Asclepias speciosa*) are present or co-dominant in some seasonally wet elevation zones. Herbaceous communities are vigorous and are not being invaded by upland species. All of these species (with the exception

of showy milkweed) have root masses that bind the soil and would be expected to maintain channel stability in frequent to moderately large floods. Showy milkweed provides important habitat for Monarch butterflies, as they only lay their eggs on, and their larvae feed on, milkweed plants.

Big Sandy Creek, Reach 5

Rating: Proper Functioning Condition

Reach 5 of Big Sandy Creek (Figure 7) is distinct from the adjacent upstream reach due to the presence of perennial surface water and the associated diverse plant community. The PFC Checklist results for this reach and our supporting comments are found in Appendix 5. The channel in this reach is "on grade," with the floodplain about 1.5 – 3 feet above the top of the channel banks. Relatively recent flood debris above the banks indicates that the floodplain is inundated at its potential frequency. There is one grove of cottonwoods in the upper part of this reach, but otherwise this species is absent, with no recruitment age class. This led us to a "no" response for Checklist Item #6 (our only "no" response on the Checklist). The cottonwoods have substantial decadent branches indicating water stress, possibly due to a sustained high water table.

Figure 7 – Orthophoto of Reach 5. Note the general lack of woody riparian vegetation.

The dense herbaceous wetland-riparian cover on the channel bottom, streambanks and floodplain are again dominated by Chairmaker's bulrush, switchgrass, Western wheatgrass and inland saltgrass, depending on the depth to the water table at a particular location. Clustered field sedge, showy milkweed and cattail (*Typha* sp.) are present or co-dominant in some seasonally or perennially wet elevation zones. Scattered cosmopolitan bulrush (*Schoenoplectus maritimus*) patches are found in wetter zones of this reach, but it is never a dominant species. These communities exhibit high vigor and are not being invaded by upland species. All of these species (with the exception of showy milkweed) have root masses that bind the soil and would be expected to maintain channel stability in frequent to moderately large floods. One Russian olive shrub (*Elaeagnus angustifolia*) exists on a pond edge in the upper part of the reach. We recommend removal of this highly invasive non-native plant as soon as possible.

Summary and Conclusions

Despite the absence of a replacement age class for cottonwoods, we determined that all reaches of Big Sandy Creek at SAND are in Proper Functioning Condition as defined by the PFC method. Significant recruitment of cottonwoods would likely occur after the next extreme flood event. Until then, a combination of healthy channel/floodplain morphology and abundant cover by native, herbaceous, soil-binding wetland-riparian species creates channel/floodplain stability that should be able to withstand moderately large flood flows without significant loss of beneficial riparian characteristics and functions.

Although the non-native shrub tamarisk (*Tamarix ramosissima*) is common in the region's riparian areas and is known to occur just outside the park, we did not observe any tamarisk seedlings or mature plants within the boundaries of SAND. The park staff is commended for the successful eradication, monitoring and control of this highly invasive species. We support continued control of tamarisk as well as eradication and control of other highly invasive, non-native plant species observed during our assessment, including *Salsola tragus*, *Kochia scoparia*, and *Elaeagnus angustifolia*.

Because of the significance of the cottonwood stands along Big Sandy Creek to the cultural and natural resource values of the park, we support establishing shallow ground water monitoring wells along the riparian corridor. These should be equipped with continuous water level recorders to provide a complete record and to greatly reduce the need for park staff to monitor the wells by hand. The main purpose is to collect water table data that can serve as a baseline for evaluating future conditions that may be affected by external development, ground water withdrawals, drought or other perturbations. The data would also be useful in understanding relationships between riparian water table conditions and the establishment and health of cottonwood trees and other riparian vegetation.

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Appendix 1: Proper Functioning Condition checklist and supporting remarks for Reach #1, Big Sandy Creek

PFC Lotic (Riparian) Standard Checklist

Name of Riparian Area: Sand Creek Massacre NHS – Big Sandy Creek

Date: 5/8/2012 Segment/Reach ID: Reach #1 - UTM X 715266.78379032, Y 4272266.6845377 to UTM X 716283.29070106, Y 4271266.5598006

River Miles: 0.95 miles Acres:_____

ID Team Observers: Joel Wagner, Mike Martin, Kevin Noon, and Tomye Folts-Zettner

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
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. Natural potential of this semi-arid, ephemeral system is bankfull flow approx. every 5-10 years. Channel is "on-grade," with floodplain no more than 2-3 feet above top of channel bank. Relatively recent flood debris above banks and observations by park staff indicate stream is flowing and flooding lower terraces at its potential frequency.

3. Metrics taken from a DEM model derived from LIDAR: channel sinuosity of about 1.15, width-to-depth ratios in the range of 20 - 30, and overall channel gradient of about 0.2 percent indicate a balance between the Big Sandy Creek channel form and the landscape setting.

4. Plains cottonwoods (*Populus deltoides*) occupy low terraces in most of this reach. No evidence of vertical instability. Riparian zone is near or at potential extent.

5. No evidence of excessive sediment inputs or adverse changes to channel form. Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which could have adverse effects on existing cottonwoods or future recruitment, and could alter herbaceous species composition.

6. For plains cottonwood, recruitment age class is absent. Tree ring analyses at SAND (Lukas and Woodhouse, 2006) indicate establishment at approx. 40-50 year intervals after very large flood events. Presently 3 age classes dating back to 1865, but no recruitment since 1950s so may be somewhat "overdue." Last large flood (1999) could potentially have supported recruitment, but past grazing practices (Dawson Ranch era) or other factors may have prevented establishment. Potential for coyote willow (*S. exigua*) is unknown (none present at this time). Coyote willow exists several miles upstream according to park staff, but no records for SAND. One tree-sized willow, likely peach-leaf willow (*S. amygdaloides*), observed in this reach.

7. With the exception of one willow tree, plains cottonwood is the only woody species. Potential for coyote willow at SAND is unknown. A diverse, vigorous, soil-binding herbaceous plant community in the channel and on the banks/floodplains is likely to maintain channel stability in frequent to moderately frequent floods.

9. Chairmaker's bulrush (*Schoenoplectus americanus*), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*) and inland saltgrass (*Distichlis spicata*) are dominant on channel bottoms, banks or low terraces, depending on depth to water table. All are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment on this creek.

11. >90% cover on >90% of banks in this reach.

13. Channel/floodplain morphology, 90-100% cover with rhizomatous wetland-riparian species and dense cottonwood provide for flood energy dissipation. No evidence of channel instability.

15. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels) are largely absent or poorly formed throughout the reach due to rarity of channel forming flows. However, lateral migration associated with natural sinuosity of the active channel has obviously taken place over the modern floodplain, which is about 200 to <500 feet wide and is bounded by fluvial terraces and other geomorphic features.

Functional Rating		Trend for Functional – At Risk:	
Proper Functioning Condition	X	Upward	
Functional – At Risk		Downward	
Nonfunctional		Not Apparent	

Notes: *Kochia scoparia* observed on channel banks and bottom in some areas and *Salsola tragus* (prickly Russian thistle) observed on some upper bank and terrace locations (both are invasive non-natives). Neither was considered a dominant species. *Eleocharis* sp. present in one pond location. *Asclepias subverticillata* and *Carex praegracilis* observed occasionally in wetter channel areas, but neither is considered a dominant species.

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

Yes _____ No X

Appendix 2: Proper Functioning Condition checklist and supporting remarks for Reach #2, Big Sandy Creek

PFC Lotic (Riparian) Standard Checklist

Name of Riparian Area: Sand Creek Massacre NHS – Big Sandy Creek

Date: 5/8/2012 Segment/Reach ID: Reach #2 - UTM X 716283.29070106, Y 4271266.5598006 to UTM X 716589.44248464, Y 4270634.4377323

River Miles: 0.4 miles Acres:_____

ID Team Observers: Joel Wagner, Mike Martin, Kevin Noon, and Tomye Folts-Zettner

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
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 somewhat more incised than in other reaches. Observed relatively recent flood wrack above channel banks, so floodplain is still inundated in relatively frequent events, though somewhat less so than in other reaches.

3. Metrics taken from a DEM model derived from LIDAR: channel sinuosity of about 1.15, width-to-depth ratios in the range of 20 - 30, and overall channel gradient at about 0.2 percent indicate a balance between the Big Sandy Creek channel form and the landscape setting.

4. Sinuosity is reestablishing in a slightly incised channel, resulting in a widening riparian-wetland zone at this lower elevation.

5. No evidence of excessive sediment inputs or adverse changes to channel form. Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which could have adverse effects on existing cottonwoods or future recruitment, and could alter herbaceous species composition.

6. For plains cottonwood, recruitment age class is absent and 1950's era trees are found only in the downstream one-third of this reach. Last large flood (1999) could potentially have supported new recruitment, but past grazing practices (Dawson Ranch era) or other factors may have prevented establishment. Potential for coyote willow (*S. exigua*) is unknown (none observed at this time).

7. Plains cottonwood is the only woody species, and it is sparse compared to riparian zones immediately upstream and downstream. Potential for coyote willow at SAND is unknown. A diverse, vigorous, soil-binding herbaceous community in the channel and on the banks/floodplains is likely to maintain channel stability in frequent to moderately frequent floods.

8. Cottonwoods appear to be healthy and do not show stress commonly associated with water table drawdowns.

9. Chairmaker's bulrush (*Schoenoplectus americanus*), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*), and inland saltgrass (*Distichlis spicata*) are dominant on channel bottoms, banks or low terraces, depending on depth to water table. All are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment on this creek.

11. >90% cover of native, bank-stabilizing herbaceous species on >90% of banks.

13. Channel/floodplain morphology, cottonwoods (though relatively sparse compared to Reaches 1 and 3), and 90-100% cover with rhizomatous, herbaceous wetland-riparian species all contribute strongly to flood energy dissipation. No evidence of channel instability. Excavated ponds in this reach provide additional energy dissipation.

15. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels) are largely absent or poorly formed throughout the reach due to rarity of channel forming flows. However, lateral migration associated with natural sinuosity of the active channel has obviously taken place over the modern floodplain, which is about 200 to <500 feet wide and is bounded by fluvial terraces and other geomorphic features.

Functional Rating

Proper Functioning Condition	X
Functional – At Risk	
Nonfunctional	

Trend for Functional – At Risk:

Upward	
Downward	
Not Apparent	

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

Yes _____ No X

Appendix 3: Proper Functioning Condition checklist and supporting remarks for Reach #3, Big Sandy Creek

PFC Lotic (Riparian) Standard Checklist

Name of Riparian Area: Sand Creek Massacre NHS – Big Sandy Creek

Date: 5/9/2012 Segment/Reach ID: Reach #3 - UTM X 716589.44248464, Y 4270634.4377323 to UTM X 717532.88964921, Y 4269915.9246457

River Miles: 1.0 miles Acres:_____

ID Team Observers: Joel Wagner, Mike Martin, Kevin Noon, and Tomye Folts-Zettner

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
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. Natural potential of this semi-arid, ephemeral system is bankfull flow approx. every 5-10 years. Channel is "on-grade," with floodplain no more than 2-3 feet above top of channel bank. Relatively recent flood debris above banks and observations by park staff indicate stream is flowing and flooding lower terraces at its potential frequency.

3. Metrics taken from a DEM model derived from LIDAR: channel sinuosity of about 1.15, width-to-depth ratios in the range of 20 - 30, and overall channel gradient of about 0.2 percent indicate a balance between the channel form and the landscape setting.

4. Plains cottonwoods (*Populus deltoides*) occupy low terraces in most of this reach. No evidence of vertical instability. Riparian zone is near or at potential extent.

5. No evidence of excessive sediment inputs or adverse changes to channel form. Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which could have adverse effects on existing cottonwoods or future recruitment, and could alter herbaceous species composition.

6. For plains cottonwood, 3 age classes are present (oldest established 1865-1885). However, recruitment age class is absent and may be somewhat "overdue" based on average establishment interval of 40-50 years. Last large flood (1999) could potentially have supported recruitment, but past grazing practices (Dawson Ranch era) or other factors may have prevented establishment. Potential for coyote willow (*S. exigua*) is unknown (none present at this time).

7. Plains cottonwood is the only woody species. Potential for coyote willow at SAND is unknown. A diverse, vigorous, soil-binding herbaceous plant community in the channel and on the banks/floodplains is likely to maintain channel stability in frequent to moderately frequent floods.

8. See note 10. below.

9. Chairmaker's bulrush (*Schoenoplectus americanus*), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*) and inland saltgrass (*Distichlis spicata*) are dominant on channel bottoms, banks or low terraces, depending on depth to water table (channel only occasionally deep enough to support bulrush). All are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment on this creek.

10. Cottonwoods at the upstream and downstream ends of this reach appear to show more dead branches than in other riparian areas, indicating possible water stress (drought or flood) at some time. However, herbaceous communities maintain strong vigor, and upland species are not invading riparian zones.

11. >90% cover of native, bank-stabilizing herbaceous species on >90% of banks.

13. Channel/floodplain morphology, 90-100% cover with rhizomatous wetland-riparian species and dense cottonwood provide good flood energy dissipation. No evidence of channel instability.

15. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels) are largely absent or poorly formed throughout the reach due to rarity of channel forming flows. However, lateral migration associated with natural sinuosity of the active channel has obviously taken place over the modern floodplain, which is about 200 to <500 feet wide and is bounded by fluvial terraces and other geomorphic features.

Functional Rating		Trend for Functional – At Risk:	
Proper Functioning Condition	X	Upward	
Functional – At Risk		Downward	
Nonfunctional		Not Apparent	

Notes: Buffalograss (*Buchloe dactyloides*) covers 70-100% of the channel bottom in a few small areas. This species does not have deep/massive roots capable of withstanding flood flows, but is only a small component of the overall cover and is not a threat to channel stability.

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

Yes _____ No X

Appendix 4: Proper Functioning Condition checklist and supporting remarks for Reach #4, Big Sandy Creek

PFC Lotic (Riparian) Standard Checklist

Name of Riparian Area: Sand Creek Massacre NHS – Big Sandy Creek

Date: 5/9/2012 Segment/Reach ID: Reach #4 - UTM X 717532.88964921, Y 4269915.9246457 to UTM X 717942.62147598, Y 4269860.9755211

River Miles: 0.27 miles Acres:_____

ID Team Observers: Joel Wagner, Mike Martin, Kevin Noon, and Tomye Folts-Zettner

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
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. Natural potential of this riparian system is bankfull flow approx. every 5-10 years. Channel is "on-grade," but is sometimes indistinct and more of a wide, variable elevation swale. Floodplain is no more than 2-3 feet above top of channel bank. Relatively recent flood debris above banks and observations by park staff indicate stream is flowing and flooding lower terraces at its potential frequency.

3. Metrics taken from a DEM model derived from LIDAR: channel sinuosity about 1.15, width-to-depth ratios in the range of 20 - 30, and overall channel gradient of about 0.2 percent indicate a balance between the channel form and the landscape setting.

4. Channel sometimes a wide, variable elevation swale rather than a distinct channel and floodplain form. No evidence of vertical instability. Riparian zone is near or at potential extent.

5. No evidence of excessive sediment inputs or adverse changes to channel form. Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which could have adverse effects on cottonwoods and alter herbaceous species composition.

6. Other than the few mature trees at the upstream end of the reach, cottonwoods are absent, and there is no recruitment age class. Last large flood (1999) could potentially have supported cottonwood recruitment, but past grazing practices or other factors may have prevented establishment. Potential for coyote willow (*S. exigua*) is unknown (none observed at this time).

7. Plains cottonwood mostly absent in this reach. Potential for coyote willow is unknown (none exist at this time). Herbaceous plant community in channel and on banks/floodplain is likely to maintain channel stability in frequent to moderately frequent floods. Channel is somewhat wetter and herbaceous wetland-riparian vegetation is somewhat more diverse than in upstream reaches. Clustered field sedge (*Carex praegracilis*) and showy milkweed (*Asclepias speciosa*) are common or co-dominant in some seasonally wet elevation zones.

8. Few cottonwoods, but herbaceous riparian-wetland community is vigorous in the channel and on the floodplain, with no invasion by upland species.

9. Chairmaker's bulrush (*Schoenoplectus americanus*), clustered field sedge, switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*) and inland saltgrass (*Distichlis spicata*) are dominant on channel bottoms, banks or low terraces, depending on depth to water table. All are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment on this creek.

10. Herbaceous communities maintain strong vigor; upland species are not invading riparian zone.

11. >90% cover of native, bank-stabilizing herbaceous species on >90% of banks.

13. Channel/floodplain morphology and 90-100% cover with rhizomatous wetland-riparian species provide good flood energy dissipation. No evidence of channel instability.

15. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels) are largely absent or poorly formed throughout the reach due to rarity of channel forming flows. However, lateral migration associated with natural sinuosity of the active channel has obviously taken place over the modern floodplain, which is about 200 to <500 feet wide and is bounded by fluvial terraces and other geomorphic features.

Functional Rating

Proper Functioning Condition	X
Functional – At Risk	
Nonfunctional	

Trend for Functional – At Risk:

Upward	
Downward	
Not Apparent	

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

Yes _____ No X

Appendix 5: Proper Functioning Condition checklist and supporting remarks for Reach #5, Big Sandy Creek

PFC Lotic (Riparian) Standard Checklist

Name of Riparian Area: Sand Creek Massacre NHS – Big Sandy Creek

Date: 5/9/2012 Segment/Reach ID: Reach #5 - UTM X 717942.62147598, Y 4269860.9755211 to UTM X 718182.97941295, Y 4268864.955147

River Miles: 0.65 miles Acres:_____

ID Team Observers: Joel Wagner, Mike Martin, Kevin Noon, and Tomye Folts-Zettner

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
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. Natural potential of this riparian system is bankfull flow approx. every 5-10 years. Channel is "on-grade" (floodplain no more than 2-3 feet above top of channel bank). Relatively recent flood debris above banks and observations by park staff indicate stream is flowing and flooding lower terraces at its potential frequency.

3. Metrics taken from a DEM model derived from LIDAR: channel sinuosity of about 1.15, width to depth ratios in the range of 20 - 30, and overall channel gradient about 0.2 percent indicate a balance between the channel form and the landscape setting.

4. No evidence of vertical instability. Riparian zone is near or at potential extent.

5. No evidence of excessive sediment inputs or adverse changes to channel form. Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table.

6. One grove of plains cottonwoods in the upper part of this reach, but otherwise absent, with no recruitment age class. Last large flood (1999) could potentially have supported cottonwood recruitment, but past grazing practices or other factors may have prevented establishment. Potential for coyote willow (*S. exigua*) is unknown (none observed at this time).

7. Plains cottonwood mostly absent. Potential for coyote willow is unknown (none observed at this time). Herbaceous plant community in channel and on banks/floodplain is likely to maintain channel stability in frequent to moderately frequent floods. Channel is wettest in this reach and herbaceous wetland-riparian vegetation is somewhat more diverse than in upstream reaches. Clustered field sedge (*Carex praegracilis*) and showy milkweed (*Asclepias speciosa*) common in some seasonally wet elevation zones and cattail (*Typha* sp.) dominates some pond shallows.

8. Few cottonwoods, but herbaceous riparian-wetland community is vigorous in the channel and on the floodplain, with no invasion by upland species.

9. Chairmaker's bulrush (*Schoenoplectus americanus*), clustered field sedge, switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*) and inland saltgrass (*Distichlis spicata*) are dominant on channel bottoms, banks or low terraces, depending on depth to water table. All are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment on this creek.

10. Cottonwoods have substantial decadent branches indicating water stress, possibly due to sustained high water table. Answered "yes" overall because wetland-riparian herbaceous communities exhibit high vigor and appear to be capable of maintaining channel stability in frequent to moderately frequent floods. Upland species are not invading riparian zone.

11. >90% cover of native, bank-stabilizing herbaceous species on >90% of banks.

13. Channel/floodplain morphology and 90-100% cover with rhizomatous wetland-riparian species provide good flood energy dissipation. No evidence of channel instability.

15. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels) are largely absent or poorly formed throughout the reach due to rarity of channel forming flows. However, lateral migration associated with natural sinuosity of the active channel has obviously taken place over the modern floodplain, which is about 200 to <500 feet wide and is bounded by fluvial terraces and other geomorphic features.

Functional Rating		Trend for Functional – At Risk:	
Proper Functioning Condition	X	Upward	
Functional – At Risk		Downward	
Nonfunctional		Not Apparent	

Notes: One Russian olive shrub exists on a pond edge in the upper part of the reach. We recommend removal of this highly invasive non-native species as soon as possible. Scattered cosmopolitan bulrush (*Schoenoplectus maritimus*) found in this reach, but never dominant.

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

Yes _____ No X

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