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Memorandum

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Subject: Updated Condition Assessments in 2023 for Oak Creek and Pleasant Creek, Capitol Reef National Park

Executive Summary

This response to Technical Assistance Request #24653 summarizes surveys of Oak Creek and Pleasant Creek in Capitol Reef National Park (CARE). The effort was undertaken to characterize each stream in relation to stream channel stability, riparian ecosystem health, cattle use, and reach conditions as previously identified in 2014. The field surveys were conducted June 27-29, 2023, with all team members from the 2014 survey reassembled to promote consistency through time. The repeated surveys come five years after CARE's Livestock Grazing and Trailing Management Plan was implemented. We used the Proper Functioning Condition assessment protocol (Dickard et al. 2015), an updated version of the same protocol used in 2014. This protocol focuses on attributes of the fluvial landforms and riparian vegetation to evaluate the stream's capacity to dissipate flood energy and maintain its channel form without significant erosion or degradation of the riparian ecosystem. Thus, this report characterizes the physical stability and resilience of a stream channel, not explicitly the condition or quality of its riparian habitats. The protocol characterizes 17 components related to stream hydrology, vegetation, and geomorphology before determining an overall rating of Proper Functioning Condition, Functional-at Risk, or Nonfunctional.

Oak Creek was rated as Functioning at Risk, the intermediate of the three possible ratings. This was an improvement from the Nonfunctional rating identified in 2014. Despite the categorical improvement, which was largely driven by a partial transition from braided to single-threaded form and improvements in riparian vegetation, the stream remains far from optimal conditions and is vulnerable to regressing back into Nonfunctional condition. Conversely, Pleasant Creek was rated to be in Proper Functioning Condition, the highest of the three possible ratings, which was unchanged from 2014. Although there are important differences between the two creeks related to their physiographic and hydrologic settings, the condition of Pleasant Creek and its riparian vegetation offers a reasonable comparison to suggest that Oak Creek is below its potential functional capacity. The causes of Oak Creek’s sub-optimal condition were not conclusively identified, but they are thought to relate to historical and recent livestock use and how these disturbances interact with the unique hydrogeomorphic setting. This report documents factors that went into assessments of Oak Creek and Pleasant Creek and offers suggestions for potential management and monitoring approaches.

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Introduction

Background

This report summarizes surveys of CARE’s Oak and Pleasant Creeks that were conducted in 2023 using the Proper Functioning Condition (PFC) assessment framework (Dickard et al. 2015). The effort responds to Technical Assistance Request #24653 and was primarily undertaken for comparison with conditions that were documented in 2014 PFC assessments, with a focus on evaluating if there have been changes at Oak Creek after initiation of a new Livestock Grazing and Trailing Management Plan (LGTMP) in 2018. The LGTMP was initiated partly to improve the condition of the park’s aquatic resources, namely Oak Creek which has experienced over a century of livestock use that was concluded to having degraded the stream’s condition, according to the 2014 survey report (Martin, Wagner, and Taliga 2015).

To maintain consistency and to limit potential impacts of survey team changes, the three survey team members from the 2014 survey were reassembled, plus a new fourth member. All team members were from national offices of the National Park Service and USDA Natural Resources Conservation Service and were hosted by CARE ecologist Joe Ceradini. The consistency in personnel increases our confidence in conclusions drawn from comparisons between the two survey years.

Oak Creek and Pleasant Creek occupy adjacent watersheds and both have stream channels that generally flow eastward through CARE (Figure 1). Under natural conditions, they provide highly valuable stream and riparian habitats in this semi-arid region. However, over a century of livestock use has occurred differently on the two streams, with Oak Creek appearing to have the more recent intensive and adverse impacts. Land use histories couple with watershed conditions to create modern stream conditions. In this report we describe three PFC assessments conducted from June 27-29, 2023: one at Pleasant Creek and two at Oak Creek. Oak Creek was divided into a Lower and Upper reach to better correspond with 2014 field surveys and in recognition that reach conditions varied within the surveyed area.

For more detailed background information on the study site and protocol, please refer to the NPS technical report written after the 2014 PFC assessments for Oak and Pleasant Creeks (Martin, Wagner, and Taliga 2015). That report includes separate introductory sections that provide full descriptions of the relevant details relating to landscape setting, climate, surface water resources, geology, hydrogeology, hydrology, ecology, and the PFC assessment protocol. Because the PFC assessment protocol lies at the core of the present report, we also summarize it here and highlight some of its intended uses, strengths, and weaknesses.

The PFC assessment protocol

The PFC assessment protocol was used in 2014, making its use in 2023 surveys particularly valuable. The 2023 effort used the current version (Second Edition) of the Bureau of Land Management’s “Proper Functioning Condition Assessment for Lotic Areas” (Dickard et al. 2015), updated from the first edition (1998) used in 2014. The newer version is mostly unchanged but contains updates that cite new science, provide better examples, clarify wording,

and provide additional details.

The PFC assessments provide the best available information at present for the study reaches. The PFC protocol is intended to “Provide a consistent approach for assessing the physical functioning of riparian areas” and to “Help establish and prioritize management, monitoring, and restoration activities” (Dickard et al. 2015). The focus on the *physical* functioning of the stream largely relates to channel stability, or resilience, and its ability to absorb and persist without drastic and/or adverse changes after experiencing the powerful forces of moderately intense floods. The protocol’s focus on physical stability describes the conditions that in turn support habitat quality and aquatic/riparian biota within the stream corridor.

It is important to keep in mind that the protocol is *not* designed to 1) “Monitor resource conditions and trends”, because it is a coarse method that “generally lacks the sensitivity to detect incremental changes,” (Dickard et al. 2015) such as those that we might expect to gradually evolve after LGTMP implementation for Oak Creek. It is also *not* meant to 2) “Assess specific resource values or be the sole method for assessing the health of the aquatic or terrestrial components of a riparian area”, because it yields only very coarse information on plants, animals, and other habitat parameters (Dickard et al. 2015). For these reasons, this repeat-PFC assessment recognizes that there are related characteristics of CARE’s stream and riparian systems that have not been comprehensively evaluated.

This repeat PFC survey affords the opportunity to evaluate changes between 2014 and 2023. In addition to evaluation of the 17 Checklist Items directly assessed in the protocol, the inclusion of “high-quality photopoints or other qualitative monitoring information can be used to help update the PFC assessment” (Dickard et al. 2015), so we include repeat photography to provide visual evidence of stream conditions during the surveys.

PFC assessments culminate by determining which of three functional ratings best describes the study reach: Proper Functioning Condition (PFC; note that the same acronym describes both the assessment method and the best possible outcome), Functional-At Risk (FAR), or Nonfunctional (NF). A stream reach in PFC has adequate landforms and vegetation to dissipate flood energy, improve water quality, capture sediment, absorb runoff pulses, develop stabilizing root systems, and maintain channel characteristics. Stream reaches in FAR condition are functioning in a more limited and/or vulnerable capacity because some of its attributes are in poor condition relative to potential natural conditions. Stream reaches in NF condition are highly degraded and lack the landforms and vegetation to dissipate flood energy, so they therefore have a low capacity to limit erosion, improve water quality, and maintain quality habitat diversity. PFC and FAR streams can be sub-divided into high/medium/low conditions within each category.

The sections that follow are structured around relevant details and explanations for the 17 PFC Checklist Items, with field data sheets for the three study reaches summarized in Appendices 1-3. Below we provide our responses to the PFC Checklist Items with comments on interpretations and relevant field observations. “Yes” is always considered the better condition for Checklist Items compared to “No”. Items are organized according to the three major categories evaluated in the PFC method: Hydrology, Vegetation, and Geomorphology.

Lower Oak Creek PFC Assessment

Oak Creek was evaluated in 2023 in two distinct sections, a Lower reach and Upper reach (Figure 1). Lower Oak Creek is the same section of Oak Creek that was visited and directly evaluated in the field during the 2014 PFC survey, when it was simply called Oak Creek and meant to represent the entire creek within CARE. Lower Oak Creek should be used for direct comparisons between survey years. Upper Oak Creek is the section of Oak Creek within the park upstream from Lower Oak Creek, and this area was not directly visited or assessed in 2014, but some attributes of its geomorphic setting offer a better comparison to Pleasant Creek.

We concluded Lower Oak Creek to be Functional-At Risk (FAR), a decision that is further explained in the Summary section that follows the detailed responses to Checklist Items below. Although still not in PFC, Lower Oak Creek in 2023 had an improved condition compared to its status in 2014 (FAR compared to Nonfunctional).

Hydrology Section

The focus of the hydrology section of the PFC assessment is to determine if the observed channel and floodplain morphology is stable and in balance with the landscape setting, given prevailing hydrologic and sediment inputs. This is done by estimating the frequency of floodplain inundation, evaluating channel morphology parameters (sinuosity, slope, and width-to-depth ratio) against expected values for the landscape setting, determining the width and potential expansion of the riparian area, and evaluating the influence of upland watershed conditions on hydrologic and sediment characteristics.

Checklist Item #1: Floodplain is inundated in “relatively frequent” events.

Lower Oak Creek has a high sediment load with single-threaded and braided channel forms in the study reach (Figures 2 and 3). In several areas a floodplain is present or building at the expected height above the channel. Even in areas where the channel is braided, there is often a floodplain feature that is accessed by higher flows. We found widespread evidence of recent overbank sediment deposition, flood debris wracking on overbank riparian vegetation, and floodplain vegetation bent over by floodwaters.

We rate this Checklist Item as “Yes”, improved from the “No” rating in 2014 when the lack of channel-floodplain formation and predominance of a more extensively braided channel corresponded little development of a floodplain above the active channel. The 2014 rating was primarily related to the braided channel form and a lack of floodplain development. Between surveys it appears that some, although not complete, development toward a single-threaded channel form occurred, and this channel form related to more defined banks with a flat floodplain surface above it.

Checklist Item #2: Beaver dams are stable.

Item rated as Not Applicable because dams were not present (unchanged from 2014).

Checklist Item #3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).

Lower Oak Creek's channel planform and gradient are largely controlled by the valley-scale sinuosity and entrenched bedrock meanders. Bedrock that occasionally outcrops into the channel bed maintains grade control and keeps the stream gradient stable. The channel's width/depth ratio is more variable and more challenging to interpret, however, because channel form in a high energy and dynamic setting is apt to undergo rapid changes in response to flashy hydrology and highly mobile sediments. Therefore, we expect that either braiding or single-thread could be considered natural channel forms in this setting, and we found both. Channel widths, and resulting channel width-to-depth ratios, have been increased by breakdown of bank structure in places. It was clear that large and recent flooding had impacted the conditions encountered in the field, including burial and removal of some vegetated streambank sections.

We rate this Checklist Item as "Yes", an improvement from the "No" from 2014. In this case, the difference reflects single-thread channel development, but it also could partly reflect a more conservative interpretation that braiding and high width/depth ratio are not necessarily unnatural in this setting.

Checklist Item #4: Riparian area is expanding or has achieved potential extent.

The riparian area appears to be expanding in a few isolated areas, with notable yet rare patches of regenerating willow and cottonwood. However, riparian expansion was not a widespread occurrence, and on the whole there were commonly areas within the riparian zone that were either unvegetated or apparently heavily browsed by recent trespass cattle (Figure 3). Native ungulates deer, elk, and bighorn sheep also browse Oak Creek, adding to the browse pressure. Similarly, the herbaceous vegetation was not clearly expanding anywhere, and it has not achieved its potential extent, as identified by the rarity of mature and recruiting plants. We rated this Checklist Item as "No", unchanged from the 2014 survey. There remains substantial room for improvement.

Checklist Item #5: Riparian impairment from the upstream or upland watershed is absent.

Upstream of the study reach there is both water diversion and water augmentation in Oak Creek, which affects the natural runoff regime. However, these upstream watershed alterations were interpreted as small compared to the channel-forming flows in this reach. Water quality impacts from upstream uses, such as cattle grazing, were not assessed in this survey protocol so no determination can be made. Impairment identified in the reach was most clearly a function of the direct impacts of cattle use of the riparian zone, be it either legacy or recent use. This item was answered "Yes", watershed impacts are absent, largely because the overriding influence on channel form was interpreted to be direct livestock impacts within the riparian zone. This item was answered "No" in 2014. This item was difficult to evaluate, and the changed answer between surveys is related to the relative weighting of local vs. watershed impacts. Although this item has categorically improved, it is not necessarily a strong sign of improved stream conditions.

Vegetation Section

The vegetation section of the PFC protocol evaluates several riparian vegetation parameters and characteristics such as species composition, age-class distribution, cover, vigor, soil moisture requirements, and ability to stabilize soils. The assessment addresses both woody and herbaceous vegetation in recognition of the different and complementary roles that they play. A complete list of identified species is found in Appendix 4.

Checklist Item #6 (Checklist Item #7 in 2014): There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance.

This Checklist Item simply specifically addresses if there are an adequate number of species present to stabilize banks, independent of their vigor and distribution. “Adequate” is defined as two species for each of the woody and herbaceous classes. Stabilizing species generally establish along stream edges, have strong and extensive root systems that protect bank soils, and have leaves and/or branches that create hydraulic roughness and dissipate flow energy. In the study reach, stabilizing woody riparian species included Fremont cottonwood (*Populus fremontii*) and coyote willow (*Salix exigua*). Stabilizing herbaceous species included Baltic rush (*Juncus arcticus*), Nebraska sedge (*Carex nebrascensis*), and spikerush (*Eleocharis palustris*). This diversity led to an answer of “Yes” to this item, improved from the “Yes & No” from 2014. However, this improved categorical rating appears to be an artifact of an improved explanation and subsequent interpretation of this Checklist Item in the updated (2015) manual, not new colonization, as these species were present in 2014 too.

Checklist Item #7 (Checklist Item #6 in 2014): There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance.

Diversity in age classes is needed for replacement of existing plants as they die. We observed many mature cottonwoods along portions of the reach, and there were at least two additional younger age classes. Young seedlings remained in the browse zone and were susceptible to herbivory mortality (Figures 4 and 5). However, there were a few scattered areas with saplings of different sizes that had escaped the browse zone and appear on their way to maturation (Figure 6). For willows, there were two apparent age classes identified, a mature and a younger recruitment/replacement class. Herbaceous species were not found to meet the age class criterion because, in general, their patches were not expanding or clearly having young shoots within or on their periphery. Additionally, in general the sod of the herbaceous vegetation was not “dense”, although our observations appear to have been adversely affected by last year’s flash floods. This Checklist Item was answered “Yes and No” (for woody and herbaceous species, respectively). This is an improvement from the “No” identified in 2014, when recruitment of cottonwood and willow seedlings and saplings was lacking.

Checklist Item #8: Species present indicate maintenance of riparian soil-moisture characteristics.

This Checklist Item assesses the vegetation present to determine if reference soil moisture is being maintained. Although we did not specifically evaluate the wetland indicator status of all species present, we did generally evaluate the composition and distribution of species groups. There were several hydrophytic wetland species present (e.g., three-square bulrush, Baltic rush,

Nebraska sedge, spikerush, cottonwoods, willow), even though their distribution and vigor were sub-optimal. These species were commonly scattered on the banks of the channel and in fewer cases further away, suggesting that there was a mosaic of soil moisture distribution with riparian plants connected to the water table or capillary fringe. There was also appreciable representation of upland species in the valley bottom, but this is not unexpected in this hydroclimatic setting. We narrowly concluded “Yes” for this Checklist Item, improved from “No” answer in 2014. This categorical improvement likely just represents a small shift in conditions and interpretations.

Checklist Item #9: Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.

This Checklist Item isolates whether the streambanks themselves have stabilizing plant communities present so that they could support channel recovery and maintenance. Specifically, it asks if these species have formed “recognizable and distinct communities on the streambanks”, *independent* of whether there is ample coverage of such communities. There are well-developed patches of stabilizing plants (e.g., cottonwood, willow, horsetail, Baltic rush) on banks along the Lower Oak Creek study reach, which would be capable of expanding to fill in gaps along the banks. In general, these species have extensive and deep root systems that can protect streambank soils from being eroded, entrained and transported by streamflow. We answered “Yes” to this item with recognition that there was a very large streamflow event last summer, and the existing plant communities withstood this disturbance. This is a categorical improvement from the “No” rating assigned in 2014, although the change does not represent a full shift from completely non-functional to completely functional.

Checklist Item #10: Riparian plants exhibit high vigor.

This is one of the most critical Checklist Items because it highlights the state of the vegetation and its stabilizing potential today. It distinguishes between healthy/robust plants vs. those that are weakened/stressed. Vigor relates to vegetation’s ability to reproduce, expand, persist, and stabilize soils. Most of the cottonwood and willow seedlings found had been heavily browsed and did not appear on a trajectory to escape herbivory and mature into reproducing individuals (Figures 4 and 5). Similarly, most of the potentially-stabilizing herbaceous species (e.g., Baltic rush, Carex sedges, horsetail) exhibited low vigor, with individuals grazed to within inches of the ground surface. Ungrazed individuals were diminutive, having shorter stature, narrower stem diameter, and more sparsely occupied patches compared to the reference potential. Additionally, portions of the herbaceous vegetation had been removed or buried by recent flooding, and it was not clear to what extent the stands would recover. We rated this Checklist Item as “No”, unchanged from 2014. In our collective professional opinion, this Checklist Item carries outsized importance in the overall PFC Assessment for Lower Oak Creek.

Checklist Item #11: An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.

This item refers to the density and extent of riparian vegetation in the reach, and like Checklist Item #10 it has disproportionately high importance in the PFC assessment. In contrast to Yes’s for Checklist Items 6-9 that affirmed the riparian vegetation’s presence and potential, here we

recognize that this potential is not presently achieved. The Lower Oak Creek reach had only roughly 20% of streambanks where vegetation was present with any moderately high vigor to protect the streambanks; this Checklist Item requires at least 70% presence for a Yes. Given the sparsity and diminutive stature of a large proportion of the stabilizing riparian vegetation, its impacts on hydraulic roughness that dissipates flood energy is unnaturally low. We rated this item as “No”, unchanged from 2014.

Checklist Item #12: Plant communities are an adequate source of woody material for maintenance/recovery.

Item rated as Not Applicable because Oak Creek does not depend on wood to maintain channel stability (unchanged from 2014).

Geomorphology Section

The focus of the geomorphology section of the PFC protocol is to determine if the stream has an apparent balance between flow, sediment, stream energy, and erosional-depositional processes. This includes evaluating fluvial geomorphic processes and their effects on stream processes and riparian conditions by evaluating if conditions exist to maintain a channel’s dynamic equilibrium through moderately high energy flows.

Checklist Item #13: Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.

This Checklist Item hinges on the idea that a channel with adequate flow resistance elements dissipates enough flood energy to limit streambank erosion and largely preserve channel form. The streambed of Lower Oak Creek has substantial grain roughness from boulders that project into the flow field. In contrast, the vigor and quantity of riparian vegetation provides less energy dissipation compared to its potential. A floodplain has developed in portions of the reach, where floodwaters can spread out to reduce flow energy. Even though there remain substantial portions of braided channel without well-defined streambanks and floodplain, in these segments a high channel width-to-depth ratio accesses secondary channels that reduce flow energy. Also, the apparently high sediment transport rate in the reach further dissipates energy. Therefore, we rate this Checklist Item as “Yes”, improved from the “No” in 2014. This categorical improvement is related to expansion of vegetated streambanks and floodplain, although it may be partly due to revised interpretations and our focus on disentangling the interacting aspects of channel condition.

Checklist Item #14: Point bars are revegetating with stabilizing riparian plants.

Revegetating point bars dissipate flow energy, capture sediment, build floodplains, and maintain dynamically stable channel dimensions. Point bars are less important channel features in steep canyon settings like Lower Oak Creek compared to low-gradient meandering channels, but nonetheless they do emerge and influence flow dynamics in some areas. Point bars were absent in braided portions of Lower Oak Creek, and in the single-channel reaches the point bars found were not densely revegetating with stabilizing riparian plants (Figure 3). The point bars were largely unvegetated or had scattered upland plants that lack the stabilizing attributes of native

riparian vegetation. Most of the riparian vegetation that was found on point bars was browsed to a very small stature, leaving it with only minimal hydraulic effects. We rated this Checklist Item as “No”, unchanged from 2014.

Checklist Item #15: Streambanks are laterally stable.

Many healthy streams have eroding banks in isolated areas (e.g., cutbanks), but widespread lateral instability is a sign that the stream is out of balance and cannot maintain its form through high flows. The substantial flash flood(s) of 2022 challenged channel stability, with some banks holding their form and others eroding. Even in straight stream segments, we found distinct clumps of vegetated herbaceous sod that remained intact, were buried in place, or were eroded and transported. Braided segments have high width-to-depth ratios and inherently low lateral stability, and the thalweg is apt to switch channels during high flows (Figure 2). The caveat to this description is that sometimes coarse-grained, flashy, semi-arid streams with naturally high sediment loads can be expected to have similar channel forms with unstable streambanks. This was a challenging Checklist Item to evaluate because an argument could be made for either option, so we rated it as “Uncertain”, differing from the “No” from 2014.

Checklist Item #16: Stream system is vertically stable (not incising).

Lower Oak Creek lacks evidence of a vertically unstable system, such as headcutting or a channel that is incised to the extent that it has lost access to its floodplain. On the contrary, there is overbank and floodplain access in many stream segments. Importantly, bedrock occasionally outcrops into the bed of the channel, providing strong vertical stability because of its erosion resistance. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).

This Checklist Item asks if the reach maintains a natural balance between the water and sediment supplied from its watershed and can transport the supplied sediment. At its downstream boundary of the reach, Lower Oak Creek approaches a 40-foot dam that traps sediment. The interpreted zone of dam influence marks the downstream boundary of the study reach and therefore does not affect our interpretation. Within the reach, however, the creek appears to be a transport reach without clear evidence of ongoing aggradation or incision. There are portions of the reach that are braided, which can be a sign that the system is out of balance with excessive aggradation. However, less braiding and more single-thread channel development since 2014 indicates a level of stability in the drainage basin. Additionally, there is known water withdrawal and also augmentation to the human-modified flows, but we interpreted the impacts to be relatively insignificant in this channel whose channel-forming discharge relates to monsoonal storms that overshadow these flow regulations. We rated this Checklist Item as “Yes”, improved from the “No” in 2014.

Summary Rating for Lower Oak Creek

Lower Oak Creek has improved since 2014, although it still has significant vulnerability to

channel instability and has a poorly developed riparian vegetation community. **We determined Lower Oak Creek to be Functional-At Risk (FAR).** FAR reaches are defined as possessing some elements of streams in PFC, but at least one of its attributes/processes gives it a high probability for degradation during moderate flood events. Within the FAR category, we rated the reach as the lowest of the three possible sub-categories, meaning that it was close to Nonfunctional condition (within-level ratings are new in the Version 2 (2015) protocol so were not included in 2014). The reach was rated as having a trend of “Not apparent”, instead of Upward or Downward. Despite the improved rating from Nonfunctional in 2014, it is not clear that the reach is likely to continue improving.

Our evaluation and conclusions were strongly affected by the poor condition and relative paucity of stabilizing riparian vegetation throughout most of the reach. The existing riparian vegetation was mostly in grazed and low-vigor condition, and it was not as prevalent as expected for a fully-functioning and stable channel in this setting under reference conditions. The evaluation and the reach’s condition rating was influenced by watershed and canyon geology, recent flash flooding, and both legacy and ongoing impacts from livestock. The historical and ongoing pressures from cattle, increasing aridity, and invasive species leave the reach vulnerable to returning to Nonfunctional condition.

The three returning members of our survey team unequivocally concluded that Lower Oak Creek improved from 2014 to 2023 (Figure 4). This was reflected in the substantial shift from Checklist Item answers, with just two Yes’s in 2014 and ten in 2023. However, a portion of this categorical improvement is likely influenced by evolved interpretations. In 2023 the survey team was less certain of the current braiding as reflecting unnatural instability in this semi-arid and steep environmental setting that experiences flashy flows and monsoonal storms. Also, Lower Oak Creek braiding was less extensive in 2023, and revegetation has occurred, albeit minimally. In the 2023 evaluation we emphasized evaluating Checklist Items in full isolation of each other, compared to the slightly more integrated interpretations from 2014. For these reasons, quantifying the number of Checklist Items that shifted is less representative of the degree of change than comparing the overall rating (i.e., transitioning from Nonfunctional to FAR). Some of the Checklist Items that the survey team deemed most important remained No’s. Checklist Items related to riparian vegetation *potential* were rated positively, but those related to current vegetation vigor, abundance, and expansion are more influential on today’s landscape and were in poor condition.

Upper Oak Creek PFC Assessment

As described above, in 2023 Oak Creek was evaluated in separate Lower and Upper reaches. Because Lower Oak Creek matched the portion of Oak Creek that was visited and directly evaluated in 2014, it should be used for primary comparisons through time. Upper Oak Creek is located within the park upstream of Lower Oak Creek, and it is presented separately here

because during the field visit it was determined that it differed from Lower Oak Creek in important ways. **We determined that Upper Oak Creek was also “Functional at Risk” (FAR).** However, we rated it as being the middle of the three sub-levels for FAR (better than the lowest sub-level identified for Lower Oak Creek), meaning that it was found to be intermediate between PFC and Nonfunctional conditions. The reach also had a trend of “Not apparent”, instead of Upward or Downward, because it is unclear if it will improve toward PFC.

The most notable difference between Oak Creek reaches within the framework of PFC Checklist Items was that Upper Oak Creek’s riparian vegetation was in better condition and expanding compared to Lower Oak Creek. The geomorphic reach setting also differed as the valley bottom was wider and less constrained by hillslopes, which facilitated more stream meandering instead of the channel being as tightly constrained by the canyon (Figure 7). The wider setting also allowed cattle pressure to spread out, and we found meaningfully less trampling and browse of the channel and banks in Oak Creek’s Upper reach. Like at Lower Oak Creek, however, the overall reach conditions and character are strongly influenced by watershed and canyon geology, recent flash flooding, and both legacy and recent cattle impacts.

Upper Oak Creek is likely the more appropriate of the Oak Creek reaches to compare to Pleasant Creek because of their more similar physiographic settings related to their positions upstream from the monocline. The valley bottom is less confined in Upper Oak Creek compared to Lower Oak Creek.

Overall, our evaluations for Upper Oak Creek largely mirrored Lower Oak Creek, so *the text in this section is abbreviated to highlight differences between the reaches instead of providing a full independent summary of Upper Oak Creek.* Please see the Lower Oak Creek section (above) and Appendix 2 for additional information on Checklist Items not included in this section. Table 1 highlights ratings for all PFC Checklist Items for the two Oak Creek reaches in both study years. Checklist Items #4 and #14 were rated differently, so those two and the two others whose explanations differed are elaborated below. These differences led to a slightly improved overall rating in the PFC assessment (FAR-mid vs. FAR-low).

Table 1. Comparison of PFC Checklist Items for the Oak Creek study reaches in 2014 and 2023. Note the improvements in ten items between years for Lower Oak Creek, while two items differed between the Oak Creek reaches within 2023.

Checklist Item	Topic	2014 Lower Oak Cr.	2023 Lower Oak Cr.	2023 Upper Oak Cr.
1	floodplain access	No	Yes	Yes
2	beaver dams	NA	NA	NA
3	balanced channel	No	Yes	Yes
4	expanding riparian	No	No	Yes
5	upland/upstream impairment	No	Yes	Yes
6	veg. diversity	Uncertain	Yes	Yes
7	veg. recruitment	No	Yes & No	Yes & No

8	soil moisture	No	Yes	Yes
9	streambank veg.	No	Yes	Yes
10	veg. vigor	No	No	No
11	veg. prevalence	No	No	No
12	wood availability	NA	NA	NA
13	energy dissipation	No	Yes	Yes
14	point bar veg.	No	No	Yes
15	lateral stability	No	Uncertain	Uncertain
16	vertical stability	Yes	Yes	Yes
17	erosion/deposition	No	Yes	Yes

Checklist Item #3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).

Compared to Lower Oak Creek, there was greater sinuosity which related to less valley confinement. This higher sinuosity allowed for more point bar development, providing critical areas for riparian vegetation expansion (Figure 7). Additionally, it appeared that during the recent cattle trailing and trespass period, the pressure from cattle was more diffuse and less impactful on the streambanks in this reach. Both the Upper and Lower Oak Creek reaches were rated “Yes” because they were compatible with their geomorphic settings.

Checklist Item #4: Riparian area is expanding or has achieved potential extent.

Although the riparian vegetation has not achieved its potential extent, in several areas young stands of cottonwoods or willows are expanding into mostly unvegetated areas along the banks and point bars (Figure 7). Some stands of woody seedlings remain within the browse zone but were unbrowsed, while other stands have grown above the browse zone and appear well on their way to maturity. Natural fluvial processes and a more diffuse cattle impact has likely facilitated the regeneration. In contrast, we did not identify clearly expanding patches of herbaceous vegetation. We rated this Checklist Item as “Yes” for Upper Oak Creek because of the woody vegetation expansion, compared to the “No” rating for Lower Oak Creek.

Checklist Item #11: An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.

There is more stabilizing vegetation on Upper Oak Creek compared to Lower Oak Creek, but it is still much less than the 70% benchmark and therefore had a “No” rating for both reaches.

Checklist Item #14: Point bars are revegetating with stabilizing riparian plants.

Revegetating point bars dissipate flow energy, capture sediment, build floodplains, and maintain dynamically stable channel dimensions. Point bars are more prominent channel features in this reach compared to the straighter Lower Oak Creek reach, which relates to channel sinuosity.

Some point bars were actively revegetating with willow and cottonwoods in areas where browse and trampling pressure is less. Revegetation is not occurring to the extent expected under reference conditions, but it nonetheless remains impactful. The larger stature and relatively high vigor of plants on some of the point bars leaves them capable of dissipating flow energy and stabilizing sediments. We rated this Checklist Item as “Yes”, compared to the “No” from Lower Oak Creek.

Pleasant Creek PFC Assessment

The Pleasant Creek study reach extends from where the stream enters the park down to the top of the bedrock-confined canyon monocline section found in the downstream-portion of the park (Figure 1). The field survey extended upstream to within 0.5 miles of the park boundary, and reports from park staff that the stream character remained similar allowed us to not travel the entire reach. This 2023 reach is the same as was characterized in 2014. The 2014 survey completed separate upstream and downstream Pleasant Creek PFC assessments but combined them in the overall evaluation because they were similar and effectively one reach. We found the same in 2023, so we completed just one PFC assessment in the field and report it here.

We determined Pleasant Creek to be in “Proper Functioning Condition” (PFC), a conclusion that is further explained in the Summary section following the Checklist Items below, with field data sheets summarized in Appendix 3. Most of the Checklist Items remained essentially unchanged from their condition in the 2014 surveys. The original PFC report for Pleasant Creek (Martin, Wagner, and Taliga 2015) presents more detail and quantification, and should be referenced if additional information is desired. Our responses to the 17 Checklist Items and the functional condition ratings for Pleasant Creek are presented below.

Hydrology Section

The focus of the hydrology section of the PFC assessment is to determine if the observed channel and floodplain morphology is stable and in balance with the landscape setting, given prevailing hydrologic and sediment inputs. This is done by estimating the frequency of floodplain inundation, evaluating channel morphology parameters (sinuosity, slope, and width-to-depth ratio) against expected values for the landscape setting, determining the width and potential expansion of the riparian area, and evaluating the influence of upland watershed conditions on hydrologic and sediment characteristics.

Checklist Item #1: Floodplain is inundated in “relatively frequent” events.

To support a healthy riparian system, high flows must exceed the channel capacity and spill onto the floodplain on a fairly frequent basis. Pleasant Creek has a single-threaded channel with fully vegetated banks for most of the study reach. In most areas a floodplain is present at the expected height above the channel where it is accessible to the high sediment load floodwaters. We found

recent overbank sediment deposition and flood debris wracking on overbank riparian vegetation. Downstream of the park's Scenic Drive road, there was much more evidence of recent overbank flows compared to upstream within the Pleasant Creek study reach. The South Draw tributary enters Pleasant Creek from the south just downstream from the road and was the apparent source of a very large recent flood. Downstream from this point, there was prevalent evidence of overbank flows, channel adjustments, and vegetation impacted by floodwaters.

The channel and floodplain morphology also plays an important part in evaluating this question. Much of Pleasant Creek consists of long reaches where many of the adjacent channel features such as point bars and floodplain are very close in elevation to the active channel. In isolated segments, however, the channel appeared incised, limiting the ability of high flows to access the floodplain. Since this condition was not the norm but rather the exception, we characterize this as simply being part of a highly heterogeneous river and not alarming.

We rate this Checklist Item as "Yes", the same as in 2014, based on observations made during the site visit and our understanding of the Pleasant Creek flow regime.

Checklist Item #2: Beaver dams are stable.

Item rated as Not Applicable because dams were not present (unchanged from 2014).

Checklist Item #3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).

Channel sinuosity, gradient, and width-to-depth ratio are closely related to a stream's ability to dissipate hydraulic energy during floods. When these parameters are in balance with the landscape setting, the channel is able to handle large runoff events with limited change in channel characteristics and associated riparian-wetland plant communities. It was clear that large flash flooding in 2022 had impacted the conditions encountered in the field, including burial and removal of some vegetated streambank sections. However, even in the face of a major disturbance event, the channel parameters appeared to facilitate resilience and preservation of channel form. This was strong evidence of a functional system.

Pleasant Creek's channel planform and gradient are largely controlled by the valley-scale sinuosity and entrenched bedrock meanders. Bedrock that occasionally outcrops into the channel bed maintains grade control and keeps the stream gradient stable. However, the valley is broad enough in many stream segments and contains extensive enough sediment deposits that alluvial processes dominate, resulting in characteristic meandering alluvial channel forms such as opposing cutbanks and point bars. As evidence of this, we found self-organized bed steps in the channel. For most of its length the stream channel has defined banks and a width/depth ratio that is expected for this setting. We rate this Checklist Item as "Yes", the same as in 2014.

Checklist Item #4: Riparian area is expanding or has achieved potential extent.

A fully-expanded riparian system is formed by and supports a broad distribution of floodwaters during out of bank flows. Many of the channel features including mid-channel, side-channel and

point bars are heavily vegetated with riparian species that establish and persist with the dynamic flow regime. We did not observe widespread evidence of upland plant species invading the riparian zone, nor were there other signs of riparian zone narrowing. The overall configuration of Pleasant Creek is that of a dynamically stable channel/floodplain morphology and a riparian zone that is approaching or at its potential width. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #5: Riparian impairment from the upstream or upland watershed is absent.

Upstream of the study reach there is water diversion and water augmentation within Pleasant Creek, which affects the natural runoff regime. However, these upstream hydrologic alterations were interpreted as small compared to the channel-forming flows in this reach. The upland terraces along Pleasant Creek appeared to be in very good shape, with excellent vegetation cover and well-developed biological soil crusts. These conditions stabilize soils and make them more resistant to wind and water erosion, which limits excessive sediment contributions from the uplands. Furthermore, we did not observe any evidence of excessive deposition in the channel. We concluded that the upland watershed is not contributing to riparian-wetland degradation and rated this Checklist Item as “Yes”, unchanged from 2014.

Vegetation Section

The vegetation section of the PFC protocol evaluates several riparian vegetation parameters and characteristics such as species composition, age-class distribution, cover, vigor, soil moisture requirements, and ability to stabilize soils. The assessment addresses both woody and herbaceous vegetation in recognition of the different and complementary roles that they play. A complete list of identified species is found in Appendix 4.

Checklist Item #6 (Checklist Item #7 in 2014): There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance.

In general, we found the riparian plant communities along Pleasant Creek to be closely aligned with reference communities. This Checklist Item specifically identifies if there is an adequate number of species present to stabilize banks, resist erosion, and add hydraulic roughness to the flow. “Adequate” is defined as two species each for the woody and herbaceous classes, which was exceeded in the reach. Stabilizing species generally establish along stream edges, have strong and extensive root systems that protect bank soils, and have leaves and/or branches that create hydraulic roughness and dissipate flow energy. In the study reach, common stabilizing woody riparian species included Fremont cottonwood (*Populus fremontii*), coyote willow (*Salix exigua*), and graybark willow (*Salix eriocephala*). Stabilizing native herbaceous species included Baltic rush (*Juncus arcticus*), common three-square bullrush (*Scirpus pungens*) Nebraska sedge (*Carex nebrascensis*), horsetail (*Equisetum* spp.) and spikerush (*Eleocharis palustris*). Non-native herbaceous vegetation included yellow sweetclover (*Melilotus officinalis*) and white sweetclover (*Melilotus alba*). This diversity led to an answer of “Yes” to this item, unchanged from 2014.

Checklist Item #7 (Checklist Item #6 in 2014): There are adequate age classes of stabilizing

riparian vegetation for recovery/maintenance.

Diversity in age classes is needed for replacement of existing plants as they die. We observed at least three age classes of Fremont cottonwood, including recruitment and replacement classes, and a range of very young to mature plants for graybark and coyote willows (Figure 8). Few young seedlings and saplings were in a heavily browsed or stunted condition, indicating that they are on their way to maturity. The dominant herbaceous riparian species including common threesquare, Baltic rush, and horsetail were typically vigorous and spreading where space permitted (Figure 9). Additionally, the sod of the herbaceous vegetation was found to be dense and had infilled with individuals packing in the space permitted to them. This Checklist Item was answered “Yes”, unchanged from 2014.

Checklist Item #8: Species present indicate maintenance of riparian soil-moisture characteristics.

This Checklist Item assesses the vegetation present to determine if reference soil moisture is being maintained. The dominant woody species at Pleasant Creek are all characteristic riparian species for this region and indicate maintenance of appropriate riparian soil moisture characteristics. Perennial herbaceous wetland species including three-square bulrush, Baltic rush, horsetail and redtop were dominant or co-dominant along the banks and lower bar features over most of the reach, again indicating maintenance of wetland soil moisture regimes. Although some drier species were observed on some higher floodplain surfaces, they did not appear to represent a drying trend in the riparian zone. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #9: Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.

This Checklist Item identifies whether the streambanks have stabilizing plant communities present to support channel maintenance and recovery. The dominant woody species are common riparian trees and shrubs for this region with root masses capable of withstanding high streamflow events, as was evidenced by their resilience after the flash flooding of 2022. There are well-developed patches of stabilizing plants (e.g., cottonwood, willow, horsetail, Baltic rush, redtop), and all of the herbaceous species are strongly rhizomatous with root systems that anchor streambanks and provide roughness to help dissipate the energy of larger flood events (Figure 10). The herbaceous layer is also recovering from the recent flash flood(s) and helped to maintain channel form. We answered “Yes” to this Checklist Item, unchanged from 2014.

Checklist Item #10: Riparian plants exhibit high vigor.

This is a critical Checklist Item because it highlights the state and stabilizing potential of the vegetation today, with vigor also relating to its ability to reproduce, expand, persist, and stabilize soils. Both woody and herbaceous riparian vegetation exhibited high vigor along Pleasant Creek (Figure 9). Trees were typically robust, had little canopy dieback, did not appear stressed, and were reproducing on appropriate channel bank and floodplain surfaces. Woody vegetation vigor was also demonstrated by its ability to withstand very high flows from the 2022 flash flooding. Perennial herbaceous wetland vegetation on the streambanks and other channel and low

floodplain features appeared healthy and formed the dense root mats needed to anchor soils against erosion. The individual stems exhibited robust forms. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #11: An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.

This item refers to the density and extent of riparian vegetation in the reach, and it is another particularly important Checklist Item. The banks of Pleasant Creek were typically well-vegetated with perennial herbaceous wetland and woody riparian vegetation. This Checklist Item requires at least 70% vegetation coverage of moderately high vigor. Given the nearly full-coverage and robust stature of the vegetation, we conclude that it is capable of protecting banks and dissipating energy during floods. This conclusion was supported by the known flooding in 2022, through which much of the vegetation persisted or had recovered. We rated this item as “Yes”, unchanged from 2014.

Checklist Item #12: Plant communities are an adequate source of woody material for maintenance/recovery.

Item rated as Not Applicable because Oak Creek does not depend on wood to maintain channel stability (unchanged from 2014).

Geomorphology Section

The focus of the geomorphology section of the PFC protocol is to determine if the stream has an apparent balance between flow, sediment, stream energy, and erosional-depositional processes. This includes evaluating fluvial geomorphic processes and their effects on stream processes and riparian conditions by evaluating if conditions exist to maintain a channel’s dynamic equilibrium through high energy flows.

Checklist Item #13: Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.

This Checklist Item hinges on the idea that adequate flow resistance elements dissipate enough flow energy to limit streambank erosion and largely preserve channel form through floods. Energy dissipation usually occurs from interaction with roughness elements associated with the bed and banks such as channel features, substrate, and riparian vegetation. We identified numerous features that would contribute to energy dissipation. In the predominantly alluvial reaches the channel/floodplain morphology, specifically vegetated point bars, overflow channels, and channel bars with surface roughness like boulders, are in position to provide energy dissipation as flows rise. Additionally, there is substantial streambank and riparian corridor cover by rhizomatous herbaceous wetland species and substantial cover by cottonwoods and willows that also dissipate flow energy. At a larger scale, the valley sinuosity is a constant contributor to energy dissipation at all flows, and the high sediment transport in the reach further dissipates energy. Because channel and floodplain characteristics were adequate to dissipate energy, we rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #14: Point bars are revegetating with stabilizing riparian plants.

Revegetating point bars dissipate flow energy, capture sediment, build floodplains, and maintain dynamically stable channel dimensions. The point bars and other near-channel features on Pleasant Creek were well-vegetated with a variety of riparian species and age classes (Figures 8 and 11). There were only sparse patches of bare sediment upstream of the park road, but downstream from the tributary, impacts from the 2022 flash flooding left more bare sediment overbank. Given the other related conditions, however, it is projected that these recently aggraded overbank features will soon be covered with stabilizing riparian plants too. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #15: Streambanks are laterally stable.

Many healthy streams have eroding banks in isolated areas (e.g., cutbanks), but widespread lateral instability is a sign that the stream is out of balance and is unlikely to maintain its form through high flows. The substantial flash flood(s) of 2022 challenged channel stability, with some banks holding their form and others eroding, but ultimately the channel form and its lateral stability remained intact (Figure 12). We found evidence that riparian vegetation root networks stabilized the banks to preserve channel form (Figure 10). Along most of Pleasant Creek sinuosity is controlled by bedrock at both the valley and channel reach scales, but lateral migration does occur at an appreciable rate through the alluvial reaches. We identified many areas of point bar/cutbank morphology indicative of natural channel movement across the floodplain and terraces (Figures 8 and 11). Pleasant Creek also had a relatively consistent channel width, indicating a dynamic yet stable system. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #16: Stream system is vertically stable (not incising).

Vertical stability is an important element in evaluating conditions of erosion and deposition in riparian systems. For the most part, Pleasant Creek did not exhibit any of the attributes of a vertically unstable riparian system such as v-shaped channels, steep eroding banks, headcuts, or disconnection of the channel from the floodplain. One exception is the incised reach just upstream of the park road, which is incised for a short stretch representing less than 10% of the reach but not representative of Pleasant Creek as a whole. Furthermore, numerous bedrock outcrops and boulder steps exist along Pleasant Creek and provide stable grade control. We rated this Checklist Item as “Yes”, unchanged from 2014.

Checklist Item #17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).

The balance between the Pleasant Creek stream system and its supplied sediment load appeared to be in equilibrium, allowing it to be an effective sediment transport reach. Although there were actively eroding cutbanks (Figure 11), we did not observe areas receiving large amounts of sediment from the uplands, nor did we observe any unnatural degradation of the banks that would increase the sediment supply to the channel. Below the tributary confluence near the park road, there was substantial sediment deposition on the floodplain from recent flash flooding, but

given the apparent magnitude of that event, we did not consider this deposition to be excessive. Additionally, there is known water augmentation and withdrawal upstream of the study reach, but we interpret the impacts to be relatively insignificant in this channel whose channel-forming discharge relates to monsoonal storms that overshadow these flow regulations. We rated this Checklist Item as “Yes”, unchanged from 2014.

Summary Rating for Pleasant Creek

We determined that Pleasant Creek was in “Proper Functioning Condition” (PFC), as supported by our “Yes” answers to all 17 Checklist Items. PFC reaches are characterized as being in good enough condition to be resilient to moderate floods, meaning that the channel should not be strongly re-worked during a flood event, but rather its stabilizing vegetation and stream morphology are adequate to balance erosion and deposition to maintain a dynamic equilibrium through the disturbance. Within the PFC category, we rated Pleasant Creek as being in the middle of the three possible sub-categories, meaning that it was not especially close to dropping into the “Functional-At Risk” category, but it also was not in near-pristine functioning condition (within-level ratings are new in the 2015 protocol so were not included in 2014). The reach was rated as having an apparent trend of “Not apparent”, instead of Upward or Downward. It appears that this is a stable stream reach with the ability to handle floods without unravelling. The evaluation and the reach’s condition rating related to channel stability appears to be strongly influenced by watershed and canyon geology and recent flash flooding.

Management Implications

The Upper and Lower reaches of Oak Creek are strongly influenced by geologic setting, flows related to the semi-arid monsoonal climate, and historical and recent livestock use. Given the long history of heavy cattle and sheep use prior to implementation of CARE’s 2018 Livestock Grazing and Trailing Management Plan (LGTMP) and the flashy nature of flows, we would expect the ongoing passive recovery of Lower Oak Creek’s degraded riparian vegetation and stream channel to take decades. The LGTMP apparently has reduced cattle pressure, although implementation has been hampered when permittees trail “naïve” new animals that do not know the route or the destination. For example, our survey was timed about three weeks after the semi-annual livestock trailing, after which 20 trespass cattle apparently re-entered (or remained in) CARE and had three weeks of unauthorized access to Oak Creek, according to park staff.

Enhanced management and coordination of cattle trailing operations between the permittees and park could further improve stream stability and recovery. Interventions such as strengthening and timely maintenance of existing drift fences on Oak Creek west of the park boundary will reduce incidents of cattle trespass impacts. Modifications could also include prescribing a more deliberate cattle pathway that stays away from the streambanks and channel where possible. Feeding cattle weed-free hay prior to passthrough will encourage a faster drive without grazing and limit the spread of non-native species. To minimize riparian soil compaction, CARE could consider requiring several days of no precipitation prior to trailing. Additional trailing management methods and considerations related to the timing, route, and speed of passage

through the corridor could be used to promote less impactful use and encourage recovery of the native wetland vegetation and a properly functioning channel.

While Pleasant Creek's PFC rating is very positive with respect to the riparian system's ability to maintain its fundamental form and functions after moderately large floods, improvements can still be made. The PFC protocol does not provide a full view of stream and riparian health, and there are modifications to the livestock trailing management that would still benefit the riparian ecosystem. Trailing activities appear to be the dominant source of observed non-native vegetation such as yellow sweetclover, white sweetclover, and redtop. These species can be expected to further proliferate after future flood disturbances. CARE could consider developing trailing management prescriptions that include requiring holdover of cattle and feeding of native, weed-free hay before trailing to limit grazing on the drive and reduce the spread of non-native seeds. To minimize compaction, CARE could consider requiring several days of no precipitation prior to trailing. Additional trailing management methods and considerations such as timing, route, and speed of passage through the Pleasant Creek riparian corridor could be used to protect native vegetation and the integrity of the stream and riparian ecosystem.

More detailed understandings of stream and riparian health in CARE could emerge if additional monitoring protocols and study designs were implemented. If a focus on biotic components or habitat quality are desired, then protocols that focus on these attributes could be adopted, though would require more time and analysis. These methods could include plot-based vegetation surveys, riparian habitat focused protocols like Multiple Indicator Monitoring (Burton et al. 2011), or a customizable protocol as described in the USFS's National Riparian Core Protocol (Merritt et al. 2017). At Oak Creek, for example, a potential study design to investigate livestock impacts would be to create a series of fencing exclosures in the riparian zone, some of which keep out cattle and others that also keep out native ungulates like sheep, deer, and elk. In this way, the influences of hydro-geomorphic setting, native browsers, and modern cattle operations could be better disentangled.

Conclusions

We assessed Oak and Pleasant Creeks using the PFC assessment protocol, which uses a structured framework to characterize stream channel stability through time. The assessments concluded that Pleasant Creek was in PFC, while Oak Creek was FAR. Compared to the 2014 PFC surveys conducted on these reaches, Pleasant Creek's rating remained unchanged at the best of the three levels, while the Lower Oak Creek rating improved from the worst (NF) to the medium (FAR) rating. In our 2023 survey, Pleasant Creek scored positively in all applicable Checklist Items, while at Oak Creek four (Upper Oak Creek) or six (Lower Oak Creek) Checklist Items did not meet the "Yes" protocol standard. Ratings for all PFC Checklist Items for Pleasant Creek were unchanged between survey years 2014 and 2023. This contrasted with Lower Oak Creek, which had categorical improvements in nine of its Checklist Items.

Even with the documented improvements since 2014, it is not clear that Oak Creek will continue to improve in the near-term. The condition of Pleasant Creek and its riparian vegetation,

however, remains good and provides evidence that Oak Creek's potential remains higher than currently achieved, even with the two creeks having important differences in geomorphic setting like slope, valley confinement, and geologic units. More detailed assessments with suggested management actions were presented above in the section "Management Implications". In general, we found that a century of livestock use, recent trespass cattle, and recent flooding leave the Oak Creek riparian system below its potential, and many years of optimized management will be required for recovery.

The PFC assessment framework provides only a partial picture of stream and riparian condition, as elaborated in the Introduction section above. The protocol focuses on physical channel stability much more than biotic components and health of the stream-riparian system. CARE's streams are also strongly influenced and constrained by geology, making the PFC protocol less sensitive to disturbances like grazing impacts compared to fully alluvial channels. Furthermore, the PFC protocol itself recognizes that it is a poor tool for monitoring through time because of its qualitative, subjective nature and it generally lacks the sensitivity to detect incremental changes (Dickard et al. 2015). If a more precise view of stream conditions or a focus on biotic components and habitat quality of riparian systems are desired, then more data collection using alternative protocols that require more time and analysis will be required.

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Figures

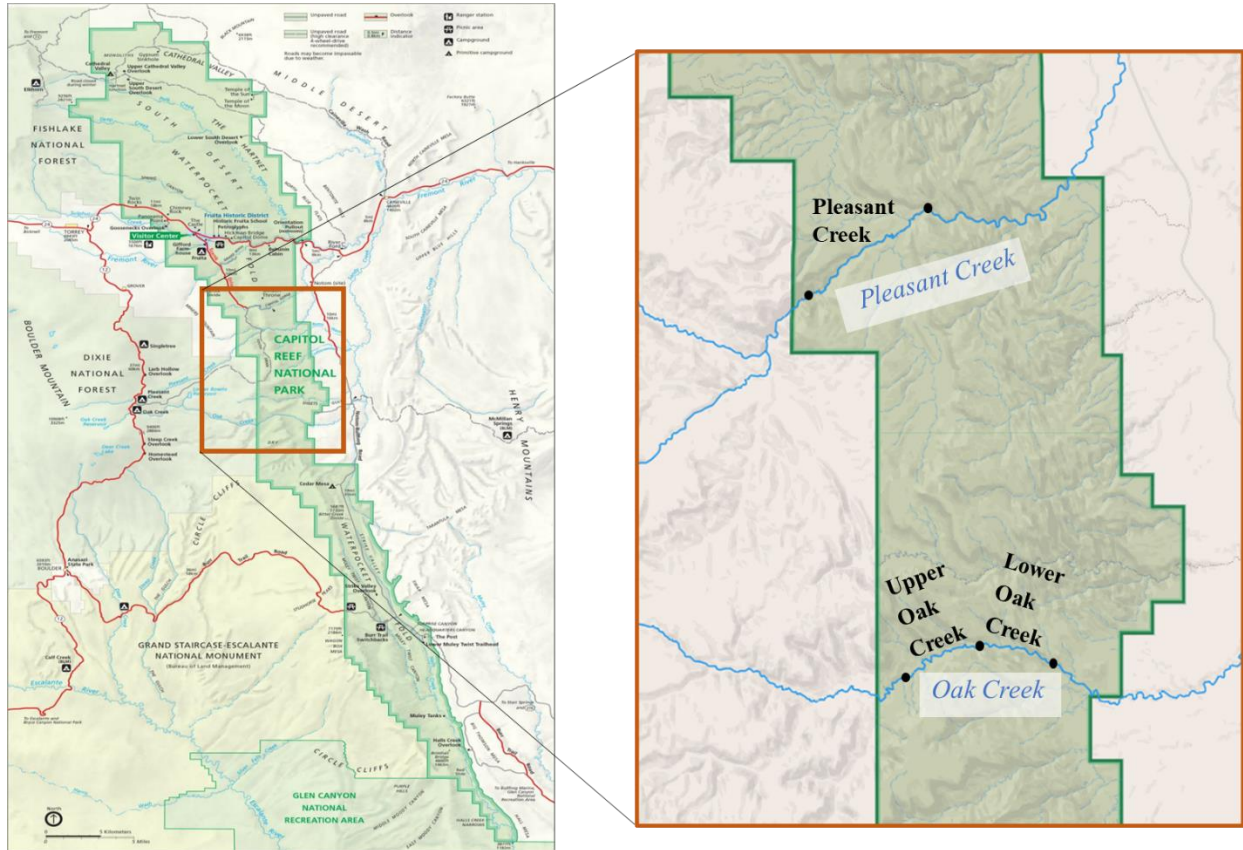


Figure 1. Map of Capitol Reef National Park, with inset at right showing the left-to-right flowing Oak and Pleasant Creeks. The 2023 study reaches visited in the field are bounded with black dots.



Figure 2. Repeat photos of two locations in Lower Oak Creek where the channel remains braided and without well-defined banks. Note that little channel form or streambank development occurred from 2014 to 2023, but in the top right photo willow regeneration has expanded as seen by the green band across the photo center.

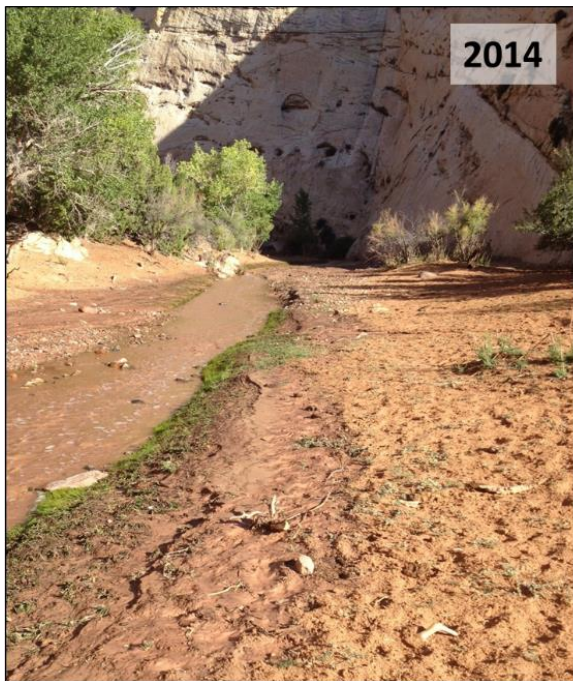


Figure 3. Lower Oak Creek repeat photos of two locations showing upstream views of the channel. Note that there is very little riparian vegetation, although in 2023 there are isolated woody riparian plants that have established or grown to be more than a few inches in height.



Figure 4. Lower Oak Creek repeat photos with upstream view. Note that in 2014 vegetation was heavily grazed to within inches of the ground, while in 2023 there was woody vegetation growing a few feet above ground surface but was still browsed.



Figure 5. Photo from Lower Oak Creek showing a low density (i.e., one plant) of heavily browsed Fremont cottonwoods along a single-threaded channel reach.



Figure 6. Upper (top) and Lower (bottom) Oak Creek photos showing isolated Fremont cottonwoods that have escaped the browse zone and appear on their way to maturity.



Figure 7. Photo of Upper Oak Creek showing an alluvial section with regenerating willows. Note the wider valley setting and greater revegetation that characterized Upper Oak Creek compared to Lower Oak Creek.



Figure 8. Two sets of Pleasant Creek repeat photos showing typical downstream (top) and upstream (bottom) views in an alluvial reach (Figure 7 in Martin, Wagner, and Taliga 2015). Note the low point-bars with dense woody riparian vegetation. The arrow points to the river-right side of the same rock in all four photos. The channel migrated to the outside of the bend (river left) between photo years.



Figure 9. Pleasant Creek photo showing dense and vigorous herbaceous vegetation and replacement-class cottonwoods.



Figure 10. Streambank on Pleasant Creek downstream from the park road. A flash flood in 2022 eroded into the bank, but a strong root network from healthy riparian vegetation limited the erosion and stream widening while preserving a single-threaded channel form with identifiable banks.



Figure 11. Upstream view of Pleasant Creek repeat photos for a migrating cutbank (Figure 8b in Martin, Wagner, and Taliga 2015). Note that the bank has eroded to the left and toward the photo point into the hillslope deposits, and also note the multi-age class woody vegetation on the point bar.

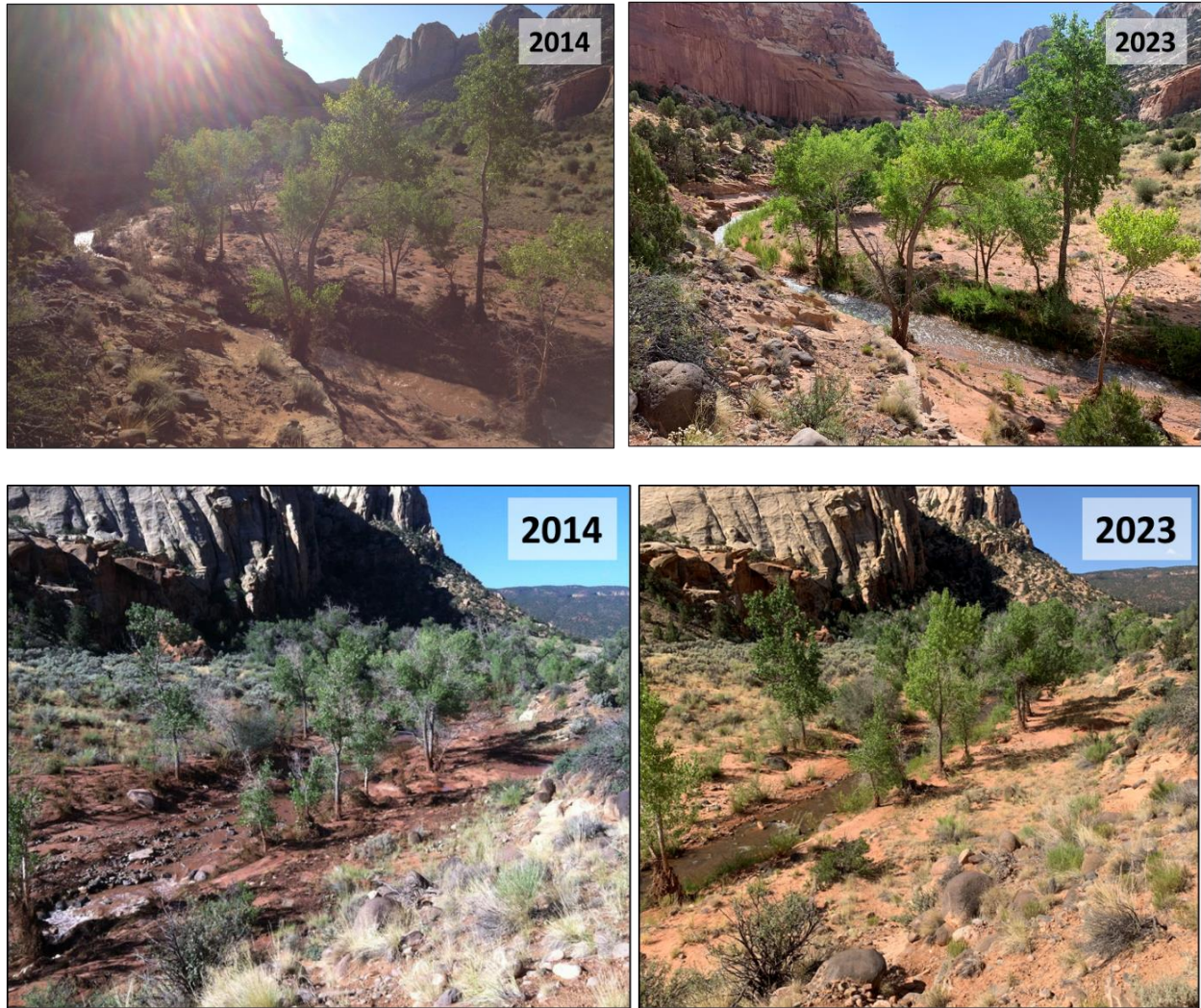


Figure 12. Pleasant Creek repeat photos from near the downstream extent of the study reach (Figures 9 and 10 in Martin, Wagner, and Taliga 2015). Note the dark overbank deposits from a flood the day before the 2014 photo, and cottonwoods and riparian vegetation remain relatively unchanged.

Appendix 1: PFC Riparian Standard Checklist for Lower Oak Creek

Name of Riparian Area: Lower Oak Creek, Capitol Reef National Park

Date: 6-27-2023

Segment/Reach ID: Oak Creek Dam through 2014 field survey reach

(38°04'59" N, 111°08'16" W to 38°05'10" N, 111°09'40" W, WGS 84)

Miles: 1.37 stream miles

ID Team Observers: WRD: Derek Schook, Joel Wagner, Mike Martin. NRCS: Christine Taliga

Note that a bold red X signifies a change in condition from 2014 to 2023, and all changes recorded were improvements.

¹ identifies Checklist Items ranked differently between Upper and Lower Oak Creek reaches.

Yes	No	N/A	HYDROLOGY
X			1) Floodplain is inundated in “relatively frequent” events
		X	2) Beaver dams are stable.
X			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
	X ¹		4) Riparian area is expanding or has achieved potential extent
X			5) Riparian impairment from the upstream or upland watershed is absent

Yes	No	N/A	VEGETATION
X			6) There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X	X		7) There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X			8) Species present indicate maintenance of riparian soil-moisture characteristics
X			9) Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.
	X		10) Riparian plants exhibit high vigor
	X		11) An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows
		X	12) Plant communities are an adequate source of woody material for maintenance/recovery.

Yes	No	N/A	GEOMORPHOLOGY
X			13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy
	X ¹		14) Point bars are revegetating with stabilizing riparian plants
XX			15) Streambanks are laterally stable.
X			16) Stream system is vertically stable (not incising).
X			17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition)

(Revised 2015)

Functional Rating:

Proper Functioning Condition (PFC)	_____
Functional – At Risk (FAR)	<u> x </u>
Nonfunctional (NF)	_____

Trend (for Functional At Risk):

Upward	_____
Downward	_____
Not Apparent	<u> x </u>

Functional Sub-Rating:

 FAR – low

Appendix 2: PFC Riparian Standard Checklist for Upper Oak Creek

Name of Riparian Area: Upper Oak Creek, Capitol Reef National Park

Date: 6-27-2023 **Segment/Reach ID:** Oak Creek upstream from 2014 field survey extent
(38°05'10" N, 111°09'40" W to 38°04'43" N, 111°10'45" W, WGS 84)

Miles: 1.26 stream miles (to 3/4 mi from upstream park boundary)

ID Team Observers: WRD: Derek Schook, Joel Wagner, Mike Martin. NRCS: Christine Taliga

¹ identifies Checklist Items ranked differently between Upper and Lower Oak Creek reaches.

Yes	No	N/A	HYDROLOGY
X			1) Floodplain is inundated in “relatively frequent” events
		X	2) Beaver dams are stable.
X			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).
X ¹			4) Riparian area is expanding or has achieved potential extent
X			5) Riparian impairment from the upstream or upland watershed is absent

Yes	No	N/A	VEGETATION
X			6) There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X	X		7) There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X			8) Species present indicate maintenance of riparian soil-moisture characteristics
X			9) Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.
	X		10) Riparian plants exhibit high vigor
	X		11) An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows
		X	12) Plant communities are an adequate source of woody material for maintenance/recovery.

Yes	No	N/A	EROSION/DEPOSITION
X			13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy
X ¹			14) Point bars are revegetating with stabilizing riparian plants
X	X		15) Streambanks are laterally stable.
X			16) Stream system is vertically stable (not incising).
X			17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition)

(Revised 2015)

Functional Rating:

Proper Functioning Condition (PFC)	_____
Functional – At Risk (FAR)	<u> x </u>
Nonfunctional (NF)	_____

Trend (for Functional At Risk):

Upward	_____
Downward	_____
Not Apparent	<u> x </u>

Functional Sub-Rating:

 FAR – middle

Appendix 3: PFC Riparian Standard Checklist for Pleasant Creek

Name of Riparian Area: Pleasant Creek, Capitol Reef National Park

Date: June 28 & 29, 2023

Segment/Reach ID: Upstream and Downstream (all combined)

(38°11'10" N, 111°10'20" W to 38°10'00" N, 111°12'21" W, WGS 84)

Miles: 2.73 stream miles (to 1/2 mi from upstream park boundary)

ID Team Observers: WRD: Derek Schook, Joel Wagner, Mike Martin. NRCS: Christine Taliga

* All Checklist Items scored the same in 2023 and 2014.

Yes	No	N/A	HYDROLOGY
X			1) Floodplain is inundated in “relatively frequent” events
		X	2) Beaver dams are 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 area is expanding or has achieved potential extent
X			5) Riparian impairment from the upstream or upland watershed is absent

Yes	No	N/A	VEGETATION
X			6) There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X			7) There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance * order of Questions 6 and 7 swapped from prior protocol
X			8) Species present indicate maintenance of riparian soil-moisture characteristics
X			9) Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.
X			10) Riparian plants exhibit high vigor
X			11) An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows
		X	12) Plant communities are an adequate source of woody material for maintenance/recovery.

Yes	No	N/A	EROSION/DEPOSITION
X			13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy
X			14) Point bars are revegetating with stabilizing riparian plants
X			15) Streambanks are laterally stable.
X			16) Stream system is vertically stable (not incising).
X			17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition)

(Revised 2015)

Functional Rating:

Proper Functioning Condition (PFC)

 X

Functional – At Risk (FAR)

Nonfunctional (NF)

 Trend (Functional – At Risk): N/A

Upward

Downward

Not Apparent

 Functional Sub-Rating: PFC – middle

Appendix 4: Plant Species List

Plant species were identified opportunistically while walking the Oak Creek and Pleasant Creek study reaches on June 27-29, 2023. Oak Creek vegetation was sometimes hard to identify in places because the site was denuded and grazed to stubble by trespass cattle. Much of the plant diversity was attributed to the associated uplands. Species identification was performed by Chris Taliga (USDA NRCS) and Ethan Ostraff (CARE seasonal botanist).

Table A4-1. Plant species Identified at Oak Creek (Lower and Upper reaches combined) and Pleasant Creek.

Site	Scientific Name	Synonyms	Common Name
Oak Creek	<i>Artemisia frigida</i>		Fringed sagebrush
Oak Creek	<i>Artemisia tridentata</i> var. <i>tridentata</i>	<i>Artemisia tridentata</i> (133638)	Basin big sagebrush
Oak Creek	<i>Asclepias speciosa</i>		Showy milkweed
Oak Creek	<i>Betula occidentalis</i>		Water birch
Oak Creek	<i>Bromus</i> sp.		
Oak Creek	<i>Campanula parryi</i>		Parry's harebell
Oak Creek	<i>Carex nebrascensis</i>		Nebraska sedge
Oak Creek	<i>Castilleja linariifolia</i>		Wyoming paintbrush
Oak Creek	<i>Cercocarpus intricatus</i>		Dwarf mountain mahogany
Oak Creek	<i>Chrysothamnus</i> sp.		
Oak Creek	<i>Cirsium vulgare</i>		Bull thistle
Oak Creek	<i>Clematis ligusticifolia</i>		White virgin's-bower
Oak Creek	<i>Distichlis spicata</i>		Desert saltgrass
Oak Creek	<i>Eleocharis</i> sp.		
Oak Creek	<i>Equisetum arvense</i>		Field horsetail
Oak Creek	<i>Fraxinus anomala</i>		Singleleaf ash
Oak Creek	<i>Glycyrrhiza lepidota</i>		Nuttall's licorice
Oak Creek	<i>Juncus arcticus</i>	<i>Juncus arcticus</i> var. <i>balticus</i> (228511), <i>Juncus balticus</i> (143439), <i>Juncus balticus</i> var. <i>montanus</i> (213087), <i>Juncus balticus</i> var. <i>mexicanus</i> (228526)	Baltic rush
Oak Creek	<i>Juncus</i> spp.		unidentified
Oak Creek	<i>Medicago sativa</i>		Alfalfa
Oak Creek	<i>Melilotus officinalis</i>		Yellow sweet-clover
Oak Creek	<i>Oxytenia acerosa</i>		Copperweed
Oak Creek	<i>Populus fremontii</i> var. <i>fremontii</i>	<i>Populus fremontii</i> (119656)	Fremont cottonwood
Oak Creek	<i>Rhus aromatica</i> var. <i>trilobata</i>	<i>Rhus aromatica</i> ssp. <i>trilobata</i> (207900), <i>Rhus trilobata</i> (126786)	Squawbush
Oak Creek	<i>Salix exigua</i> var. <i>stenophylla</i>	<i>Salix exigua</i> (119734)	Coyote willow
Oak Creek	<i>Salix</i> sp.		Strapleaf willow
Oak Creek	<i>Scirpus pungens</i> var. <i>longispicatus</i>	<i>Scirpus pungens</i> (141773)	Three-square bulrush
Oak Creek	<i>Shepherdia argentea</i>		Silver buffaloberry
Oak Creek	<i>Stipa hymenoides</i>	<i>Oryzopsis hymenoides</i> (145077)	Indian ricegrass
Oak Creek	<i>Tamarix chinensis</i>	<i>Tamarix ramosissima</i> (117482), <i>Tamarix pentandra</i> (199434)	Five-stamen tamarisk
Pleasant Creek	<i>Agropyron cristatum</i>	<i>Agropyron dasystachyum</i>	Crested wheatgrass

Site	Scientific Name	Synonyms	Common Name
		(141872)	
Pleasant Creek	<i>Agrostis stolonifera</i>	<i>Agrostis alba</i> (142857)	Redtop
Pleasant Creek	<i>Amelanchier utahensis</i>		Utah serviceberry
Pleasant Creek	<i>Aristida purpurea</i>	<i>Aristida fendleriana</i> (140379)	Purple three-awn
Pleasant Creek	<i>Artemisia filifolia</i>		Sand sagebrush
Pleasant Creek	<i>Artemisia frigida</i>		Fringed sagebrush
Pleasant Creek	<i>Asclepias speciosa</i>		Showy milkweed
Pleasant Creek	<i>Astragalus mollissimus</i> var. <i>thompsoniae</i>	<i>Astragalus mollissimus</i> (122152)	Woolly milkvetch
Pleasant Creek	<i>Betula occidentalis</i>		Water birch
Pleasant Creek	<i>Bouteloua gracilis</i>		Blue grama
Pleasant Creek	<i>Bromus tectorum</i>		Cheatgrass
Pleasant Creek	<i>Castilleja linariifolia</i>		Wyoming paintbrush
Pleasant Creek	<i>Cercocarpus montanus</i>		Alder-leaf mountain mahogany
Pleasant Creek	<i>Chaenactis douglasii</i>		Hoary dusty-maiden
Pleasant Creek	<i>Chenopodium desiccatum</i>		Desert goosefoot
Pleasant Creek	<i>Chenopodium</i> spp.		
Pleasant Creek	<i>Cleome lutea</i>		Yellow beeplant
Pleasant Creek	<i>Cornus sericea</i> var. <i>sericea</i>	<i>Cornus sericea</i> (155953), <i>Cornus stolonifera</i> (130571)	Red-osier dogwood
Pleasant Creek	<i>Distichlis spicata</i>		Desert saltgrass
Pleasant Creek	<i>Elymus elymoides</i>	<i>Sitanion hystrix</i> (146020)	Squirreltail
Pleasant Creek	<i>Elymus salinus</i>		Salina wildrye
Pleasant Creek	<i>Equisetum arvense</i>		Field horsetail
Pleasant Creek	<i>Eriogonum alatum</i>		Winged wild buckwheat
Pleasant Creek	<i>Festuca arundinacea</i>		Tall fescue
Pleasant Creek	<i>Glycyrrhiza lepidota</i>		Nuttall's licorice
Pleasant Creek	<i>Juncus arcticus</i>	<i>Juncus arcticus</i> var. <i>balticus</i> (228511), <i>Juncus balticus</i> (143439), <i>Juncus balticus</i> var. <i>montanus</i> (213087), <i>Juncus balticus</i> var. <i>mexicanus</i> (228526)	Baltic rush
Pleasant Creek	<i>Juncus longistylis</i>		Long-style rush
Pleasant Creek	<i>Juncus</i> spp.		
Pleasant Creek	<i>Juncus torreyi</i>		Torrey's rush
Pleasant Creek	<i>Juniperus osteosperma</i>		Utah juniper
Pleasant Creek	<i>Koeleria macrantha</i>	<i>Koeleria cristata</i> (184483), <i>Koeleria nitida</i> (143372)	Junegrass
Pleasant Creek	<i>Mahonia fremontii</i>	<i>Berberis fremontii</i> (95988)	Fremont's mahonia

Site	Scientific Name	Synonyms	Common Name
Pleasant Creek	<i>Medicago sativa</i>		Alfalfa
Pleasant Creek	<i>Melilotus officinalis</i>	`	Yellow sweet-clover
Pleasant Creek	<i>Mentzelia albicaulis</i>		White-stem blazingstar
Pleasant Creek	<i>Oenothera caespitosa</i> var. <i>marginata</i>	<i>Oenothera caespitosa</i> (289377)	Long-tube evening-primrose
Pleasant Creek	<i>Oenothera elata</i>	<i>Oenothera hookeri</i> (188841)	Western evening-primrose
Pleasant Creek	<i>Opuntia polyacantha</i> var. <i>polyacantha</i>	<i>Opuntia polyacantha</i> (105986)	Plains prickly-pear
Pleasant Creek	<i>Pediocactus simpsonii</i>		Simpson's hedgehog cactus
Pleasant Creek	<i>Penstemon comarrhenus</i>		Dusty penstemon
Pleasant Creek	<i>Penstemon eatonii</i> var. <i>eatonii</i>	<i>Penstemon eatonii</i> (130627)	Eaton's firecracker
Pleasant Creek	<i>Penstemon eatonii</i> var. <i>undosus</i>		Undulate penstemon
Pleasant Creek	<i>Penstemon palmeri</i> var. <i>eglandulosus</i>	<i>Penstemon palmeri</i> (130685)	Palmer's penstemon
Pleasant Creek	<i>Pinus edulis</i>		Two-needle pinyon
Pleasant Creek	<i>Pinus ponderosa</i> var. <i>scopulorum</i>	<i>Pinus ponderosa</i> (93115)	Ponderosa pine
Pleasant Creek	<i>Populus angustifolia</i>		Narrow-leaved cottonwood
Pleasant Creek	<i>Populus fremontii</i> var. <i>fremontii</i>	<i>Populus fremontii</i> (119656)	Fremont cottonwood
Pleasant Creek	<i>Psilostrophe sparsiflora</i>		Greenstem paperflower
Pleasant Creek	<i>Psoralidium lanceolatum</i> var. <i>lanceolatum</i>	<i>Psoralidium lanceolatum</i> (159874), <i>Psoralea lanceolata</i> (123683), <i>Psoralea lanceolata</i> var. <i>lanceolata</i> (505093)	Lemon scurf-pea
Pleasant Creek	<i>Purshia mexicana</i> var. <i>stansburyana</i>	<i>Purshia mexicana</i> (106662)	Cliff-rose
Pleasant Creek	<i>Quercus gambelii</i> var. <i>gambelii</i>	<i>Quercus gambelii</i> (102209)	Gambel's oak
Pleasant Creek	<i>Salix eriocephala</i> var. <i>ligulifolia</i>		Strapleaf willow
Pleasant Creek	<i>Salix exigua</i> var. <i>stenophylla</i>	<i>Salix exigua</i> (119734)	Coyote willow
Pleasant Creek	<i>Salix</i> sp.		
Pleasant Creek	<i>Scirpus pungens</i> var. <i>longispicatus</i>	<i>Scirpus pungens</i> (141773)	Three-square bulrush
Pleasant Creek	<i>Sclerocactus</i> spp.		
Pleasant Creek	<i>Shepherdia argentea</i>		Silver buffaloberry
Pleasant Creek	<i>Sphaeralcea parvifolia</i>		Small-leaf globemallow

Site	Scientific Name	Synonyms	Common Name
Pleasant Creek	Stanleya pinnata		Prince's-plume
Pleasant Creek	Stipa comata var. comata	Stipa comata (146104)	Needle-and-thread
Pleasant Creek	Stipa speciosa		Desert needlegrass
Pleasant Creek	Tamarix chinensis	Tamarix ramosissima (117482), Tamarix pentandra (199434)	Five-stamen tamarisk
Pleasant Creek	Thelesperma subnudum var. subnudum	Thelesperma subnudum (138110)	Scapose greenthread
Pleasant Creek	Townsendia incana		Hoary townsendia
Pleasant Creek	Yucca harrimaniae var. harrimaniae	Yucca harrimaniae (144232)	Harriman's yucca

Appendix 5: Coordinates of study reaches and photos

Table A5-1. Coordinates (WGS 84) for the study reach boundaries and photographs included as figures.

Stream Reach	Object of Interest	Latitude	Longitude
Lower Oak Creek	Boundary – downstream	38.08306°N	111.13778°W
Upper/Lower Oak Creek	Boundary – upstream/downstream	38.08611°N	111.16111°W
Upper Oak Creek	Boundary – upstream	38.07861°N	111.17917°W
Pleasant Creek	Boundary – upstream	38.16667°N	111.20583°W
Pleasant Creek	Boundary – downstream	38.18611°N	111.17222°W
Lower Oak Creek	Repeat photo (Figure 2, top)	38.08601°N	111.15394°W
Lower Oak Creek	Repeat photo (Figure 2, bottom)	38.08480°N	111.14261°W
Lower Oak Creek	Repeat photo (Figure 3, top)	38.08293°N	111.13807°W
Lower Oak Creek	Repeat photo (Figure 3, bottom)	38.08335°N	111.13854°W
Lower Oak Creek	Repeat photo (Figure 4)	38.08560°N	111.14961°W
Lower Oak Creek	Photo (Figure 5)	38.08347°N	111.13865°W
Lower Oak Creek	Photo (Figure 6, bottom)	38.08633°N	111.15276°W
Upper Oak Creek	Photo (Figure 6, top)	38.08562°N	111.15997°W
Upper Oak Creek	Photo (Figure 7)	38.08196°N	111.17329°W
Pleasant Creek	Repeat photo (Figure 8, top)	38.17447°N	111.19528°W
Pleasant Creek	Repeat photo (Figure 8, bottom)	38.17454°N	111.19509°W
Pleasant Creek	Photo (Figure 9)	38.17971°N	111.18160°W
Pleasant Creek	Photo (Figure 10)	38.18086°N	111.17983°W
Pleasant Creek	Repeat photo (Figure 11)	38.16937°N	111.20101°W
Pleasant Creek	Repeat photo (Figure 12, top)	38.18625°N	111.17263°W
Pleasant Creek	Repeat photo (Figure 12, bottom)	38.18626°N	111.17261°W