Sand Creek Massacre National Historic Site, National Park Service,
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Goals:
The objectives of this project were to review available natural and cultural resources research reports that have been submitted to the park (reports identified below), evaluate the findings, conclusions, and recommendations, determine if any conclusions or recommendations are in conflict with one another, and summarize the findings and recommendations into one set of findings and recommendations for park management. The park is beginning its first General Management Plan and Comprehensive Interpretive Plan, and it is critically important that the park fully understands its baseline of natural and cultural resources data and resources management objectives to guide the planning process.

This project attempts a synthesis and summarizes the various project reports, and, where possible, provides an analysis of the reports to see where the points of agreement, contradictions, etc. exist. This project identifies where there are contradictions or questions that would benefit from additional research, and summarizes key findings. Comments are presented to suggest how site manifestations of global environmental change will likely influence the management actions, and lastly, this report identifies how management might best achieve desired future conditions.

Reports requested for review:
1 Sand Creek Massacre NHS Vegetation Classification Study and Inventory of Plants at Sand Creek Massacre NHS (Roath report)
2. Pollen Analysis at Sand Creek Massacre NHS
3 A Study of 1864 Environmental Conditions (Environmental History)
4. A Preliminary Assessment of Wetland, Riparian, Geomorphology, and Floodplain Conditions at Sand Creek Massacre NHS
5. Prairie Dog Management Plan and Environmental Assessment
6. Inventory of Rare and Listed Species at Sand Creek Massacre NHS
7 Sand Creek Massacre NHS Bird Inventory
8. Riparian Forest Age Structure and Past Hydroclimatic Variability (Tree Ring Study)
9. Fish Survey at Sand Creek Massacre NHS
10 Geoarcheological Assessment of the Sand Creek Massacre Site
11. An Ethnological and Ethnohistorical Assessment of Ethnobotanical and Cultural Resources of Bent's Old Fort National Historic Site and the Sand Creek National Historic Site
12 Special Soils Survey Report, Sand Creek Massacre NHS
13. Special Resources Study and Environmental Assessment: Site Location Plan (Vol 1)
14. Sand Creek Massacre Project, Special Resources Study, Vol 2.

15. The NPS plant species list summary prepared by Tomye Folts-Zettner 6/08.

Summary

1. **Are there conflicts among these reports?**

An obvious conflict is a conclusion of the pollen analysis study relative to findings from either the Environmental History or Roath reports. The pollen findings make the case that the site was dominated by a weedy dicot, whereas all other information suggests this area was dominated by grasses. This conflict can be resolved IF the pollen results are assumed to have been heavily influenced by very small area vegetation inputs, rather than a sample of vegetation at the site. While the site may have been heavily grazed during the 19th century, the majority of the site in 1864 was native grassland, not an area dominated by weedy dicots. The pollen work does, however, provide information on the age of the wetland. The finding indicates the site would have been a logical location for use by Native Americans for a very long period of time. Such use does explain the local abundance of a weedy species in the pollen record.

There are conflicts about the landscape configuration of the areas involved in the massacre. The oral accounts include mention of rocks which are not present at the site. However, the current morphology of the bluffs and eroded banks of portions of Sand Creek do appear 'rock-like' even though their composition does not include rock in a conventional sense. This apparent conflict is not viewed as a science issue.

There are minor conflicts, mostly plant nomenclature or landscape terminology, which are identified below. An argument is presented that reconstructed past plant communities may be inappropriate models for future management. Of modest concern are the statements in the Special Resource Study, vol 2, which incorrectly summarizes the local climate (pg 55). Corrected information is provided herein.

What are the key consistent findings?

The SAND site is – and has been -dynamic in terms of its vegetation composition. At some time in the distant past, vegetation was destabilized, presumably by drought, contributing to present-day topography. More recently, the colder period of the little ice age may have favored mesic species that maintained legacies through the more recent centuries. As noted in the Environmental History study, the bison herds, the re-introduction into North America of the horse which facilitated the migrations and development of Native American cultures, certainly had impacts on the site and likely modified dominance within plant communities during the 18th and 19th centuries. Within these long-term directional shifts, the relative abundance of vegetation and the fauna that exploit this vegetation as both habitat and food resources have varied annually, due primarily to water availability, and these have further varied among years, due to the frequency of fire and intensive (but perhaps infrequent) grazing events. Finally, the flood plain at the site has seen the 'rise and fall' of cottonwood groves as these appear and disappear along Sand Creek over century-scaled time intervals. The intensive use of these groves as winter forage for horses by the early 1800s may have contributed to at least some of the general patterns observed on the eastern plains of Colorado by 1864.

Since the time of the massacre, what appears to have been intense and chronic grazing by cattle and perhaps horses has altered vegetation composition. Areas plowed in past decades for crops have been

reseeded with native vegetation, but the soils and composition of this vegetation is altered from what existed pre-plow. The challenge to maintain the site in a form compatible with its mission of historical conservation must find ways to mitigate unacceptable legacies from post-massacre land uses.

2. What are the major research needs?

I am uncertain if oral traditions have been maintained that would allow for a continuation of the collection of ethnobiological information about the flora and fauna found at SAND. This information was underdeveloped in existing work, but that deficiency is believed to be due to the loss of the knowledge base, not the fault of investigators. Continued work to develop and highlight the plants found at SAND that were used by the Cheyenne and Arapahoe peoples would appear to be an appropriate educational and research activity. Because almost all plants found at SAND have fairly large regional distributions, ethnobotanical findings from other projects should be applicable to SAND (e.g., project at Ft Laramie though Michael Harkin's program at U. of Wyo.). These plants might also be grown in a garden accessible to visitors; some might be useful in restoration projects.

The existing vegetation data set needs to be analyzed to 1) provide a summary characterization of the site, and 2) to better understand the extent to which grazing and other disturbances have influenced the vegetation composition of the site. While references are made to a generic vegetation composition, vegetation analyses need to be summarized and presented in a manner to support forward-looking management activities. These efforts are assumed to be those that would maximize the historical and conservation potential of the site, given the realities of spatial limitations of this native grassland and the vagaries of climate. Specifically, understanding the roles of grazing and fire and using these (or their absence) as management tools is viewed as very important. Further, 'novel' management activities such as mowing, creative revegetation, etc., also offer possible opportunities to address conservation issues confronting the site.

The Roath transects may also be used to form the basis for future inventory and monitoring efforts. While transect studies do not provide complete species lists, they do provide an excellent and cost-effective way of monitoring the abundance of most species and are useful in monitoring for changes in community structure. An interesting exercise would be to ask "how many replicate transects are required to characterize the SAND communities?" The existing data could be subsampled and the ability to predict community composition using (say) half of the transects could be evaluated. If, for example, the same community composition and species richness (numbers of species) could be obtained from half of the sampling effort, this would be a cost-effective finding that might allow more frequent sampling or application of monitoring resources to other high-priority activities. In any event, high inter-annual variability in the abundances (or, as assessed here, 'hits' or cover) of SAND plant species are to be expected.

A somewhat more academic exercise could be conducted integrating vegetation findings with the two soil survey reports, which should provide a baseline assessment of the importance (or lack thereof) the variability in soil conditions in influencing vegetation patterns. Such an analysis might show where current and future management actions are likely to be more or less successful with respect to enhancing or suppressing specific plant species or relative abundances of species.

Achieving desired densities of prairie dogs and use of acceptable methods such as creative vegetation regimes to limit the extent of prairie dog communities remain important research questions.

Scenario planning for a site with a longer growing season (a very high probability event) with the same or lower annual precipitation (a likely event) appears warranted. Overall, one might predict a more arid environment and explore management activities and mechanisms that increase the resilience of the existing ecosystem to this driver.

Nowhere in any of the reports was average precipitation for this site plotted, but the annual pattern of precipitation was incorrectly noted on pg 55 of the Special Resources Report, Vol 2. The data reported here from the Eads station indicates a very strong "summer wet" signature (Figure 1). Historically, this pattern would select for warm season grasses, particularly when facilitated by spring or autumn fires that tend to suppress cool season plant abundance. An isotopic analysis of the light and heavy fractions of soil carbon of the site could provide an index of the relative abundance of the C_3 and C_4 vegetation that was found at this site, and we would expect that the ^{13}C value of the heavy carbon fraction should be dominated by that carbon which was fixed by plants in the past. Such an analysis could validate the assertion regarding the warm-season graminoid dominance at this site, but further identify the extent to how the historical communities responded to this climate. This ratio can also be compared to current cover estimates of the vegetation to provide one assessment of vegetation change.

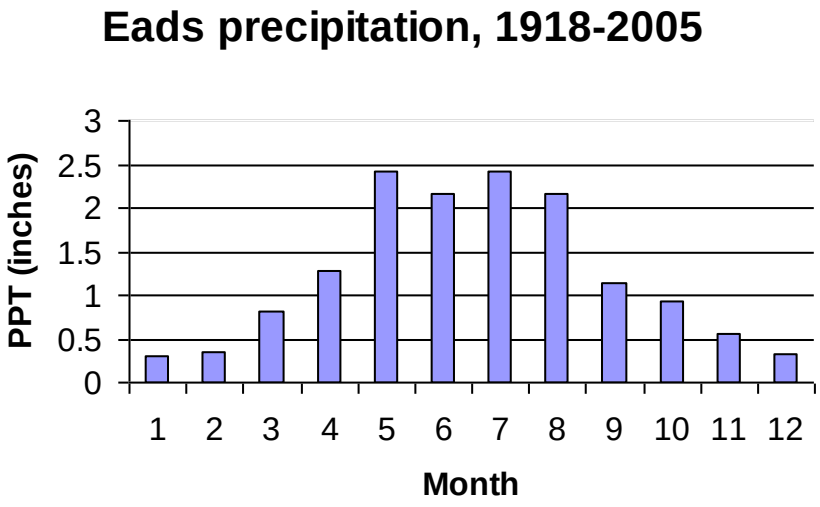

Figure 1. Average precipitation for Eads, the nearest long-term weather station for SAND.)Western Regional Climate Center, wrcc@dri.edu, Period of Record: 1/ 1/1918 to 12/31/2005).

More recently, the site has experienced the 'directional drivers' (e.g., climate, CO_2 concentrations, N deposition, etc.) associated with global environmental change. The current suite of SAND reports is consistent in not addressing these potential impacts. That is a concern because we do not know how resistant or resilient the site is to these directional drivers. An analysis of how these drivers may have already contributed to the current composition of the site and how these drivers may endanger desired vegetation components clearly is a management concern and research need. The recent addition of a weather station (as part of the COlorado AGricultural Meteorological nETwork – COAGMET program), can help establish the relevance of using surrounding long-term data records for this analysis.

Future Desirable conditions.

In 1864, the Sand Creek region was a native grassland containing riparian areas and limited wetlands associated with a perennial spring. Most non-native species such as Kochia (*Kochia scoparia*) were not present, although a subset of non-native species such as Russian thistle (*Salsoli iberica*) may have appeared on-site within the life-times of the survivors of the massacre. The most recent vegetation surveys as well as personal site visits in 2007 and 2008 indicate no immediate serious threats to native species from invasive, non-native plant species. However, sage (*Artemisia spp*, mostly *A. filifolia)* is likely much more abundant than it was in 1864 as a result of concurrent fire suppression and a century of chronic grazing at intensities that likely were in excess to those from bison and horses that structured the plant communities in 1864. Periodic site use by large numbers of Native American horses undoubtedly had short-term impacts, but grasses of the Great Plains were adapted to high-intensity, short-term grazing. Most of these species are not adapted to chronic, moderate to heavy grazing (and in particular the taller species cannot tolerate chronic late growing season grazing). Chronic grazing can favor a subset of the grasses (mostly buffalo grass and blue grama), increase densities of largely inedible sage species, and allow for opportunistic growth of weedy species. Chronic grazing also reduced fuel loads such that widespread fire likely became a much rarer phenomenon, at least at local scales. Restoring the dominance of the grassland should employ those techniques that favor the grasses over sagebrush. Both mowing and appropriately-timed fire appear to be management tools that can accomplish this restoration activity.

Recent reviews of climate trends in North America at the latitude of SAND suggest that the growing season is expanding, and has expanded by perhaps as three weeks in the last 50 years (unpublished results of Boulder NOAA scientists Dr. Klaus Wolter and Pieter Tans). Exactly how this will play out in arid to mesic prairie remains unknown, but higher evapotranspiration from a longer growing season with unchanged precipitation is a high-probability prediction. Maintaining the desired abundance of mesic species may become more difficult. Retaining litter on the soil surface therefore might reduce spring soil warming as well as surface evapotranspiration rates. Elsewhere, grasslands are seeing the expansion of cool-season species, (exploiting earlier or later growing season windows), but this response is also consistent with fire suppression.

Research Activities for Future Desired Conditions (FDC) Management

As emphasized elsewhere in this report, the rules that organize the composition of plant communities have changed over the last few decades (Cole et al. 2008; Seastedt et al. 2008); the historical range of natural conditions and natural disturbances that contributed to the composition of this site in the 1860s cannot, in their entirety, be restored. The historical climate, atmospheric chemistry, and natural disturbance regime no longer exist, and while management activities can mitigate some changes, *ultimately the NPS must decide species composition goals and find management activities that advance the site towards those goals.*

The major threats to this site are (listed in order of concern)

1. Conversion of a grassland to shrubland as a result of grazing legacies and local impacts from global environmental change drivers. (Certain shrubs may benefit from enhanced carbon dioxide levels, as affected by increased nitrogen deposition (Morgan et al. 2007)).

2. Destabilization of soils due to intensive drought. Will grazing activities by prairie dogs amplify or attenuate this threat?

3. Community vegetation transformations following drought, due to changes in both length of growing season and propagule abundance.

A research project that attempts to link current plant community composition (the Roach et al. report) with available soil and site use history information seems like a logical first priority that might inform management options. A re-inventory of selected plots could identify specific soils or sites most sensitive to current changes.

Ref: Morgan, J.A. et al. 2007. Carbon dioxide enrichment alters plant community structure and accelerates shrub growth in the shortgrass steppe. Proc. Nat. Acad. Sci. 104: 14724-14729.

Project Reviews:

1. **Site Inventory of Plants at Sand Creek Massacre NHS (Roath et al. draft report 2007, as modified by Southern Plain Network, 2008)**

Conceptual issues:

"The Historical Climax Plant Community (HCPC) represents the natural potential plant communities found on relict or relatively undisturbed sites" (NRCS 2003). This concept employs the general ecosystem model that such areas are determined by the state factors identified by Jenny (1980): climate, biota, topography, parent material, and disturbances such as glacial and drought histories, fire, grazing intensities, etc. However, the one-to-one correspondence of a generalized community to a small area such as SAND has limitations. For example Roath et al. noted that "some key plant species such as fourwinged saltbush and big bluestem were completely absent from the site." While post 1860s human disturbances have been substantial, it's doubtful that these species (presumably common or dominant under the HCPC model) would have been singled out to be extirpated these from the site. A more reasonable hypothesis is that these species, if present, were initially rare. *Thus, the comparison of community composition with HCPC expectations, while an interesting academic exercise, should not be used as the sole restoration guide.*

A second concern about the HCPC guide is simply that 'the rules that organize the composition of plant communities' have changed over the last few decades (Cole et al. 2008; Seastedt et al. 2008); the historical range of natural conditions and natural disturbances that contributed to the composition of this site in the 1860s cannot, in their entirety, be restored. The historical climate, atmospheric chemistry,

and disturbance regime no longer exists, and while management activities can mitigate some changes, *ultimately the NPS must decide species composition goals and find management activities that advance the site towards those goals.*

The HCPC appears to assume a more mesic climate that has occurred either recently or during much of the documented history of the SAND site (see Mitchell et al. 2007). Periodic droughts, along with periodic fires, clearly influence the composition of the vegetation at this site. As mentioned in the Mitchell et al. (2007) review, both eastward and westward of this region, we know that periodic fires occurred at fairly frequent return intervals (2-4 year fire returns 300 miles to the east, and 7-12 year return intervals at the Colorado Front Range). Reduction of fuels by drought, overgrazing, or both would have reduced fire return intervals in this region during the 1800s, and it is possible that they were below the hypothesized 20-year burn interval for this region. At heavily used areas, such as SAND, this might overestimate the fire return interval. Nonetheless, fire was an organizing factor of the biotic community to a modest degree at this site.

Methodologies. The raw data for this report are apparently available, although this information was not included in the documents I've received. *It is absolutely critical to have the raw data available for future research and monitoring.* Further, there's a master's thesis ready to be written based upon the first inventory work. Summaries by soil type, by disturbance regime, as well as an overall Park summary would be very useful products. The patterns of plant richness as a function of soils and disturbance regime would also be of major interest.

There are unidentified plants listed in this report. This is expected due to the limited seasonality of the study, but it's probably important to have well-trained individuals versed in rare species as well as in "early detection and eradication" techniques often walk the site?

The vegetation report lacks a summary. What is the most common plant species on SAND? What are the differences among the major soil types (loam, sand, salt meadow). How does current prairie dog grazing impact respective communities?

A preliminary assessment indicated a total of 207 tentative plant species were identified at SAND. Of the 180 identified species, 167 were native and 13 were introduced.

*Specific comments/edits on the 2007 draft report***:** (Note: if these issues have been addressed in the 2008 edited report this is noted here)

Pg 23 What is scientific name of poison milkweed? *Asclepias subverticillata*?)

Pg 28 change "resistant to change to change…" to "resistant to change…" I question the assertion of "reduced infiltration" without empirical measurements. These slopes are so shallow I've got to believe the sites are very, very stable even under their altered (prairie dog) status. (Issues on Pg 28 were corrected in the 2008 report)

Given the prairie dog status and the assumptions that these animals were likely present in the past, the inferences in Table 1 (potential comp vs. current comp) is a bit of a distortion since the baseline should be "loamy early seral under prairie dog grazing"

And in general…some of these areas are so small that the "expected" is likely based on a much larger sampling area. So when we find a large local assemblage of native species well above "baseline" levels, we shouldn't be surprised and, similarly, when we find the rare species missing, this too is not a surprise?

The dominance of sand dropseed in some of the 'loamy' soils makes me think they're not so loamy…esp. with western wheat essentially absent from these. The co-abundance of side-oats grama makes me think the "loamy early-mid serial" stage, is not correct. An analysis of vegetation differences among sites given similar classifications might suggest some microsite soil differences or historical disturbances not discussed in the present effort.

Cover can vary from 35>60% in the Loamy A,B? This emphasizes the importance of grazing and grazing histories?

The loamy R site shows what happens when grazing is excluded: high build-up of western wheatgrass, but also sand dropseed and inland saltgrass are abundant! Again, a more methodical analysis of vegetation differences seems appropriate. It's strange that this is the only site where western wheat is "within normal" based upon the NRCS classification.

Overflow Mid Seral. Contains some unqualified statement (pg 99) "The…community has lost many tallgrass species, important forbs, and shrubs." A) Possibly, the site never had them, or b) possibly the site was "too small" to have them. Some 'value' statements like "Energy and nutrient cycles have been greatly impaired and infiltration is greatly reduced due to the "root pan" of blue grama. (These statements imply data not in evidence!) (comments now are on pg 59 of 2008 report.)

Overflow B site missing western wheat…which was expected to compose 35-40%! Again, this emphasizes the limitations of the HDPC use in localized areas?

Overflow D…another grazing exclusion result.

Pg 120. Floodplain "Historically, fires occurred infrequently." Data? (remains on pg 120 of 2008 report).

Pg 120. Grazing destroys prairie cordgrass? I've not seen this. My experience is that cordgrass is only heavily grazed when everything else has been consumed.

Where is the current percent composition defined? Why doesn't this add up to 100% for grasses and forbs? (e.g. pg 130)

These data unchanged in 2008 version. Values exceeding 100% are possible if "hits" include more than one species per point…but this would need to be clarified in methodologies.

Sometimes photo records don't match up with data or demonstrate how localized sampling can vary from landscape perspectives. The photos on pg 138 seem to indicate a much larger role of sagebrush in the % of cover of site N (pg 138)

Salt meadow (pg 152) lowest cover…caused by cottonwood shading? "A grove of cottonwood trees occupy the stratum." (pg 150) The analysis of "out of whack" conditions (pg 150) seems to ignore the trees? One might envision this community showing decadal to century-scale patterns as cottonwoods appear and disappear at specific sites.

Table 24: no summaries on % grasses, forbs. (This appears to have been fixed in the 2008 report)

Sands C = water tank disturbance area.

Sands RT: no summaries in table…and subsequent (These appear to have been added in 2008)?

Pg 185 *Amarthanthus retroflexus* identified as "non-native".

Is the heath aster native to Colorado? Not in the Plant's database map.

Sands G…nice diversity! A function of sample size?

Veg composition is done with one sample size (e.g., n=80, pg 222) but then cover is done with a larger sample size? (ground cover, n = 360, pg 223)???? What appears to be reported, here, is that 80 plots were sampled with 6 points each, but then we would have 420 points? Is it n=60 on pg 222 or n=420 on page 223??? Here's where a raw data check would be made if the raw data were available.

Sandy bottomland Early-Mid Seral. This site shows high diversity. What is frequently flooded (monthly, yearly…?) (pg 228)

Refs:

Jenny, H. 1980. The Soil Resource. Springer Verlag, NY.

Cole, D.N. et al. 2008. Naturalness and beyond: protected area stewardship in an era of global environmental change. The George Wright Forum 25: 36-56.

Seastedt. R.J. Hobbs and K.N. Suding. 2008. Management of novel ecosystems: are novel approaches required? Frontiers in Ecology and the Environment. On-line.

Comparisons of Plant species lists: NPS inventory list prepared by Tomye Folts-Zettner compared with that of the Roath Report.

Sand Creek NPS needs an official master list of vascular plants, and the list prepared by Folts-Zettner appears to largely accomplish this. Such lists should include inventory dates as well as synonyms. Here, I compared the list prepared by Folts-Zettner and compared it to that prepared by Roath et al. Presumably, the former list included all of those of the latter, so the only issues involve the implications of "missing species" from the Roath list. I have not attempted to ascertain all issues related to synonyms or other sources of variation. Clearly, the Roach report includes unidentified plants ("spp") which imply additional species of a given genus might be present. In any event, the two lists may allow one to evaluate the completeness of the transect inventories of Roath. If the discrepancies in the lists are real, then a modest number of relatively rare species have not been included in the transect inventories. This is not viewed as a deficiency, but rather the reality of transect sampling outcomes. The NPS inventory and monitoring program obviously needs to make sure that standard procedures include periodic complete species inventories as well as periodic transect surveys. The latter will likely be particularly useful to assess community change to the directional environmental drivers discussed above. Clarification of the following species may be appropriate.

Species that are missing in Roath report unless otherwise noted include: Asclepias subverticillata misspelled in the Roath report; Calamovilfa gigantea; Dalea cylindriceps; Dalea nana; Delphinium carolinianum ssp virescens needs species check; Descurainia pinnata; Euphorbia esula; Helianthus petiolaris; Ipomopsis laxiflora; two subspecies of Lappula identified in Folts-Zetter but only one in Roath; Linaria dalmatica; Machaeranthera pinnatifida and M. tenacetifolia; Oonopsis engelmannii; Packera tridenticulata; both species of Pediomelum, Physalis hispida; Poa glancifolia in Roath only; Redfieldia flexuosa; Salsola iberica in Roach only; two species of Schoenoplectus; (S maritimus =Scirpus americanus); Tradescantia occidentalis; Tripterocalyx micranthus; Typha angustifolia

2. **Pollen analysis of sediment cores recovered from the Sand Creek Massacre NHS**. (Mensing, Univ. Nevada, Reno.)

Comments upon methodologies: This reviewer lacks the expertise to judge the quality of the methodologies, but these appear to be adequate. Plant species identifications need to be standardized to match that used by Roath et al. (2007) and the NPS plant survey report.

Comments upon findings: *The results presented here appear to be localized and/or site specific. While there is no reason to doubt the pollen abundances found here, there are strong reasons to doubt that these findings have generality at sites beyond the sampling areas. A conclusion of the report (pg 1 of discussion, second paragraph) is not supported by other studies.*

The abundance of *Amaranthus* (probably *Amaranthus retroflexis*, redroot Amaranth or redroot pigweed) as well as the *Chenopodium* spp. appear well in excess of what likely was present in the past, or amounts currently on the site. While this study looks at pollen abundance and not plant abundance, these species occupy only a small percent of the flora now (Roath et al. 2007), and there are no historical accounts that suggest these species were abundant in the past anywhere in this region. Unless one can evoke a massive soil disturbance scenario, (and there appear to be none for SAND around the 1860s), this species was –and remains - at most a limited component of the site.

The only reference I could find to suggest any other scenario was in the SCMS Environmental History document (Mitchell et al. 2006), which included the anecdote, "One night he feasted on lambsquarters" (*Chenopodium album*), "an edible plant that he reported was found only near old Indian camping grounds" (pg 26, line7-8). Thus, the soil core and subsequent analysis may reflect a "local hotspot" of these species.

Given that fact, the relative stability of the pollen counts for these groups might argue that human disturbances have not been excessive since the 1850s? The increase in pollen of *Artemesia* would argue for heavier grazing. The presence of *Pinus* and *Alnus* pollen in the samples collectively demonstrate that pollen has been transferred in from distant locations, yet the dominance by the weeds suggests an overwhelming effect of local pollen deposition.

3. **Sand Creek Massacre Site: An Environmental History** (Mitchell, Langfield, Fiege, 2007)

4. A modestly edited version of this report could be published as a book. This report reads well, and appears to be very well documented. The authors appear to have used many of the same sources identified in the Site Location study prepared in 2000. The authors have accepted what may currently be mainstream theory about the state of the western prairies in the 1800s. The combination of increased human populations, pre-existing huge herds of bison, and an exponential explosion in the number of horses, accompanied by droughts characteristic of this region, produced what appears to be an 'overgrazed' landscape. Such a landscape, theoretically, could have moved SAND towards the "early to mid seral" vegetation compositions discussed in the Roath et al. (2007) report. Thus, the deviation from the "Historic Climax Plant Communities" may have begun earlier than in the 20th century.

5. Both eastward and westward of this region, we know that periodic fires occurred at fairly frequent return intervals (2-4 year fire returns 300 miles to the east, and 7-12 year return intervals at the Colorado Front Range). Reduction of fuels by drought, overgrazing, or both would have reduced fire return intervals in this region during the 1800s, and it is possible that they were below the hypothesized 20-year burn interval for this region. At heavily grazed areas, and SAND could have been one of those, this might overestimate the fire return interval. Nonetheless, fire was an organizing factor of the biotic community to a modest degree at this site.

6. Comments about the technical accuracy of this document are minor, but include:

7. Pg 17, line 1. "tallgrasses" are usually considered warm season grasses and do not green up early. Chances are good these were all "cool season grasses", all of which would be considered mixed grasses. (Prairie sandreed (*Calamovilfa longifolia*) does green up earlier than most tallgrass species, but it's not on the current species list for SAND).

8. Pg 22, line 7. Buffalo grass is *Buchloe dactyloides*, the synonym listed is no longer valid. A few plant scientific names thereafter also are synonyms or misnomers for plant species used in the Roath (2007) report.

9. Page 60, first sentence. There's a potentially large difference in the landscape impacts of bison and cattle grazing IF fences were not involved. Bison were able to travel much farther from water, so the intensity of the grazing impacts was spread over a larger area. Cattle are much more likely to graze at or short distances from water; impacts are more localized. Bison impacts per pound of animal are perhaps a bit larger than those of cows (data from Konza Prairie, Towne et. Al. 2005), but it was the containment and seasonality of grazing that really produced the impacts.

10. Page 68. Vegetation list. This should match up with vegetation summaries and nomenclature from Roath (2007). Roath reports no fourwing saltbush (*Atriplex canescens*, not *Chenopodium amaranthus*). As suggested elsewhere, the findings of the pollen core study cannot be generalized to characterize SAND landscape.

Ref: Towne, E. G., D. C. Hartnett and R. C. Cochran. 2005. Vegetation trends in tallgrass prairie from bison and cattle grazing. Ecological Applications **15**: 1550-1559.

11. **A Preliminary Assessment of Wetland, Riparian, Geomorphology,and Floodplain Conditions at Sand Creek Massacre NHS** (Noon et al. 2005)

This report establishes the estimates of the 100 year flood plain and makes appropriate observations based upon that measurement. As noted in the report, the present floodplain appears to have been the consequences of larger flow regimes during a more mesic period and therefore the current floodplain is 'large' relative to anticipated flood runoff. This assumes no unusual upstream developments, but no such developments are anticipated.

Specific comments/observations.
The concern about erosion at this site and potential damage caused by any surface disturbance is real. However, in mitigating vehicle or even foot traffic, effects on surface runoff should also be considered. Vegetation adjacent to trails and roads is 'subsidized' in terms of water and nutrients, and this will select for species unlikely to be those previously adapted to local conditions.

The hydraulic problems associated with County Road W crossing were noted. The wetland at this site appears to have been enhanced during the 20th century to provide a water source for fire control purposes (Tilmant et al. 2006). If restored to more 'natural' conditions, this benefit may be lost. While artificial, there's little doubt the wetland area provides wildlife values not previously present. Among the options for dealing with the obvious flooding issues associated with the current configuration of culverts, a combined culvert and low water crossing design might be added to other options. While as

unnatural as the road, itself, designing this crossing for higher flows should still consider ways to maintain the wetland.

5. Prairie Dog Management Plan and Environmental Assessment (draft). (Sovell 2008)

This report appears to be an adequate synthesis of knowledge, but is missing the arguments for maintaining or even enhancing populations of this species in areas where they have the potential to function as keystone species (Miller et al. 2007). My major concerns with the proactive management suggestions in this report are fourfold. First, as mentioned elsewhere in this report, the assumption that precipitation will return to averages recorded in the 20th century remains uncertain. Accordingly, the analysis of prairie dog-vegetation also contains substantial uncertainty. Second, the prairie dogs appear associated with species of concern at SAND (mountain plover and burrowing owl; Hanni 2007). Third, an assessment of vegetation change associated with current prairie dog colony activity and paired uncolonized areas have not been conducted (although the data are available?). One interpretation of the vegetation inventories of this site conducted by Roath et al. (2007) is that in previous centuries prairie dogs may have occupied a much larger expanse of this area than current populations, and this historical influence is reflected in the very high forb abundance present in the current vegetation composition. Finally, this report concludes (pg 10) that proactive control efforts are likely to stimulate population growth, thereby resulting in rapid recovery of the population. If that's the case, why control in the first place?

In any event, a 'go slow' recommendation for proactive management of these important species seems appropriate. Perhaps meetings with private landowners will dictate some control measures at boundaries. Would it be appropriate for the Cheyenne and Arapaho peoples to weigh in on the significance of this species at the site?

"We conclude that the available information does not justify holding distribution and numbers of prairie dogs at a level that is too low to perform their keystone ecological function. We further conclude that it is especially important that prairie dogs be sufficiently abundant on public lands to perform this function" (Miller et al. 2007). The site has sufficient topography to (one would hope) prevent the prairie dogs from totally colonizing the area, but this topography might be facilitated with creative vegetation barriers.

Ref: Miller BJ, Reading RP, Biggins DE, Detling, James K.Forrest, Steve C., Hoogland, John L.Javersak, Jody, Miller, Sterling D., Proctor, Jonathan, Truett, Joe, Uresk, Daniel W. Prairie Dogs: An ecological review and current biopolitics. 2007. Journal of Wildlife Management 71: 2801-2810.

6. **Bird Inventory** (Hanni 2007)

A second opinion should perhaps be sought out to make sure the sampling intensity of this project was adequate (e.g., pg 3), but the species list seems complete to a non-specialist. This report provides a baseline inventory that now can be used and expanded through time. Reference to an "upland sage

habitat" (pg 3) presumably refers to the grassland transect. There is no natural "upland sage habitat" at this site.

The presence of 16 species of conservation concern highlights the value of this property for avian conservation. All site management activities need to be evaluated in terms of their potential positive and negative impacts on avifauna.

7. **Rare Species Inventory** (Sovell 2007).

This report provides baseline information on species of conservation concern. The report supports other studies regarding the absence of certain fish and plant species. The report's recommendation regarding a 'go slow' approach to plans for the reestablishment of such species as the lesser prairie chicken appears insightful.

8.**Riparian Forest Age Structure and Past Hydroclimatic Variability**. (Lukas and Woodhouse 2006)

As this report emerged from my own research institution, I must be considered in conflict with the authors and independent evaluation of this effort should be obtained. That said, this report provides information about the age structure and recruitment of cottonwood trees into the Sand Creek floodplain. These findings appear compatible with the historical accounts.

The work also supports the current model that cottonwood population dynamics would show interesting dynamics at both temporal and spatial scales. Along the reach of Sand Creek in SAND, for example, individual stands of trees would be recruited under similar climate/flood scour conditions at similar times, and such stands would inhibit subsequent regeneration. Die-back and an opening of the canopy would result in conditions favorable for reestablishment. Across the plains one can envision an undulating pattern of regrowth, maturation, and die-back of cottonwoods across the floodplain. At present, a maturing cottonwood forest occupies a substantial portion of SAND, but given the current age structure of the trees, the site may return to its 1864 configuration in the not-too-distant future. Of note is that the last large cohort of cottonwoods were seedlings during what was a hot and dry interval, demonstrating that simple rules about climate and regrowth of riparian forests is more complex that models based upon climate averages. Herbivory, or the absence thereof, could, for example, be a factor in seedling establishment.

Reconstruction of the climate of this region would likely show the period of Native American and European expansion into this region to be one that was perhaps more benign than what existed in the centuries prior to this period. In reconstructing the climate of the Western US, Cook et al. (2004) note that:

> "…this drought (in the early 2000s) pales in comparison to an earlier period of elevated aridity and epic drought in AD 900 to 1300, an interval broadly consistent with the Medieval Warm

Period. If elevated aridity in the western United States is a natural response to climate warming, then any trend towards warmer temperatures in the future could lead to a serious long-term increase in aridity…" (pg 1015).

Since those authors penned those words, the prognosis for the western U.S. continues to be one where drought scenarios have higher probabilities than other climate configurations (J. Overpeck, Univ. Ariz., pers. communication to TRS). This expectation of droughts that mimic (at a minimum) the intensities of those observed in the 1930s and 1950s should always be considered in management activities.

Ref: Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.A. Meko, and D.W. Stahle. Long-term aridity changes in the western United States. Science 306: 1015-1018.

9. **Fish Survey at Sand Creek Massacre NHS**, March 14, 2006 (Tilmant et al. 2006)

This report collaborates the rare species inventory, indicating that only the plains killfish has, to date, been positively identified as a resident of Big Sandy Creek. No additional inventories should be necessary until, perhaps, after then next major flow events on the Big Sandy. Species can be expected to be exchanged along that stream during high flow and deposited in permanent sites. However, localized extirpations clearly occur.

10. **An Ethnological and Ethnohistorical Assessment of Ethnobotanical and Cultural Resources of Bent's Old Fort National Historic Site and the Sand Creek National Historic Site** (Campbell 2007)

I do not possess the training to evaluate the dominant social science aspects of this work. Certainly the encyclopedic coverage of this report is acknowledged. The author clearly felt a "big picture" approach was required, and that approach has value. Here, we're provided extensive detail about the culture of the Cheyenne and Arapahoe during the mid to late 1800s, a focus that emphasizes the complexity of the cultures. Regretfully, the amount of time and detail paid to ethnobotanical information specific to SAND was modest at best. If possible, this particular portion of the project should be expanded and continued IF sources for this information are still available.

Among the reports I've read, the number of Cheyenne and Arapahoe killed in the massacre appears to be "over 150" (Mitchell et al. 2007) to "over 500" (Campbell 2007). Both numbers are appalling; but the best estimate should be reported? It would appear that Campbell chose to use the number reported by Chivington, which I assume is in error.

The scientific name for chokecherries (pg 74) is *Prunus virginiana*. This error is repeated on pg 214, where a reference URL is given that didn't exist at the time it was checked.

Pg 1558. There are some missing numbers that need to be added here.

Possible follow-up projects for the ethnobotany work:

Those species listed within the Campbell (2007) report need to be matched up with the vegetation inventory at SAND. What might be of interest is to note how the Cheyenne and Arapahoe nomenclature for the plants matches up with the concept of 'species', and how these patterns were affected by the use(s) of the plants?

11. **Special Soil Survey Report, Sand Creek Massacre National Historic Site, Colorado.** Draft July 2006. (NRCS report, survey date 12/19/2005.)

This report provides an update on the information provided by the Soil Survey of Kiowa County conducted by the USDA SCS (Anderson et al.) published in 1981. At the time of this writing I lacked a full version of this report, but it provides information similar to that published in 1981. These data will become the benchmarks for subsequent long-term soil monitoring activities recommended for NPS networks.

12. **Sand Creek Massacre project, volume 1: Site location study. Volume 2: Special resource study and environmental assessment.** Denver, CO: National Park Service 2000, Intermountain Region.

These reports have provided the background research in the general ecological and socio-economic history of the site. The near-encyclopedic reporting of all known relevant documentation, along with extensive oral histories, makes these volumes the core references for subsequent historical studies and analyses. As mentioned earlier, the only inaccuracy I could find in either of the reports involved the characterization of the SAND annual climate.

As noted by Emily Yost's web posting:

> "The Sand Creek Massacre National Historic Site Study Act of 1998 directed the National Park Service to "identify the location and extent of the massacre area and the suitability and feasibility of designating the site as a unit of the National Park Service system" and prepare alternatives for management, administration, and protection of the area. The National Park Service worked with the State of Colorado, the Northern and Southern Cheyenne tribes, Northern and Southern Arapaho tribes to locate the massacre site. The National Park Service Sand Creek Massacre project team used an integrated, multi-disciplinary approach to identify all potential locations of the massacre.
>
> The site location study was completed in 1999 with the cooperation of property owners, Cheyenne and Arapaho descendents, local residents, and scientists. Key features of the massacre lie within the site's mapped boundary: the encampment, sandpit area where the fiercest fighting occurred, and the paths of the military's approach and Indian's flight."

Yost's review provides an excellent summary. The ten years since the writing of these reports has not produced any historical inconsistencies with these documents. While there will always be uncertainties regarding the exact plant community configuration at the time of the massacre, and there will also be

uncertainties regarding specific details of the massacre itself, all available, relevant historical information appears to have been retrieved and reviewed.

Addendum:

In late August of 2008 I received a copy of "Environmental and Resources Update", prepared by J.C. Campbell. This report is a compendium of pre- and post- massacre accounts by individuals who directly or indirectly had information about SAND. The document provides natural history anecdotes in addition to important historical information. This document should assist future researchers who attempt to reconstruct the cultural and environmental features of this site over the last 200 years.