Snake River Gravel Pit, Grand Teton National Park and John D. Rockefeller National Parkway: Injury Assessment Due to the Introduction of *Carex feta* Bailey and Restoration

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Background

In 1992, the National Park Service (NPS) received notice that a 1950s-era gravel mining pit located near the Snake River was in violation of the Clean Water Act. The NPS, EPA, and the Army Corps of Engineers (ACOE) developed a wetland mitigation plan and EA; the FONSI was signed in 2002. Implementation of the plan was a cooperative effort using funds from the Federal Lands Highway Program and the State of Wyoming Abandoned Mine Lands (AML) Program to reclaim the site to a mix of wetland, oxbow ponds, and upland ecosystems similar to the naturally occurring ecosystems on the adjacent undisturbed Snake River floodplain. Wyoming and Grand Teton National Park signed an MOU on February 11, 2002 (AML Project 17F-8), which called for AML to design and bid the work through their consultant, with NPS design input and review. Plans clearly identified the native species to be planted and that all seed for plant propagation was to be collected from locations within 15 km of the restoration site.

In June 2003 contractors planted more than 550,000 herbaceous wetland plants and 35,000 willow stakes for the purpose of site restoration. The planting contract specified that three native *Carex* (sedge) species were to be planted (*Carex aquatilis* Wahlenb, *Carex utriculata* Boott, and *Carex vesicaria* L.).

In July 2004, I observed that many of the *Carex* that were planted on site, and were flowering, were not these three native species (Cooper 2004a). My observations were based on the fact that the *Carex* in question was densely caespitose, the leaves were yellowish in color, and the inflorescence was of many small, tightly packed spikes (see cover photograph). These characteristics distinguished this species from the three natives that were specified in the planting contract. It was also apparent that this species had not invaded from adjacent areas, as it was in rows, equally spaced, and the plug where the original planting was placed could be identified. Thus, it appeared that a large number of plants of an unknown species not specified in the planting plan had been introduced to the site by the plant contractor.

In August 2004, samples of this species were sent to experts in *Carex* taxonomy at the University of Michigan and Washington State University. They independently identified the plants as *Carex feta* Bailey**,** a species native only west of the Sierra

Nevada and Cascade Range in the Pacific coast states of the US and southwestern Canada (Cooper 2004b; Flora of North America Association 2002).

This species is not native to Wyoming or the Rocky Mountains and was not included in contract specifications. This species has never been found in Yellowstone or Grand Teton National Park, or John D. Rockefeller Jr. Memorial Parkway. An estimated 144,217 individuals of *Carex feta*, totaling 34% of all sedges alive in August 2004 were found on over 30 acres of National Park Service land.

Introduction

This assessment of damage to natural resources of the John D. Rockefeller, Jr. Memorial Parkway, a National Park Service Unit co-managed with and adjacent to Grand Teton National Park, and adjacent to Yellowstone National Park is based on information collected from August 2004 thru January 2006. The assessment information is a compilation of information collected by the following people and their assistants:

Dr. David Cooper, Colorado State University
Joel Wagner, National Park Service Water Resources Division
Pamela Benjamin, Supervisory Ecologist, Intermountain Region, National Park Service
Dr. Kelly McCloskey, Ecologist, Grand Teton National Park
John Moeny, Biologist, Grand Teton National Park
Dr. Joy Mastroguiseppe, Washington State University
Dr. Anton Reznicek, University of Michigan

Methods

Initial Assessment 2004

In August 2004, following identification of the exotic species as *Carex feta*, David Cooper, Kelly McCloskey and John Moeny designed and conducted vegetation

sampling at the Snake River Pit to assess the amount of damage, quantified as the number and proportion of exotic plants present (Cooper 2004a; Grand Teton National Park 2006a). Transects were located in the upper and lower sedge planting zones throughout the project area. The location of these zones was determined using the planting plan that had been used in 2003 for installing the herbaceous and willow stake plants. Transects ranged in length from 50-100 meters. Along each transect 5 to 12 circular plots of 1.5 m radius were sampled. The location of the center point of each plot along each transect was determined using a random number table. If the number selected would result in overlapping circles a new number was selected so that plants could only be sampled once. Within each circular plot all *Carex* plants were identified to species, and the number of individuals of each species was tallied for that plot, and averaged across the entire study site.

Carex plants had been grown from seed in 5.5 cu. inch plastic tubes, and were removed from the tubes when planted. However, the planting location for each tubeling could be identified. In addition, some planted "individuals" contained more than one species of *Carex*, for example *C. feta* with *C. aquatilis* and in these cases the presence of both species was recorded. Our data indicated that 34% of the 424,170 *Carex* planted on site were *Carex feta*. Thus, at least 144,217 *Carex feta* plants had been planted on the site. Since our assessment was done during the summer following the initial planting, it is likely that some tubeling mortality had occurred between the time of planting and our assessment, therefore 144,217 should be considered a minimum number of *Carex feta* planted. In addition, only the upper and lower sedge zones were analyzed but *Carex feta* had also been planted in the willow zone.

Attempted Eradication Fall 2004, Summer 2005

On September 21-24, 2004, and again in early July 2005 National Park Service crews attempted to eradicate *Carex feta* from the site through the use of a glyphosate-based, aquatically-labeled herbicide. This was a plant specific treatment, which directly sprayed each of the *Carex feta* plants on site. Because many thousands of *Carex feta* plants had flowered and produced fruits before identification and eradication

was possible in 2004 (see cover photo from 2004), a soil seed bank was produced during 2004, which likely included tens of millions of seeds.

Second Assessment Summer 2005

A second assessment of the number of *Carex feta* individuals on site was conducted in 2005 after the first attempted eradication. I and an assistant sampled the upper and lower sedge zones, as well as the willow zone of the site. We sampled a circular plot, 2 m in radius, around each ground water monitoring well that had been installed in 2005 within the zones planted in 2003. These wells were installed prior to the earthwork to measure depth to ground water and the data were used to determine the elevation of the final restoration surfaces. The wells were retained after the restoration and monitored to determine the depth to water table throughout the site. These are wells 14, 15, 17, 23, 25, 39, 43, 44, 45, 48, 49, 52 and 53. Wells 23, 25, 39, 43, 45, 49, and 53 occur at boundaries between upper and lower sedge zones, and the location of the plot center was moved directly up or down slope so that the entire plot could be within a single planting zone. At these wells two plots were sampled, one reflecting the upper and a second the lower zone were both analyzed. Within each plot all *Carex* were counted, and identified to species as in the first assessment performed in August 2004. In these plots 27.38% of the herbaceous plants sampled in the upper sedge zone, 17.98% in the lower sedge zone, and 4.64% sampled in the willow zone were *Carex feta*. These numbers were lower than we found in the 2004 assessment because the herbicide treatment in September 2004 had targeted and killed many of the *Carex feta* plants which could no longer be identified.

Surveys for *Carex* spp. seedlings were conducted in 2005 by John Moeny, who found large numbers of *Carex* seedlings in the vicinity of adult *C. feta* plants. Samples of these seedlings were sent to Dr. Anton Reznicek for identification. Dr. Reznicek cited several morphological characteristics that led him to believe with 90% certainty that the seedlings were *Carex feta* and not any of the three native *Carex* species. This is especially likely because the native *Carex* planted on site had not produced flowers by the end of 2004, thus seeds would not have been deposited on site.

Complete Site Eradication Required Summer/Fall 2006

Eradication of the introduced species was not successful and a significant *Carex feta* soil seedbank existed by the end of 2004 and 2005. National Park Service scientists, and managers, in coordination with researchers and restoration scientists developed a plan to completely eradicate vegetation on the site and remove the soil seed bank (Grand Teton National Park 2006b, c). The eradication plan included multiple treatments of the entire site with an Imazapyr-based herbicide as well as soil removal to a depth of approximately 4 inches to remove the soil seed bank and plant roots. The herbicide selected has a pre-emergent residual effect, which will likely inhibit the development of native as well as exotic vegetation for up to one year following application. The removal plan was implemented in 2006, and will be followed by site restoration including replanting the desired native plant species in the future. Execution of this plan was necessary to prevent continued damage at this site and the possible spread of the exotic plant to sites on surrounding park lands, other public lands, and private lands downstream along the Snake River (Grand Teton National Park 2006d,e). Additional eradication and monitoring efforts will occur in 2007 and 2008. Eventual site restoration may begin as early as Spring 2009, however substantial wetland plant cover will not be present until 2010 or later. During the eradication and monitoring phase no site recovery will occur, resulting in additional years of lost services for this wetland site.

Results

Area of injury

The area of injury is 45.8 acres, which includes 19.7 acres of wetland (willow, lower sedge, and upper sedge planting zones), 10.1 acres of uplands, and 16.0 acres of open water. We include open water as an area of injury because *Carex* were to form an emergent pond margin cover that is important habitat for boreal toad tadpoles, and the lack of vegetation surrounding the ponds is part of the injury, as it impacts ecosystem processes and their function as wildlife habitat.

Extent of injury to Wetlands

The site was planted in 2003. The exotic plant species was identified in 2004. This species adversely impacted the planted native species in wetlands and pond margins through its presence, competition for light, space, and resources, and because the 144,217 native plants that were supposed to be planted were not planted since 2003. *Carex feta* is tufted, meaning it did not spread as the native rhizomatous species would have, and vegetation development was slower than it would have been with the native species. Thus, this species would never have provided the complete ground cover desired for either the wetlands or pond margins. Between fall of 2004 and 2006 wetland function has been diminished by repeated herbicide treatments reducing herbaceous cover and biomass, which was done in direct response to the exotic species being present.

The application of herbicide killed many native plants, and plant cover at the site declined after the herbicide applications began in fall 2004. During 2006 all plant cover was removed, and the site will remain nearly devoid of plants during 2007 and 2008. Replanting is scheduled to begin in 2009. A short-term increase in plant cover and site functioning occurred in 2003 and through the summer of 2004, then a reduction in cover in fall 2004 and 2005, culminating in zero cover in 2006-2008. From the summer of 2006 through 2008 the site will function at 0% of the potential planned for the site. In 2009 or 2010 when planting occurs wetland functions will begin to accrue with full services anticipated in approximately 15 years. Had the correct species been

planted in 2003 the function would have begun to accrue at that time – instead it will begin at earliest in 2009.

Timeline **A**, below, was the initial time line for vegetation and wetland function development if native species had been planted. The data are percent of ecological functioning, with 100% being the fully restored site that is fully functioning. I anticipate that it will take approximately 15 years for 100% of wetland functions to develop. Timeline **B** is what happened due to the exotic *Carex feta* being planted. Timeline B includes the years 2003-2005 following plantings where native and exotic *Carex* were on site, the applications of herbicide, and soil removal in 2006, and anticipated replanting with native species in 2009.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
A.	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%
B.	5%	10%	5%	0%	0%	0%	5%	10%	15%	20%	30%

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
A.	95%	97.5%	99%	100%						
B.	40%	50%	60%	70%	80%	90%	95%	97.5%	99%	100%

Extent of Injury to Uplands

Vegetation that comprises the uplands surrounding the Snake River Pit is a diverse dryland meadow dominated by grasses and herbaceous dicots with occasional patches of lodgepole pine (*Pinus contorta*). Restoration of the uplands began in 2004 with a direct seeding of species whose seeds had been collected from the surrounding areas in the previous years. Seedling establishment was fair to good during the growing seasons of 2005 and 2006, with grasses reaching reproductive maturity and the herbaceous dicots beginning to establish. It is estimated that in 2005 the site was 5% recovered and in 2006 recovery was at 10%. Following the herbicide application and site excavation in 2006, the uplands were rendered completely barren. It is anticipated that the uplands will remain in an unvegetated state (0% recovery) during years 2007 and 2008 while *Carex feta* management occurs.

Restoring the diverse community that exists on the nearby uplands will take many years. Some species can be seeded, but others will require direct plantings. Below is a timeline that depicts the progression of recovery by year. A restoration prescription by year follows.

Timeline **C**, below, was the initial time line for upland vegetation development if *Carex feta* had not been planted. The data are percent of ecological functioning, with 100% being the fully restored and fully functioning site. Timeline **D** is what happened due to *Carex feta* being planted. Timeline D includes the years 2005 when upland plant seeding occurred, soil removal in 2006, and anticipated replanting with native species beginning in 2009.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
C.	5%	10%	30%	50%	60%	70%	80%	90%	95%	100%	
D.	5%	10%	0%	0%	5%	10%	30%	50%	60%	70%	80%

	2016	**2017**	**2018**
C.			
D.	90%	95%	100%

Restoration

Primary Restoration of Wetlands

Following the identification of *Carex feta* in 2004, injuries to the site were quantified and restoration began during the late summer of 2004.

2004. The first activity to occur was the blockage of all surface water outlets on site to reduce the probability that water transported seed would travel off site. This activity required a backhoe to push dirt across the outlets that occurred on the southwestern portion of the site. The second activity was the application of herbicides to attempt to kill *Carex feta*. NPS EPMT (Exotic plant management team) crews came to the site in September 2004 and spent 128 hours spraying herbicide on *Carex feta*.

2005. Additional herbicide applications to *Carex feta* were performed this year. *Carex feta* seed germination tests were performed by Grand Teton National Park staff this year to determine whether its seed were germinable.

2006. In 2006 a soil seedbank analysis was performed to determine the soil depths at which seeds were present (Grand Teton National Park 2006c). This research concluded that most seeds are within 4 inches of the soil surface. This soil thickness was the thickness proposed for removal that occurred in 2006. During 2006 several activities were conducted. Monitoring was conducted within a 5 mile radius of the Snake River Pit to identify whether *C. feta* had escaped from the site (Grand Teton National Park 2006d). Although *Carex feta* was not found in the surrounding landscape, this does not ensure that this exotic has not escaped and additional monitoring should be undertaken in the future. An additional survey was conducted in Yellowstone National Park, and was restricted to wetland areas known to be used by Canada geese, which are a potential seed dispersal vector (Grand Teton National Park 2006e). No *Carex feta* plants were found in Yellowstone. A third study was performed at the SRP to determine whether an overall reduction in *Carex feta* plants had occurred between 2004 and 2006 along the transects established to determine the number of plants present in 2004 (Grand Teton National Park 2006a). Late in the summer of 2006 soil excavation began at the Snake River Pit. The purpose of the excavation was to remove the *C. feta* seed bank and any existing live *C. feta* plants. One or 2 GRTE employees were present on site for the majority of

excavation to determine whether the contractor was completing the project to specifications. A specific goal was to accurately assess whether at least four inches of soil was being removed from the site — the contracted depth of excavation. The contractor removed at least 4 inches for the area, and an average soil thickness of 7.78 inches was removed and placed in the disposal site. In 2007 NPS will conduct weed control on the removed soil. In 2008 the disposal site will be capped with soil from the North Park Road project. It will be seeded in 2008 or 2009 with native upland plant species. Immediately following excavation the contract called for "roughing" the soil surface to create microtopographic variability required for optimum revegetation success. A number of transects were topographically surveyed before and after excavation to ensure that the correct thickness of soil was removed. The methods used are presented in a report, Snake River Pit Soil Removal (Grand Teton National Park 2006c).

2007. During 2007 GRTE staff will perform three detailed monitoring efforts (early, middle and late summer) at the SRP site to determine whether *Carex feta* or other *Carex* seedlings have established from seed missed by the soil excavation. Any *Carex* seedlings found will be treated with herbicide. Ground water monitoring wells will be reinstalled during 2007 where destroyed by soil removal during 2006. Wells will be monitored at least bimonthly to collect data on water table depth and elevation. These data will be used for designing the planting plan for 2009. Monitoring in Grand Teton and Yellowstone must occur during 2007 and in subsequent years to ensure that *Carex feta* has not spread to these areas. Seed of *Carex aquatilis, C. utriculata, C. vesicaria* and *Calamagrostis canadensis* and upland plants will be collected in the late summer of 2008 from nearby wetlands by NPS staff.

2008. During 2008 GRTE staff will perform three detailed monitoring efforts (early, middle and late summer) at the SRP site to determine whether *Carex feta* or other *Carex* seedlings have established from seed missed by the soil excavation. Any *Carex* seedlings found will be treated with herbicide. Seed of *Carex aquatilis, C. utriculata, C. vesicaria* and *Calamagrostis canadensis* will be collected in the late summer of 2008 from nearby wetlands by NPS staff. This seed will be stored over winter and treated in a suitable manner to facilitate germination, and propagation for planting on site in early summer 2009. The seed collection, storage and propagation will be performed by a

contractor. Ground water monitoring wells will be monitored at least bimonthly to collect data on water table depth and elevation that will be used for designing the planting plan. A planting plan will be developed in the fall of 2008 and the areas to be planted as lower sedge, upper sedge, and willow zones will be identified, and suitable seed numbers collected to grow plants for each planting zone.

2009. The planting zones, lower sedge, upper sedge, and willow, will be identified in the field and flagged, as soon as the snow has melted from the site. Plants will be installed into the appropriate zones starting in late May 2009. Dormant willow stems will be collected and planted in May, followed by planting of *Calamagrostis canadensis, Carex aquatilis, C. utriculata* and *C. vesicaria* tubelings. Post-planting long-term plots will be established to monitor the success of the plantings, and an initial round of data collected in late summer.

2010. Monitor ongoing injuries and determine whether corrective action is needed.

2011. Monitor ongoing injuries and determine whether corrective action is needed.

2012. Monitor ongoing injuries and determine whether corrective action is needed and a three year plant survival and spread report completed.

Primary Restoration for Uplands

2007. Herbicide application and management of *Carex feta* and other exotic plant species. Native species seed collection for direct seeding and container plant propagation.

2008. Continue herbicide application and management of *Carex feta* and other exotic plant species. Continue seed collection. Begin greenhouse production of select species to be transplanted into the uplands. Seed uplands in the fall of this year with a native grass seed mix.

2009. Monitor establishment of seeded species and perform weed control as necessary. Over-seed uplands with a mix of herbaceous dicot species that will add species and life form diversity to the site.

2010. Continued establishment of seeded species and exotic plant control. It is estimated that some of the plants that were seeded in 2008 will reproduce and add to the seedbank. Additionally, some nearby plant species will have begun to colonize the upland edges adding to the restoration. In the fall of this year, direct transplant the container grown plants into the site to round-out the site in species number and life-form (grasses, herbaceous dicots, shrubs, trees).

2011. Continued establishment of seed species. Species planted in 2009 should be approaching maturity and begin to add to the seed bank. Container plants will be established, but not mature.

2012. The site will mature from 2012 to 2018. Plant species inventories should be conducted in 2013 and 2014 to make sure that the site is not missing species or life-forms that exist in the surrounding uplands. If certain components are missing, they should be direct seeded or container grown and transplanted into the site.

Monitoring Ongoing Injury From 2004-2009.

Annual monitoring should occur as described above during 2007 and 2008 to determine whether *Carex feta* occurs on site. This monitoring should be a careful and thorough site analysis by trained botanists. All *Carex* seedlings found will be flagged, and removed completely, including roots, or treated with herbicide by qualified NPS personnel. In addition, existing and new ground water monitoring wells should be monitored biweekly during the summers of 2007 and 2008 to collect data on water table depth and its elevation that will be critical to the development of a planting plan. After planting in 2009, approximately 60-100 permanent plots should be established to monitor the survival and spread of the planted species, and to ensure the integrity of the vegetation composition. Plots should be approximately 2 m in radius, centered on each of the approximately 40 ground water monitoring wells that will be in place by end of 2007. In addition, 20 additional vegetation plots should be randomly established in each of the three planting zones, lower sedge, upper sedge, and willow. Immediately following planting, and at the end of 2009, all planted *Carex* and willows in each 2 m radius plot should be monitored for survival and species identity. Each plant should be counted, so that the number of individuals of each species is tabulated. Similar censuses

should occur in early summer 2010, late summer 2010, and late summer 2011. In addition, the late summer analyses should include an estimate of the percent canopy coverage for all plant species present in each plot. This will provide both a list of all species present, and changes in plant coverage which are excellent indicators of site recovery and development into a functioning wetland.

Compensatory Restoration

Both wetland and upland compensatory restoration project(s) will be at the former (abandoned) Flagg Ranch site adjacent to the Snake River. This site is located ~2 km north of the Snake River Gravel Pit (Figure 1) and historically contained floodplain wetland ecosystems similar to those at the gravel pit site, and uplands similar to those occurring near the gravel pit. The goal of the compensatory restoration is to remove human placed fill, restore the pre-disturbance hydrologic regime, and plant sites with suitable native plant species to restore the vegetation and wetland characteristics.

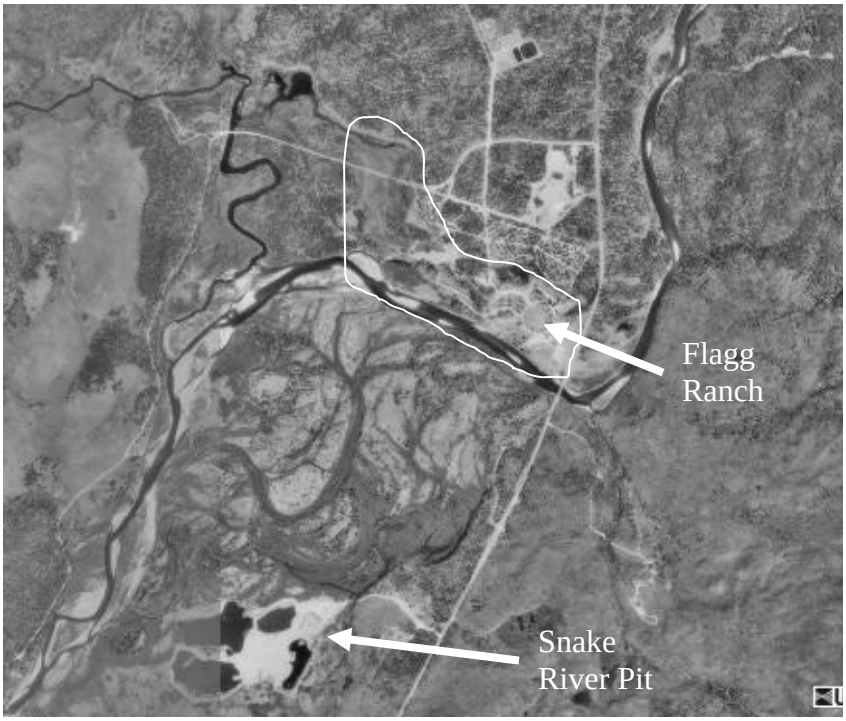

Figure 1. Locations of Snake River gravel pit and Flagg Ranch are shown in the black and white air photograph. The Snake River flows through the photo from top right to lower left. The highway running north to south is US 191/287.

The former Flagg Ranch site is a high priority restoration need of the National Park Service because the site has been disturbed by construction of visitor facilities, and is located within prime wildlife habitat along a riparian corridor. There are numerous fill piles in wetlands and on the Snake River floodplain, and areas where vegetation was removed that could be restored.

Compensatory Restoration Projects

Disturbances to the Flagg Ranch site include filling, vegetation removal, and ground disturbance. We have identified 16 areas that were disturbed and where restoration could occur. Some projects are for wetlands and others for uplands. Each is identified in Figures 2 and 3, and discussed here. In Table 1 I identify the restoration area, fill thickness and fill volume.

Site 1 is the triangular area of fill located just west of the current Flagg Ranch, and is 1.27 acres in size. This is an excellent wetland restoration option, which would require the removal of approximately 4,085 m^3 of fill to restore the former ground surface elevation. Our ground water monitoring wells indicate that the water table is close to the original ground surface, so removing the fill would restore the pre-impact hydrologic regime. The site should then be planted with *Salix boothii, S. lemmonii, Carex utriculata, C. aquatilis* and *Calamagrostis canadensis.* Some portions of this site may have supported willow stands, while others may have been largely *Carex.* Additional soil pits will be necessary to determine the exact fill thickness throughout the site, but based upon our test pits, an average of 0.79 m of fill is present. This fill could be transported upslope to the Flagg Ranch without impacting the adjacent undisturbed wetlands.

Site 2 is a small area of fill (0.13 acre) (Table 2) that has hummocky fill piles that were dumped by trucks. Willow removal also occurred. The fill should be removed, and the site planted to wetland vegetation similar to site 1.

Site 3 is a historic road that runs parallel with the Snake River. It does not appear that fill was placed in this site, but willows were cleared. Thus, wetland restoration would be a planting effort.

Site 4 is a large area of fill (1.27 acres) identified as the hummocky terrain created by a large number of truck loads that were dumped along the southern bluff margin.

Approximately 1357 m^3 of fill are present. More work is necessary to determine the exact volume of fill present, but once the fill is removed to the historic ground surface, wetland restoration could be accomplished and the site planted as described for site 1. A road already exists to the site from the bluff.

Site 5 is the area between sites 3 and 4. It is heavily disturbed by truck passages, and appears to be able to support upland vegetation.

Sites 6, 7, 8 and 9 are roads and other areas that were cleared of native vegetation. These areas could be restored to native wetland vegetation (sites 6, 7, 8) or uplands (site 9). We have no data to indicate that fill was placed on these sites so planting may be the only activity necessary for restoration.

Site 10 is another large disturbed wetland area (1.29 acre) at the base of the bluff. It is unclear whether any fill is present, and this area should be investigated further via backhoe pits. It is possible that the native vegetation was just cleared. This wetland restoration project would include planting of species similar to site 1, and possibly fill removal.

Site 11 is a road segment through a willow stand. No fill was found, and planting would be necessary to restore the native wetland vegetation.

Site 12 has a small area of fill and a larger area from which willows were cleared. Fill removal and planting are necessary to restore this site to a wetland.

Site 13 is a large area that was filled and vegetation removed. Wetland restoration would require both fill removal and replanting.

Site 14 contains the largest volume of fill that we found on the Flagg Ranch site, 6188 yd^3, which was used to partially fill a natural pond and sedge marsh. Wetland restoration would require fill removal and planting with *Carex utriculata* and *C. vesicaria*.

Site 15 is a large area of upland that has been filled. Since the water table depth even once the fill was removed would be too deep to support wetlands, the restoration goal should be upland vegetation. Thus, fill removal may not be necessary to restore the native upland vegetation.

Site 16 is a very large site and includes most of the area where the former Flagg Ranch buildings were located. Some fill is present but most of the site is disturbed uplands and should be restored to uplands.

Figure 2. Location of the 16 project sites overlain on a high quality air photograph.

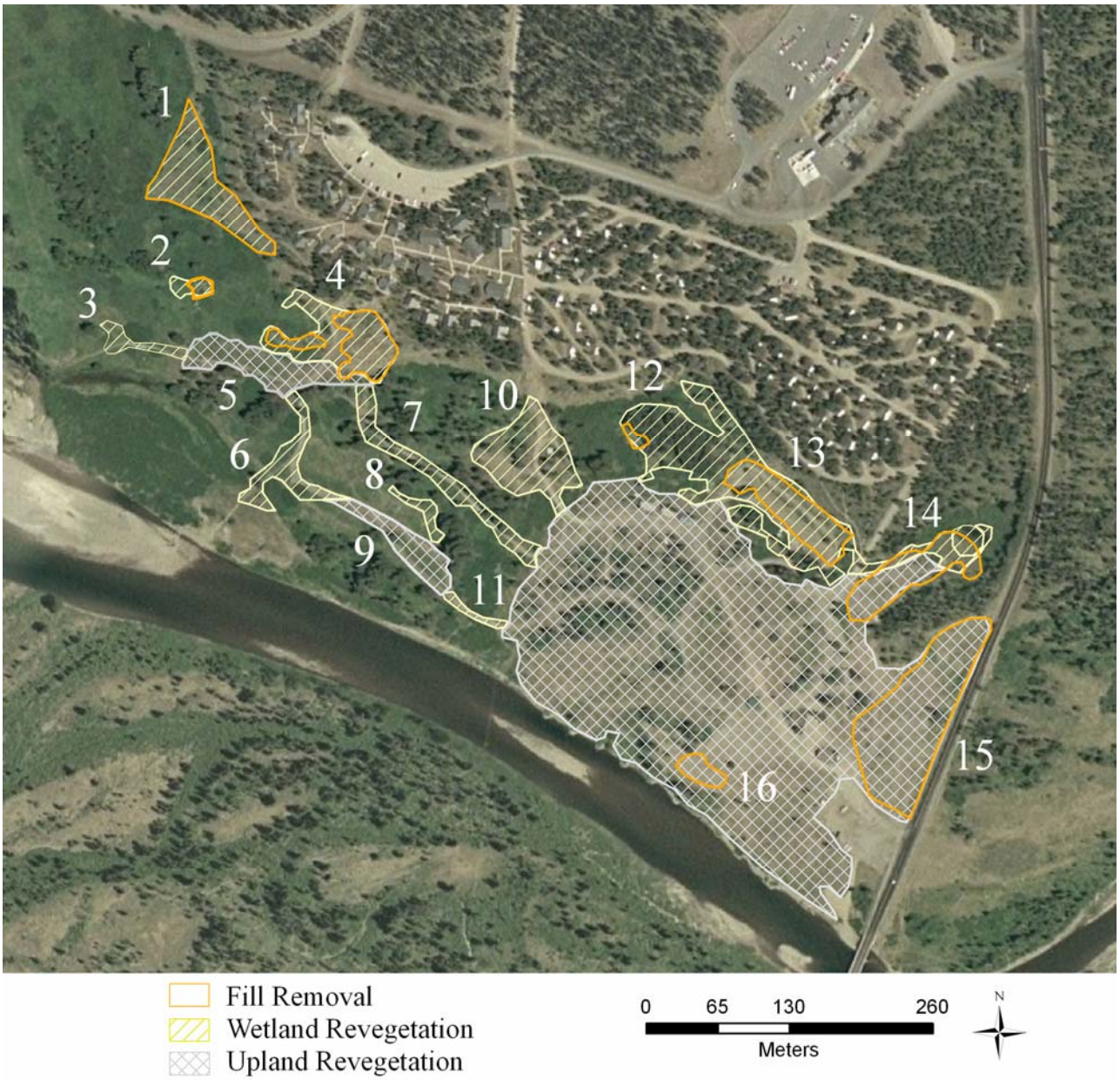

Figure 3. Location of the 16 proposed restoration projects, and identification of whether they include fill removal, and whether they are upland or wetland projects.

Table 1. Restoration area in m^2 and acres, area of fill in m^2, thickness of fill in m, and fill volume in m^3 and yd^3 for restoration areas at the Flagg Ranch. The potential restoration area for sites 12, 13, and 14, as well as 15 and 16 are combined.

Site	Restoration Area m^2	Restoration area acres	Fill Area m^2	Average Fill Thickness (m)	Fill m^3	Fill yd^2
1	5,154.87	1.27	5,154.87	0.79	4,085.13	5,343.35
2	513.14	0.13	293.30	0.61	178.79	233.86
3	870.50	0.22				
4	5,145.05	1.27	2,967.71	0.46	1,356.84	1,774.75
5	3,802.35	0.94				
6	2,450.95	0.61				
7	3,210.09	0.79				
8	581.02	0.14				
9	2,362.59	0.58				
10	5,208.00	1.29				
11	395.19	0.10				
12		3.74	250.88	0.46	114.70	150.03
13			3,690.18	0.55	2,024.58	2,648.15
14	15,122.84		3,880.31	1.22	4,730.87	6,187.98
15		21.92	10,167.87	0.30	3,099.17	4,053.71
16	88,703.60		768.12	0.76	585.31	765.59
Total	133,520.18	32.99	27,173.24		16,175.39	21,157.41

Compensatory Site Revegetation Approaches

Willow plantings can be used for vegetation restoration in many of the restoration sites following fill removal, or directly into the existing soil. Plantings should be dormant stems that are at least 2-3 feet long, and inserted into the soil so that at least 18 inches of the stem is below ground. Stems must be planted vertically. Many areas have gravel or cobble soils that are compacted, and will be hard to insert willow stakes into. These areas will have to be ripped with a backhoe to allow planting. The water table depth under many areas in the former Flagg Ranch is ~1 m deep in June. Likely the water table is ~0.5 m deep in May of a normal snowmelt runoff year. Thus, planting

must occur as early in May as the site is available so that willows are collected prior to leaf out, and planted while the ground water table is high.

Carex utriculata, C. vesicaria, C. aquatilis, and *Calamagrostis canadensis* should be grown from seed collected along the Grassy Lake road just west of the study site. Seedlings should be propagated in a commercial nursery and planted on site after fill is removed. The best time for planting will be in early June. The most likely locations for planting *Carex* are sites 1 and 14.

Upland revegetation approaches were outlined in previous sections of this report.

Compensatory Restoration Site Prioritization

The 16 restoration sites were prioritized by GRTE staff. The order presented below reflects projects that they felt could potentially provide good habitat value. The location of each site is shown in Figures 2 and 3, and the area and amount of fill are presented in Table 1. Each site and the proposed restoration project is described above. Each project is more fully described in Cooper and Patterson (2007).

Priority	**Site**	**Type**
1st	2	wetland
2nd	1	wetland
3rd	15/16	upland
4th	14	wetland
5th	3	wetland
6th	5	upland
7th	6	wetland
8th	9	upland
9th	8	wetland
10th	7	wetland
11th	11	wetland
12th	12	wetland
13th	4	wetland
14th	10	wetland
15th	13	wetland

Compensatory Restoration Site Recovery Rates

The restoration potential for wetlands and uplands at the Flagg Ranch site are shown in the following two tables. Lines E represent the percent of ecological functioning, relative to 100%, if the wetland restoration projects are not implemented. Lines F represent the percent increase in ecological function if the wetland restoration projects are implemented. Lines G represent the percent of ecological functioning, relative to 100%, if the upland restoration projects are not implemented. Lines H represent the percent increase in ecological function if the upland restoration projects are implemented. These tables assume that wetland and upland restoration projects are implemented in 2009. The wetland recovery to 100% functioning will take 15 years, while the upland will take 10 years.

WETLAND RESTORATION RECOVERY RATES

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
E.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
F.	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%

	2020	**2021**	**2022**	**2023**
E.	0%	0%	0%	0%
F.	95%	97.5%	99%	100%

UPLAND RESTORATION RECOVERY RATES

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
G	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
H	5%	10%	30%	50%	60%	70%	80%	90%	95%	100%

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