Pinyon Environmental, Inc.

July 13, 2018

2018 Vegetation Monitoring Activities on Reclaimed and Reference Plots

Ralston Quarry
Golden, Colorado

Prepared For:

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Pinyon Project No.:

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1. Introduction

From June 19 through June 21, 2018, Pinyon Environmental, Inc. (Pinyon), conducted vegetation monitoring activities on reclaimed and reference plots at the Asphalt Paving Construction Co., LLC., Ralston Quarry (Site), located in the town of Golden in Jefferson County, Colorado (Figure 1). The purpose of this project was to compare Site conditions to previous studies and to evaluate current Site conditions. This annual report satisfies conditions of the mining permit that the Ralston Quarry has with Jefferson County.

1.1 Project Location

The Site is located along the eastern edge of the foothills approximately eight miles northwest of Golden, Colorado (Figure 1). Highway 93 is located east of the Site and numerous two-tracks are located on the Site. Ralston Creek, which flows from west to east, is located north of the Site. Ralston Reservoir is northwest of the Site and Upper Long Lake is northeast of the Site.

Topography at the Site is varied and steep in some areas. The Site straddles a hogback which bisects the Site from north to south. The top of the hogback ridge is approximately 6,500 feet above mean sea level. There are a mix of ecosystems at the Site ranging from grasslands in the eastern portion to shrublands in the western portion (especially along the west side of the hogback).

The Site is actively being mined for gravel and rock products. Several residential properties are located west and north of the Site, but the area surrounding the Site mainly consists of open pasture land.

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2. Background and Summary

Pinyon was first contracted during the summer of 2003 to conduct the vegetation study. Prior to that time the study was conducted by Dr. John Emerick, formerly with the Colorado School of Mines. According to the 2001 report vegetative sampling began in 1995; however, the 2001 report was the only report available to Pinyon for review (Emerick, 2001).

Herbaceous vegetation sampling and data collection has been conducted at seven reference plots in undisturbed areas since 1995 (Figure 2). Four plots in an area that had been regraded and seeded in 1994 (i.e., the reclaimed area) were initially sampled in 1996. Data obtained at these 11 plots includes cover and biomass estimates for each plot (Figure 2). In addition, two shrub transects that parallel the top of the ridge to the west and east were used to estimate the cover and density of shrub species along the ridge crest (Figure 2).

Since Pinyon took over sampling in 2003, species diversity has been consistently higher in the reference plots compared to the reclaimed plots (Graph 1). When averaged over the past 16 years, the reference plots have an average of 56 species per plot while the reclaimed plots have an average of 20 species per plot. Large changes in the average number of species per plot were noted in 2011; it is likely that species that occur in lower numbers were sampled in previous years but did not happen to occur in the random quadrats sampled in 2011. Recently, the gap between the number of species in the reference plots versus the reclaimed plots has consistently increased year to year (comparing year to year data from 2015 through 2017). The increased gap may be due to the type of seeded species used to revegetate the reclaimed plots (for example, one species may be outcompeting other species and creating a monoculture). Additionally, the reclaimed plots are located near the active mine, the activities of which may be affecting fitness from indirect impacts such as dust deposition which is known to affect productivity rates (Farmer, 1993).

Mean vegetative cover has been consistently higher in the reference plots compared to the reclaimed plots (Graph 2). The reference plots have an average of 65% mean vegetation cover and the reclaimed plots have an average of 43% mean vegetation cover when averaged over the past 16 years. The type of seeded species used to revegetate the reclaimed plots and/or the type of species currently established in the reclaimed plots (for example, grasses and other weedy species versus native subshrubs and shrubs) may be a factor in this difference.

Mean productivity estimates (measured as biomass) has consistently been higher in the reference plots compared to the reclaimed plots (Graph 3). Averaged over the past 16 years the reference plots have a mean productivity estimate of 397 grams while the reclaimed plots have a mean productivity estimate of 243 grams. The type of seeded species used to revegetate the reclaimed plots and/or the type of species currently established in the reclaimed plots (for example, grasses and other weedy species versus native subshrubs and shrubs) may be a factor in this difference.

Shrub density for Transects 1 and 2 averages to approximately one shrub per square meter along the transects over the past 13 years (years 2003 through 2005 were left out of the analysis due to changes in methodology) (Graph 4). Averaged over the past 13 years, percent cover of shrubs was 21% cover for Transect 1 and 19% cover for Transect 2 (years 2003 through 2005 were left out of the analysis due to changes in methodology) (Graph 5). Shrub density and shrub cover have remained fairly consistent among and between Transect 1 and Transect 2 over the years. This is likely a result of the long-life span of shrubs and due to the fact that there is little disturbance in the areas where the transects are located.

In recent years (since approximately 2015), there has been a general trend in decreasing biomass productivity within the reference plots (Pinyon, 2015 through 2017). One possible reason for this could be that the continued biomass sampling (yearly harvesting of vegetation) has affected the growth patterns within the reference plots. The vegetation cover in the reclaimed plots is comprised more of seeded grasses than the reference plots. Grasses tend to respond favorably to grazing pressure (which biomass sampling mimics). The reference plots include a higher variety of forbs, including woody forbs such as buckwheats (*Eriogonum spp.*) and cacti (*Opuntia polyacantha* and *Echinocereus viridiflorus*). These woody forbs tend to grow slowly and respond negatively to continued cutting. Based on visual assessments during site visits the vegetation in the reference plots was noticeably different from the surrounding area. Confining both the cover and biomass sampling to the same 10 quadrats within a plot may be skewing these results.

To test the effects of continued sampling in established plots the sampling methodology was changed in 2018 to complete five quadrats to measure cover within the existing plots and five quadrats outside of the existing plots, with two quadrats for productivity inside of the existing plots and two outside of the existing plots. Although mean vegetation cover and mean productivity estimates for both the reference and reclaimed plots increased from 2018 to 2017, it does not appear that this change in methodology was driving the differences in data.

In future years, it may be useful to assess species evenness (i.e., relative abundance) and/or categorize species by functional groups (for example, native versus non-native or noxious weeds). Species diversity (i.e., the number of different species at a site) does not necessarily indicate the overall function of a site the way the species evenness or functional groups may. These assessments may be sensitive enough to detect difference between quadrats sampled inside of versus outside of established plots.

3. Methods

A total of seven reference plots and four reclaimed plots were sampled in 2018 (Figure 2). All reclaimed plots are located in the southern portion of the Site (Plot 8 through Plot 11), while the reference plots are located in the eastern and northern portions of the Site (Plot 1 through Plot 7) (Figure 2). Each plot was established by using the lower left-hand corner of the plot as the plot origin. Plots are oriented so that the bottom edge of the plot (i.e., the lower left-hand corner) is always located on the downhill side of the plot. Photos were taken from the bottom center of each plot (Appendix A). Each plot is divided into 27 one-by-one-meter quadrats (three quadrats long and nine quadrats wide).

The corners of all the reclaimed plots and the majority of the reference plots on the west side of the hogback are marked with rebar or T-posts. They are also fenced with barbed wire intended to limit access of browsing and grazing animals. The quadrats in these plots have been marked with rebar; however, some of the rebar has fallen or tipped over in the past.

All reference and reclaimed plots were found in 2018. However, in 2017 it was discovered that Plot 4-NE was not located on Ralston Quarry's property. Therefore, this plot was re-established on Ralston Quarry's property in 2018 (Figure 2).

In previous years, ten quadrats were randomly selected using a random number generator prior to visiting the Site for sampling. In 2018, five quadrats located within the plots were randomly selected using the same methodology prior to the Site visit, while an additional five quadrats were randomly selected in the field using a stratified sampling technique (i.e., random sampling within a 5-meter radius of the existing plots). This was done in order to address concerns about the effects of long-term sampling in the established plots. In total, ten quadrats were sampled for cover (five inside of the plots and five outside of the plots) and four quadrats were sampled for productivity (two inside of the plots, two outside of the plots) per plot.

Cover is generally the percentage of the ground surface in the quadrat covered by vegetation or some other element such as rock or litter. Productivity is measured as the mass of plant material covering the quadrat. Percent cover and productivity are two methods commonly used to assess plant growth. Within each quadrat measured for cover, a species list was compiled and percent cover for each species was estimated using a 1-meter by 1-meter frame (i.e., visual estimation). Rock, bare ground, and litter cover were also estimated for a total of 100 percent. Within each quadrat measured for productivity, plant material was clipped at the base of the plant with garden clippers and weighed in plastic bags using precision spring scales. The weight was standard wet weight expressed in grams and an average weight over the four quadrats was calculated for each plot.

A belt transect sampling method was used to estimate the cover and density of shrubs within the two shrub transects. Each transect was 50 meters long and 2 meters wide (1 meter on either side of center). Within each belt a count of individual shrubs by species was conducted and then a line transect was completed along the tape to estimate percent cover by shrub species using the point-intercept method. Transect 1 was located on the west slope of the ridge, just north and east of Plot 1-NW, and Transect 2 was located on the east slope of the ridge, just north and west of Plot 4-NE (Figure 2). Photographs were taken of each plot and of the transects to document Site conditions and assist with future re-sampling (Appendix A).

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4. Results and Discussion

4.1 Species Diversity - Plots

A total of 56 species were noted in the seven reference plots (Figure 2, Tables 1, 2, and 6). The overall number in 2018 is 13 species lower than in 2017, although the species composition is similar. Seven species new to the reference plots were noted, all of which are native species except one. The 2018 Site visit was conducted approximately one week earlier than the Site visit in 2017, indicating phenology may be a factor in the new species. It is likely that the new species are uncommon in the study area and happened to occur in the random quadrats that were sampled. Changing methodologies (i.e., sampling outside of plots) may also be a contributing factor.

A total of 18 species were identified in the four reclaimed plots (Figure 2, Tables 3, 4, and 6). This is two species less than that identified in 2017. Smaller annual forbs may have finished blooming and/or may not have started to bloom yet and/or have been hidden by species with more cover such as smooth brome (*Bromus inermis*) or yellow sweet clover (*Melilotus officinalis*).

The number of species observed per reference plot (Plots 1 through 7) ranged from 21 to 25, with an average of 22 species per plot. The highest species diversity was observed at Plots 1 and 4 (Table 1); this differs from previous years in which Plots 5 and 7 contained the highest levels of species diversity. Additionally, in previous years the west side of the ridge (Plots 1 through 3) had lower species diversity compared to the east side of the ridge (Plots 4 through 7). However, in 2018, species diversity was similar in reference plots on the east and west sides of the ridge, with both sides of the ridge having an average of 22 species per plot.

The number of species observed per reclaimed plot (Plots 8 through 11) ranged from 9 to 13, with an average of 11 species per plot. The highest species diversity was observed at Plot 11 (Table 3); this differs from previous years in which Plots 8 and 9 contained the highest levels of species diversity. Overall, the average number of species in the reclaimed plots (11 species) was 50% of the average number of species in the reference plots (22 species). The gap between the number of species in the reference plots versus the reclaimed plots has consistently increased year to year (comparing year to year data from 2015 through 2017). The increased gap may be due to the type of seeded species used to revegetate the reclaimed plots (for example, one species may be outcompeting other species and creating a monoculture). Additionally, the reclaimed plots are located near the active mine, the activities of which may be affecting fitness from indirect impacts such as dust deposition which is known to affect productivity rates (Farmer, 1993). However, the difference between the mean vegetative cover of the reclaimed plots versus the reference plots was lessened in 2018.

The average number of species observed per quadrat sampled outside of and within the established reference plots was 18 and ranged from 16 to 21 species (i.e., no difference was noted for species diversity between quadrats sampled inside versus outside of reference plots). The average number of species observed per quadrat sampled outside of the established reclaimed plots was 10 and ranged from 7 to 13. The average number of species observed per quadrat sampled inside of the established reclaimed plots was 8 and ranged from 6 to 12 species. Overall, no difference was noted in species diversity for the quadrats sampled outside of versus within established reference plots, while the quadrats sampled outside of the established reclaimed plots had slightly higher levels of species diversity compared to those within the established reclaimed plots.

4.2 Vegetative Cover - Plots

The mean vegetative cover for the reference plots was 74% (a 9% increase from 2017) and ranged from 64% at Plot 3 to 87% at Plots 1 and 7 (Table 1 and Table 6). Overall, mean vegetation cover was higher compared to 2017 for all plots except for Plot 3.

The mean vegetation cover for the reclaimed plots was 64% (a 17% increase from 2017) and ranged from 55.5% at Plot 9 to 75% at Plot 11 (Table 3 and Table 6). Overall, mean vegetation cover was higher compared to 2016 and 2017 for all plots.

The mean vegetative cover for quadrats sampled outside of and inside of the established reference plots was 82% (i.e., no difference between mean vegetative cover outside versus inside of the established reference plots). The mean vegetative cover for the quadrats sampled outside of the established reclaimed plots was 89%, while the mean vegetative cover for quadrats sampled inside of the established plots was 91% (difference of 2%).

The overall increase in mean vegetation cover from 2018 compared to 2017 may be due the type of vegetation present, for example, yellow sweet clover and rubber rabbitbrush, both of which grow tall and create a lot of cover. The new study design of sampling outside of the established plots does not appear to be a driver in this difference.

4.3 Biomass - Plots

The mean productivity estimate (measured as biomass) for the seven reference plots was an average of 620 grams per square meter (g/m^2), which is the highest average noted since 2014 (Table 6 and 7). Biomass estimates for the seven reference plots ranged from 425 g/m^2 in Plot 4 to 800 g/m^2 in Plot 6 (Table 7). The mean biomass productivity estimate for the four reclaimed plots was 438 g/m^2, which is the highest average noted to date (Table 6 and 7). Mean biomass estimates for the four reclaimed plots ranged from 318 g/m^2 in Plot 10 to 590 g/m^2 in Plot 8 (Table 7).

The mean biomass productivity for reclaimed sites has been lower than the reference sites since the study began in 2003. For both the reference and reclaimed sites there has been a general decreasing trend in mean biomass productivity from year to year (Table 6 and Table 7). However, 2018 showed an increase in mean biomass productivity for both the reference and reclaimed sites. This overall increase may be due to the new study design of sampling outside of the established plots.

The mean biomass productivity for the quadrats sampled outside of the established reference plots was 571 grams, while the mean biomass productivity for the quadrats sampled inside of the established reclaimed plots was 669 grams (difference of 98 grams). The mean biomass productivity for the quadrats sampled outside of the reference plots was 443, while the mean biomass productivity for the quadrats sampled inside of the established reclaimed plots was 434 (difference of 9 grams).

4.4 Transects

Shrub density for Transect 1 was 0.052 shrubs per square meter and shrub cover was 22% (Table 5 and 6). Shrub density for Transect 2 was 0.005 shrubs per square meter and shrub cover was 26% (Table 5 and 6).

Although the cover of shrubs along Transect 2 was higher than along Transect 1, the density of shrubs was lower (i.e., there were fewer shrub individuals in Transect 2, but the shrubs were larger in size). This relationship of fewer but larger shrubs at Transect 2 has been observed since 2013.

The shrub density and percent cover for Transect 1 increased from 2017 to 2018. The shrub density for Transect 2 decreased slightly, while percent cover increased slightly from 2017 to 2018.

5. Conclusions

In general, the reference plots tend to have a higher number of species (species richness) than the reclaimed plots. The reference plots also have a higher mean vegetative cover compared to the reclaimed plots. This trend was noted in 2003 and has been continuing through 2018. However, the difference between the mean vegetative cover of the reclaimed plots versus the reference plots was lessened in 2018. This does not appear to be a result of new methodology sampling outside of the established plots. This new methodology does not seem to be driving the high mean productivity estimate for the reference plots (only one other year, 2014, had higher levels). The mean productivity estimates for the reclaimed plots were also higher than in 2017.

The most noticeable difference between the 2017 data compared to the 2018 data is the increase of mean vegetative cover and mean productivity estimates for both the reference and reclaimed plots. Additionally, species diversity decreased in both reference and reclaimed plots. It was hypothesized in 2017 that the continued biomass sampling (yearly harvesting of vegetation) may have affected the growth patterns within the plots. Therefore, in 2018, sampling methodology was changed to complete five quadrats to measure cover within the existing plots and five quadrats outside of the existing plots, with two quadrats for productivity inside of the existing plots and two outside of the existing plots. This change in methodology may have accounted for some of the effects of continued sampling in one location. For example, Plot 2 had higher amounts of diffuse knapweed (*Centaurea diffusa*) inside of the existing plot (perhaps as a result from the annual disturbance of clipping vegetation), while skunkbrush sumac (*Rhus trilobata*) was noted in much higher amounts outside of the existing plot. However, this trend was not consistent among all plots. Next year it may be useful to assess species evenness (i.e., relative abundance) and/or categorize species by functional groups (for example, native versus non-native or noxious weeds). Species diversity (i.e., the number of different species at a site) does not necessarily indicate the overall function of a site the way the species evenness or functional groups may. These assessments may be sensitive enough to detect difference between quadrats sampled inside of versus outside of established plots.

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