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Hanford Site Post-Fire Vegetation Monitoring Report for Calendar Year 2021

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000031

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Hanford Site Post-Fire Vegetation Monitoring Report for Calendar Year 2021

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1.0 INTRODUCTION

The Hanford Site presents an expanse of shrub-steppe habitat that provides exceptional value to plants and animals located on the Site and in the surrounding greater Columbia Basin. The greatest threat to this habitat is fire-related conversion to a cheatgrass-dominated monoculture. In order to decrease future fire risk and to disrupt the positive feedback cycle between cheatgrass and fire, land managers can make efforts to restore native vegetation following a fire. The goal of this report is to analyze vegetation recovery post-fire in both restored and unrestored areas to inform future post-fire response actions.

1.1 BACKGROUND

The Hanford Site consists of 1425 km^2 of land that has been closed to the public since the 1940s. Though sections of the Hanford Site have been developed, it contains one of the last remaining continuous stretches of shrub-steppe in the Columbia Basin. This stretch of land provides habitat for endangered, threatened, and rare species of plants and animals, and acts as a refuge for species that rely on shrub-steppe to survive. Though the habitat on the Hanford Site is not heavily threatened by development like other areas of the Columbia Basin, fire presents a threat to the integrity of the ecosystem. As fires become more frequent and intense in shrub-steppe areas, planning post-fire restoration and monitoring has increased in importance and is a crucial management tool in retaining shrub-steppe ecosystems.

High-quality big sagebrush (*Artemisia tridentata*) communities have a perennial herbaceous understory, mainly in the form of bunchgrasses such as bluebunch wheatgrass (*Pseudoregnaria spicata*) and needle-and-thread grass (*Hesperostipa comata*) (HNF-61417). Spacing between individual perennial bunchgrasses creates gaps in fuel availability that reduce fire efficiency and prevent fires from spreading over large areas (Whisenant 1990). The extent of high-quality sagebrush communities is declining, both at Hanford and throughout the Columbia Basin (Bakker et al. 2011). A significant contributor to this decline is the introduction of invasive annual grasses and subsequent reduction in the fire-return interval, causing increased fire frequency and intensity (Whisenant 1990). Cheatgrass (*Bromus tectorum*) is an annual grass that has invaded much of the arid west and contributed heavily to increasing fires (Whisenant 1990).

Along with the introduction of European settlers to the West came the invasion of nonnative plant species, some capable of outcompeting and displacing native species (Klemmedson and Smith 1964). One of the most habitat-altering invasive plant species in the shrub-steppe ecosystem is cheatgrass, which was first found in the Pacific Northwest in 1889 (Mealor et al. 2013). The range of cheatgrass now extends through all 50 states and it has become the dominant annual grass in much of the Columbia Basin and Great Basin, with an estimated annual spread rate of 14% (USDA 2019, Mealor et al. 2013). Cheatgrass is a winter annual that germinates before the majority of the native grasses, giving it a competitive advantage in securing water and space resources. It does not exhibit the same spacing as bunchgrasses and will blanket the understory, resulting in a large amount of continuous biomass that act as fuel, increasing the frequency, duration, and intensity of wildfires (Knapp 1996, Whisenant 1990). Once burned, cheatgrass survives in the seed bank and recolonizes the area, often outcompeting

native plants at the Hanford Site (Humphrey and Schupp 2001). As Mealor et al. (2013) describes:

> *Since the invasive can outcompete native seedlings at a disturbed site, fire can lead to a positive feedback cycle of increased fire frequency and increased dominance of cheatgrass*.

Wildfire has been a significant driver in changing vegetation cover throughout the Hanford Site (HNF-61417). Historically, shrub-steppe habitat in the west experienced fire approximately every 32 to 70 years (Wright et al. 1979). The majority of the Hanford Site has burned at least once in the last 40 years, some areas as many as five times as of 2020 (Figure 1). Sagebrush are slow to reestablish in areas that have burned multiple times, resulting in not only a loss of native understory plants to cheatgrass after fire but also a loss of the dominant overstory shrub. Recovery of sagebrush canopy cover after a fire has been estimated to take over 100 years in the shrub-steppe environment (Cooper 2007). As of 2017, areas containing cheatgrass as a component of the understory encompass approximately 65% of the Hanford Site (HNF-61417). The extensive cover of cheatgrass and associated increase in fire frequency amplifies the chance of future fires and threatens the longevity of the shrub-steppe habitat at the Hanford Site.

1.2 PURPOSE AND NEED

Without intervention and active management, cheatgrass fires result in a loss of total plant diversity and can result in the complete loss of the sagebrush overstory (Mealor et al. 2013, Bakker et al. 2011). The Inter Mountain Basins Big Sagebrush Steppe ecological system is considered to be imperiled and the Inter Mountain Basins Semi-Desert Shrub-Steppe and Inter-Mountain Basins Active and Stabilized Dune ecological systems are considered to be critically imperiled in Washington State (Rocchio and Crawford 2015). These three systems make up the majority of the Hanford Site and fire poses a major risk to the stability of the native vegetative communities in these areas (HNF-61417).

In order to decrease future fire risk and to disrupt the positive feedback cycle between cheatgrass and fire, land managers can make efforts to restore native vegetation following a fire. Restoration post-fire is thought to be advantageous; immediately following a fire cheatgrass seeds are temporarily reduced in the seed bank (Humphrey and Schupp 2001). This temporary reduction in cheatgrass dominance would give native plants a chance to establish, but studies have shown that in cheatgrass-dominated areas few native seeds (less than 4%) are present in the seed bank following a fire (Humphrey and Schupp 2001). This is not sufficient to establish a strong native population, suggesting human intervention may be required.

The Hanford Site lacks sufficient data on post-fire vegetation survival and recovery. Studies have occurred on the neighboring Arid Lands Ecology Reserve measuring the effects of repeated fire on vegetation monitoring plots and the success of restoration treatments (Bakker et al. 2011). Though similar plots exist on central Hanford, limited monitoring has occurred at these sites.

The purpose of this monitoring effort is to collect and analyze data on the immediate and long-term effects of fire on plant communities to better understand vegetative succession after fire in

different habitat areas of the Hanford Site. Additionally, this monitoring effort analyzes the effectiveness of post-fire restoration in recently burned areas. These data will be analyzed and used to better plan and execute future post-fire restoration activities.

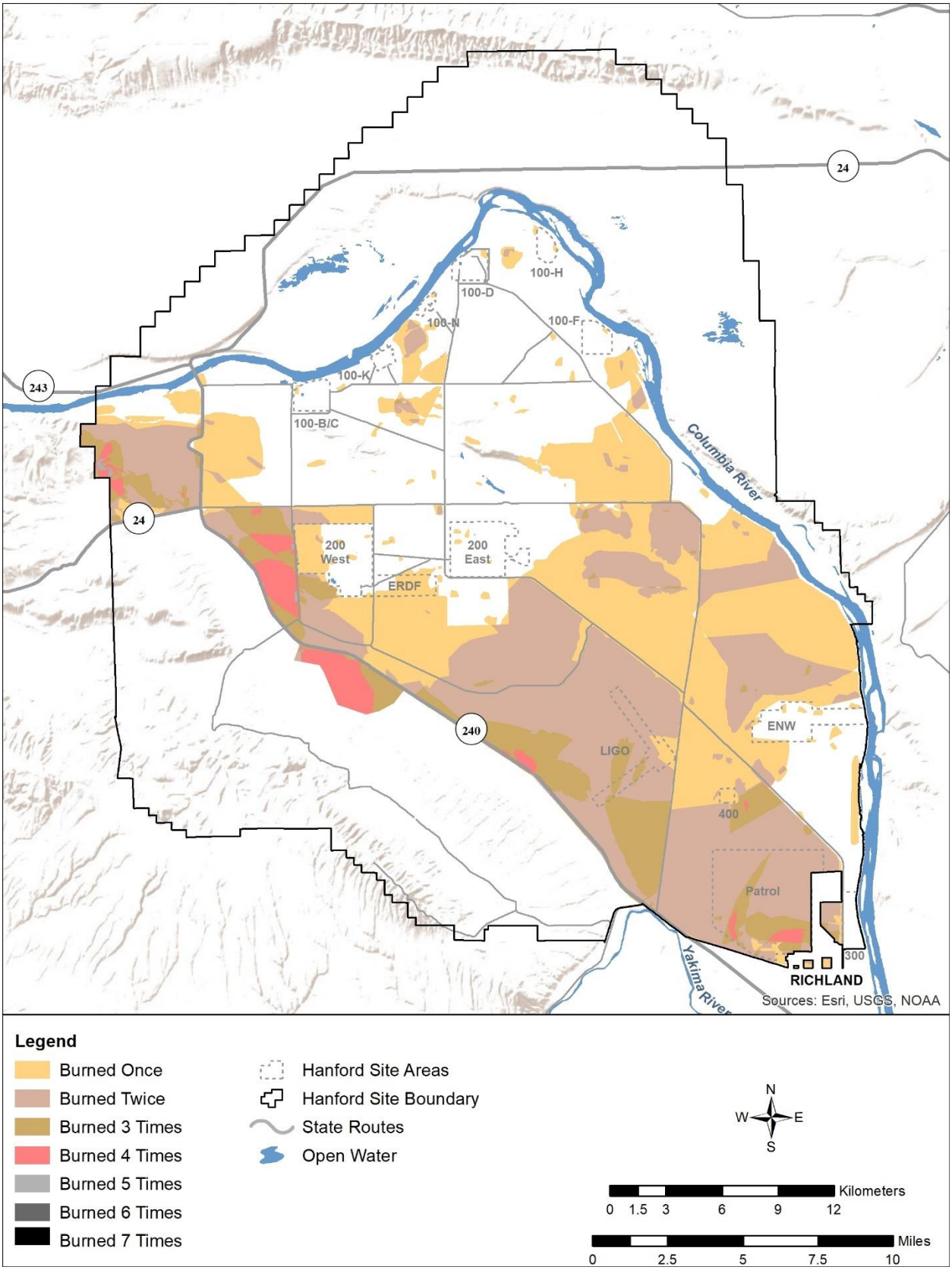

Figure 1. Hanford Site Fire Boundaries from 1974 to 2020.

1.3 REGULATORY DRIVERS

1.3.1 Federal Laws and Policy

The U.S. Department of Energy, Richland Operations Office (DOE-RL) conducts ecological monitoring on the Hanford Site to collect and track data needed to ensure DOE-RL compliance with an array of laws and policies. Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE-RL stewardship required for decision making under the *National Environmental Policy Act of 1969* and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

The Federal Wildland Fire Policy (FWFP) requires burned areas to be assessed to determine appropriate rehabilitation and restoration activities and requires those activities to be evaluated to assess their effectiveness (USDOI 2009). Additionally, this policy emphasizes prevention, which includes mitigating risks and losses to ecosystems (USDOI 2009). Though this policy applies to federal agencies governed by the Department of the Interior, aligning Hanford Site strategies with the requirements set forward within the FWFP will better align the Hanford Site's fire management strategy with that of neighboring U.S. Fish and Wildlife Service land. This monitoring effort both assesses burned areas and evaluates the effectiveness of restoration activities, aligning Hanford Site environmental stewardship with the FWFP.

1.3.2 Hanford Site Management Guidance

The *Hanford Site Biological Resources Management Plan* (BRMP, DOE/RL 96-32) is identified by the *Hanford Comprehensive Land-Use Plan* (DOE/EIS-0222-SA-01) as the primary implementation control for managing and protecting natural resources on the Hanford Site. According to Section 1.4.1 of the *Hanford Comprehensive Land-Use Plan* (DOE/EIS-0222-SA-01), the BRMP

> *provides a mechanism for ensuring compliance with laws protecting biological resources; provides a framework for ensuring that appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford biological resources; and implements an ecosystem management approach for biological resources on the Site. The BRMP provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives.*

Section 5.1.3 of the BRMP describes Fire Management practices at Hanford.

> *Burned area replanting will be considered on a case-by-case basis. Determining if replanting is needed depends on the site, pre-existing plant community, characteristics of the wildfire, level of damage sustained by native vegetation, and likelihood the burned area will further degrade if restoration actions are not performed.*

This monitoring effort documents the level of damage sustained by native vegetation and provides data regarding vegetation recovery in both the short- and long-term. This monitoring effort supports current biological resources management activities and falls under the guidance of the BRMP.

1.4 GOALS AND OBJECTIVES

The specific objectives of this monitoring report are to:

- Provide first-year data on post-fire restoration
- Provide long-term data on natural post-fire vegetation recovery
- Evaluate the impacts of post-fire restoration actions
- Evaluate the natural recovery of vegetation in historically burned areas
- Recommend actions to improve post-fire vegetation management.

This monitoring report is the first report in a multi-year effort to analyze short- and long-term vegetation recovery after fire on the Hanford Site. The results of this effort will help inform future post-fire management activities and provide crucial data on the natural recovery of Hanford Site habitats after fire.

1.5 SCOPE OF MONITORING REPORT

The remaining sections of this monitoring report cover the following topics:

- **Section 2** provides background on the large (more than 100 acres) fires that occurred in 2020 and describes any post-fire restoration efforts that occurred.

- **Section 3** summarizes the methods used in short- and long-term post-fire monitoring.

- **Section 4** presents the results of the monitoring effort for calendar year 2021.

- **Section 5** discusses the results and their overall implications for post-fire vegetation recovery on the Hanford Site.

- **Section 6** lists the literature cited throughout this report.

2.0 2020 FIRE SUMMARY

This section describes the large (more than 100 acres) fires that occurred on the Hanford Site in 2020 and includes details regarding any post-fire restoration that occurred. Additionally, this section records the rationale behind post-fire restoration decisions and provides details regarding the post-fire restoration process. One large fire occurred on the Hanford Site in 2020, the Gable Mountain Fire.

2.1 GABLE MOUNTAIN FIRE

On May 30, 2020, a 5,510-acre fire occurred on the Hanford Site on Gable Mountain and in the surrounding area (Figure 2). The cause of this fire is believed to be lightening. The fire caused considerable damage, completely removing the majority old growth sagebrush overstory on large areas of land and leaving little surviving vegetation. The fire covered both biologically valuable sagebrush habitat and culturally significant areas and resulted in harm to biological and cultural resources. The decision to restore the burned area with a native seed mix was made based on the ecological and cultural value of the habitat.

The pre-fire vegetation cover types were evaluated to develop appropriate seed mixes for the burned area. Historic vegetation mapping data, field surveys, and photo points were used to determine what plant communities were present in the burned area before the fire. The vegetation mapping data was pulled from the 2017 report *Upland Vegetation of the Central Hanford Site* (HNF-61417), which used both field surveys and aerial photography to determine the primary grass and shrub components of habitats throughout the DOE-RL-managed portion of the Hanford Site. In order to confirm these vegetation data and to evaluate the surviving vegetative community, post-fire vegetation monitoring occurred in June once the burned area was safe to enter. In these field surveys, surveyors walked transects throughout the burned area and noted surviving plant species and distinguished which sections of the burned area were severely impacted by the fire. This survey differed from the October 2020 survey (described in Section 3.1) that established set transects for long-term monitoring. In addition to the data analysis and post-fire monitoring, historic photo points were evaluated to determine how the vegetative community had changed post-fire. Photo points showed dramatic changes in the landscape (Figure 3).

Based on the collected and existing data on vegetation composition in the burned area, three seed mixes were developed to restore the area. These seed mixes were developed to include the plants dominant in the native environment pre-fire. One seed mix targeted the areas surrounding Gable Mountain with high density sagebrush cover pre-fire, one targeted the areas surrounding Gable Mountain with low density or no sagebrush cover pre-fire, and one mix targeted the higher elevation areas that were burned on Gable Mountain. The boundaries of each seed mix are shown in Figure 4. Table 1 describes the species seeded in each mix along with the approximate rate of Pure Live Seed per acre. The seed mixes were made up of locally collected or native-grown grasses and the high-density sagebrush seed mix included big sagebrush seed in an attempt to restore the shrub layer in that area. Seed mix rates were initially calculated by doubling broadcast seeding rates in the *Hanford Site Revegetation Manual* (DOE/RL-2011-116) due to the expected lowered success with aerial seeding and restrictions on covering the seed with straw or mulch. The actual Pure Live Seed rate per acre was heavily determined by regional seed availability, which resulted in decreases in key species like needle-and-thread grass (*Hesperostipa comata*) and increases in available species like sand dropseed (*Sporobolus cryptandrus*) and prairie junegrass (*Koeleria macrantha*). Table 1 shows the broadcast seeding rates for each species, some of which are below the rate that was targeted due to availability. The three seed mixes were broadcast via helicopter over the entire burned area in January 2021, 7 months after the fire had occurred.

The area restored in this effort will be monitored annually for 5 years to track the recovery of the burned area. The first year of this monitoring is summarized in Section 4.1 of this report. The area will then be added to long-term post-fire monitoring as part of Hanford Site post-fire ecological monitoring. The methods used to evaluate post-fire recovery in this area are described in Section 3.0.

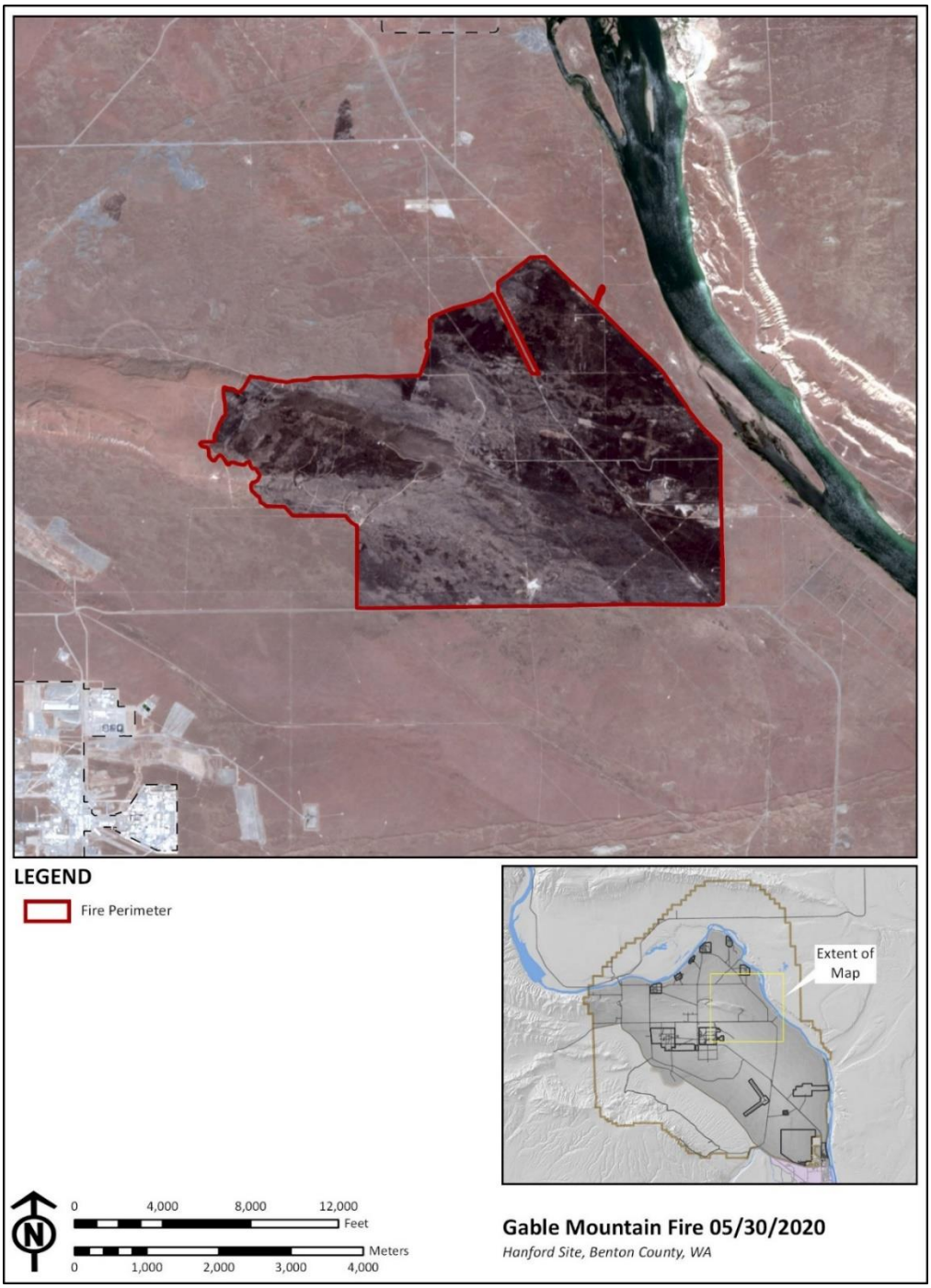

Figure 2. The Area Burned in the Gable Mountain Fire in May 2020.

Figure 3. The High-Density Sagebrush Area in 2017 (top) and after the Gable Mountain Fire in 2020 (bottom).

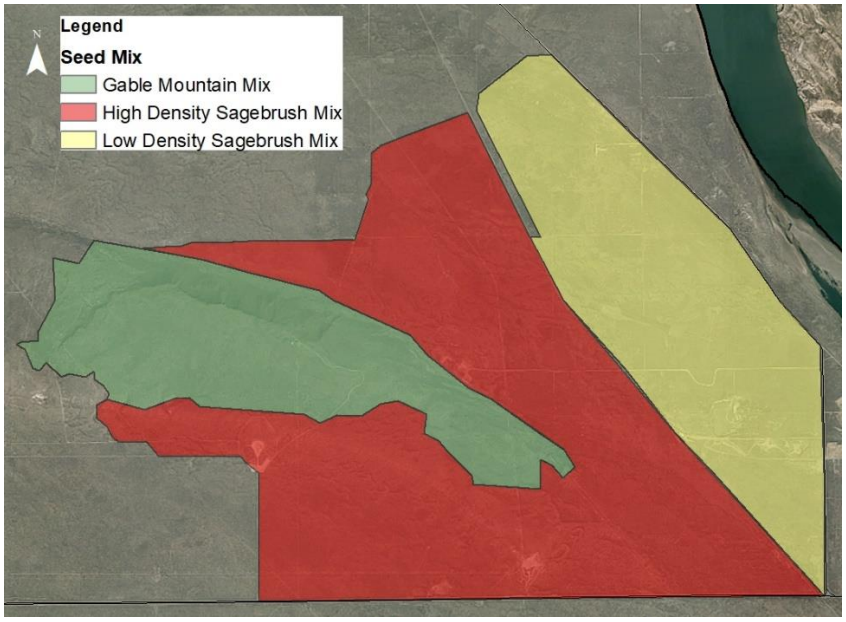

Figure 4. Locations of the Seed Mixes Used in the Gable Mountain Restoration.

Table 1. Species in the Seed Mixes Used in the Gable Mountain Restoration.

High Density Sagebrush Mix - 3,000 Acres		
Common Name	**Scientific Name**	**PLS/Acre**
Sandberg bluegrass	*Poa secunda*	7.50
Indian ricegrass	*Achnatherum hymenoides*	3.66
Needle-and-thread grass	*Hesperostipa comata*	0.04
Bottlebrush squirreltail	*Elymus elymoides*	1.45
Sand dropseed	*Sporobolus cryptandrus*	0.50
Prairie junegrass	*Koeleria macrantha*	0.95
Big sagebrush	*Artemisia tridentata*	0.24
Low Density Sagebrush Mix - 1,500 Acres		
Sandberg bluegrass	*Poa secunda*	7.17
Indian ricegrass	*Achnatherum hymenoides*	0.67
Bottlebrush squirreltail	*Elymus elymoides*	1.43
Sand dropseed	*Sporobolus cryptandrus*	0.50
Prairie junegrass	*Koeleria macrantha*	0.47
Gable Mountain Mix - 1,000 Acres		
Sandberg bluegrass	*Poa secunda*	4.00
Bluebunch wheatgrass	*Pseudoroegneria spicata*	10.00
Idaho fescue	*Festuca idahoensis*	1.00

3.0 METHODS

Similar monitoring methods were used at both the short- and long-term monitoring areas to ensure that data were easily comparable across sites and across monitoring years. Monitoring in 2021 included immediate post-fire monitoring to evaluate the surviving vegetative community, monitoring the first spring after post-fire restoration, and monitoring long-term vegetation transects.

3.1 IMMEDIATE POST-BURN MONITORING

Immediate post-burn monitoring occurs within 6 months of areas burning and has the purpose of establishing baseline transects to track the recovery of the burned area. Immediate post-burn monitoring occurred in the Gable Mountain Fire area in October 2020 with the goal of characterizing the vegetation remaining after the fire. Fifteen transects were established throughout distinct habitats within the Gable Mountain Fire area (Figure 5). The transect locations were selected to represent habitats throughout the Gable Mountain Fire area that were identified using the *Upland Vegetation of the Central Hanford Site* (HNF-61417) along with historic photo points and results from the June 2020 pedestrian survey. The transect locations also represent areas that experienced different levels of fire intensity. Transects were recorded on a global positioning system and rebar with flagging tape was placed at the start and end of each transect.

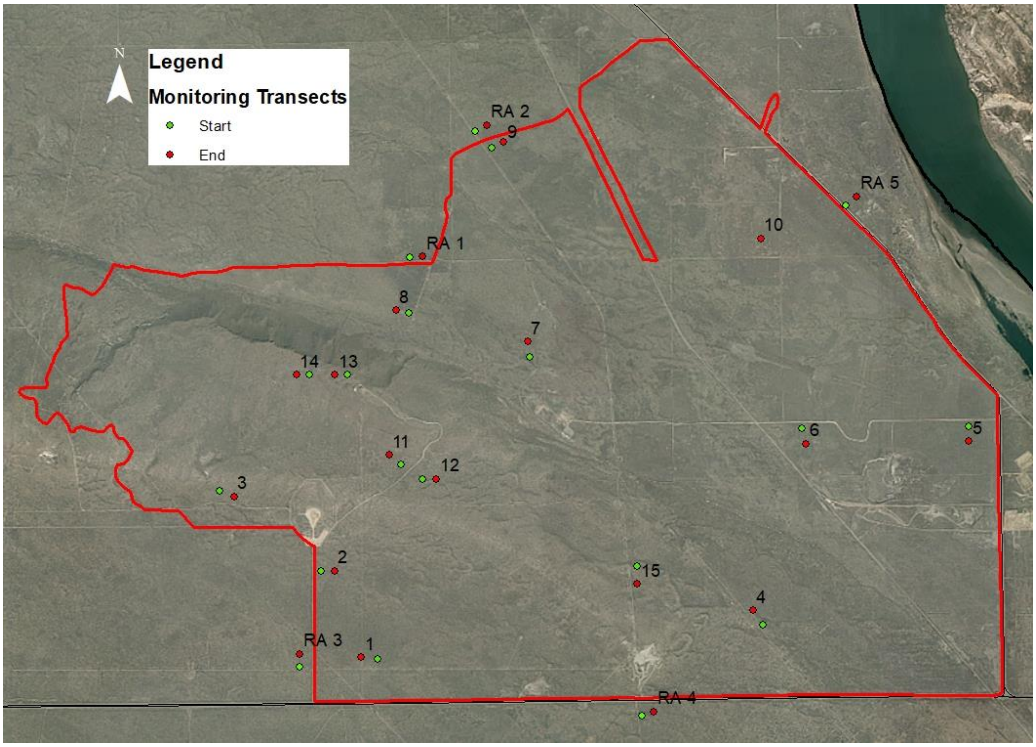

Figure 5. Monitoring Transects for the Gable Mountain Fire Area Established in 2020.

Coordinates were recorded at the start and end points of each 100-m transect. A new photo point was established at the starting point of each monitoring transect. Pictures were taken in a clockwise fashion with the first picture facing north and each subsequent picture slightly overlapping the previous. Pictures were taken horizontally with the horizon only visible in the upper 1/8 of the picture.

Plot frame data were taken along each of the transects in October 2020. These data were collected following methods described in the *Steppe Vegetation of Washington* (Daubenmire 1970) and methods used during post-fire monitoring of Biological Resources Monitoring Plan Plots (BRMP Plots) that were established in 1996 and monitored by a variety of groups (Evans and Lih 2005, Bakker et al. 2011). The plot frame transects consist of a 100-m long measuring tape, stretched from the start point to the end point so that it is straight and taut. One 20- by 50-cm plot was placed every 5 m on the right-hand side of the transect with the longest side parallel with the tape for a total of 20 plots per transect. Upon placing the plot frame, each species within the frame was identified and estimates of coverage were made for each species rooted within the area of the frame. Canopy coverage is defined by Daubenmire as "the percentage of ground surface included in the vertical projection of a polygon drawn about the extremities of the undisturbed foliage of a plant" (1970). Coverage was estimated using the following coverage classes: 1 (0-5% cover), 2 (5-25%), 3 (25-50%), 4 (50-75%), 5 (75-95%), and 6 (95-100%). In addition to plot frames, all plant species observed within 5 m of either side of the transect were recorded. In addition to plant species observed within 5 m of the transects, any classified noxious weeds encountered during the survey were recorded and marked with a global positioning system point. The noxious weed locations were sent to the Biological Controls program for eradication.

3.2 SHORT-TERM MONITORING

Short-term monitoring occurs in areas burned within the last 5 years and can occur in areas where restoration was performed. The goal of short-term monitoring is to collect data on the short-term recovery of areas after fire and to collect data on the short-term effectiveness of restoration actions. The Gable Mountain Fire area was monitored for short-term monitoring in May 2021. The same 15 transects shown in Figure 5 were revisited and monitored using the same photo point and plot frame methods used in immediate post-fire monitoring.

In addition to monitoring the 15 transects established in immediate post-fire monitoring, 5 additional reference transects were established during short-term monitoring. The goal of establishing reference transects was to evaluate vegetative cover in similar neighboring plant communities that were not affected by the Gable Mountain Fire. The unburned plant population can serve as a basis for comparison as the vegetation in the burned area grows and the community composition develops. Monitoring transects were chosen based on proximity to the burned area, vegetation layer similarity to the burned area according to HNF-61417, and accessibility. The transects were established and monitored using the same methods as the original 15 transects and will be monitored when the burn area transects are monitored, from short-term to long-term monitoring. Reference area transects are displayed in Figure 5 with "RA".

3.3 LONG-TERM MONITORING

The long-term effects of fire can impact ecosystems for decades. The majority of the Hanford Site has burned at least once in the last 40 years, and many of the burned areas have burned multiple times (HNF-61417). Documenting the long-term effects of historic fires provides data regarding vegetative community succession and recovery in the decades following a fire in situations where there was little to no human intervention. Additionally, monitoring restoration projects using these methods provides data regarding the impacts of post-fire restoration over time.

In 1996, permanent plots were established across the Hanford Site to collect information on site condition, vegetation, biotic crust, and wildlife use (PNNL-11472). Twenty of these plots, referred to as BRMP Plots, are established on the DOE-managed portion of the Hanford Site. Many of these plots have been monitored for vegetative cover using Daubenmire Plot monitoring methods at least twice since installation. The vegetative cover information includes canopy cover measurements and species lists from established transects within each of the plots.

Many of the BRMP Plots, mainly the plots located in the southern half of the Hanford Site, have experienced at least one fire event since they were initially established in 1996. Most notably, the 24 Command Fire in summer 2000 burned over 160,000 acres of land, including 60,000 acres on the southwest portion of the Hanford Site. Seven BRMP Plots that had been established and monitored in 1996 were burned in this fire, and six have been monitored at least once in the subsequent years. No long-term (greater than 10 years) data have been collected to evaluate recovery after this event. Long-term data were collected from the six BRMP plots in 2021 with the goal of gaining insight on post-fire recovery with no restoration. This information is required by the BRMP for informing decisions in whether to restore burned areas (DOE/RL 96-32). In addition to the six plots impacted by the 24 Command Fire, one BRMP plot is located within the Gable Mountain Fire area and was also monitored in 2021, bringing the total number of BRMP plots monitored to seven. The seven BRMP plots monitored in 2021 are shown in Figure 6.

The historic monitoring methods of BRMP Plots are summarized in detail in *Recovery and Rehabilitation of Vegetation on the Fitzner-Eberhardt Arid Lands Ecology Reserve, Hanford Reach National Monument, Following the 24 Command Fire* (Evans and Lih 2005):

> *Each 20 ha BRMaP [BRMP] macroplot hosts an array of 3 – 5 vegetation plots. A 1.0 km transect runs through the center of each macroplot, with five permanently marked points or point count stations located at 200m intervals. Point count locations serve as the origins of permanently marked vegetation transects oriented perpendicular to the main axis of the plot. Vegetation transects were established from each of five point count stations in big sagebrush stands, but only from point counts 1, 3, and 5 in grasslands and threetip sagebrush stands. Along each vegetation transect, visual estimates of percent cover of vascular plant species, microbiotic crust, and plant litter were recorded to the nearest full percent within 20cm x 50cm (0.1m^2) microplots (n = 20) located at regular intervals every 5m along each vegetation transect.*

The long-term monitoring methods match the methods described in immediate and short-term monitoring. Within each 49.4 ac BRMP Plot, 3 to 5 point count locations (referred to as "PC" locations in the historic data) have been established (Figure 7). Two of the point count locations were monitored in 2021, in most cases PC-1 and PC-3 were monitored for each of the 7 plots, resulting in 14 total transects performed for long-term monitoring. At each of these locations, monitors extended a 100-m tape in the same direction as the historic orientation, typically perpendicular to the 1-km line extending through the center of the plot. A 20- by 50-cm plot is placed at 5-m intervals parallel to the vegetation transect for a total of 20 plots per PC location, the same methods as the immediate and short-term monitoring. Canopy cover data and estimates of bare ground and biotic crust were recorded using Daubenmire's monitoring methods, along with all species within 5 m of each side of the 100-m tape.

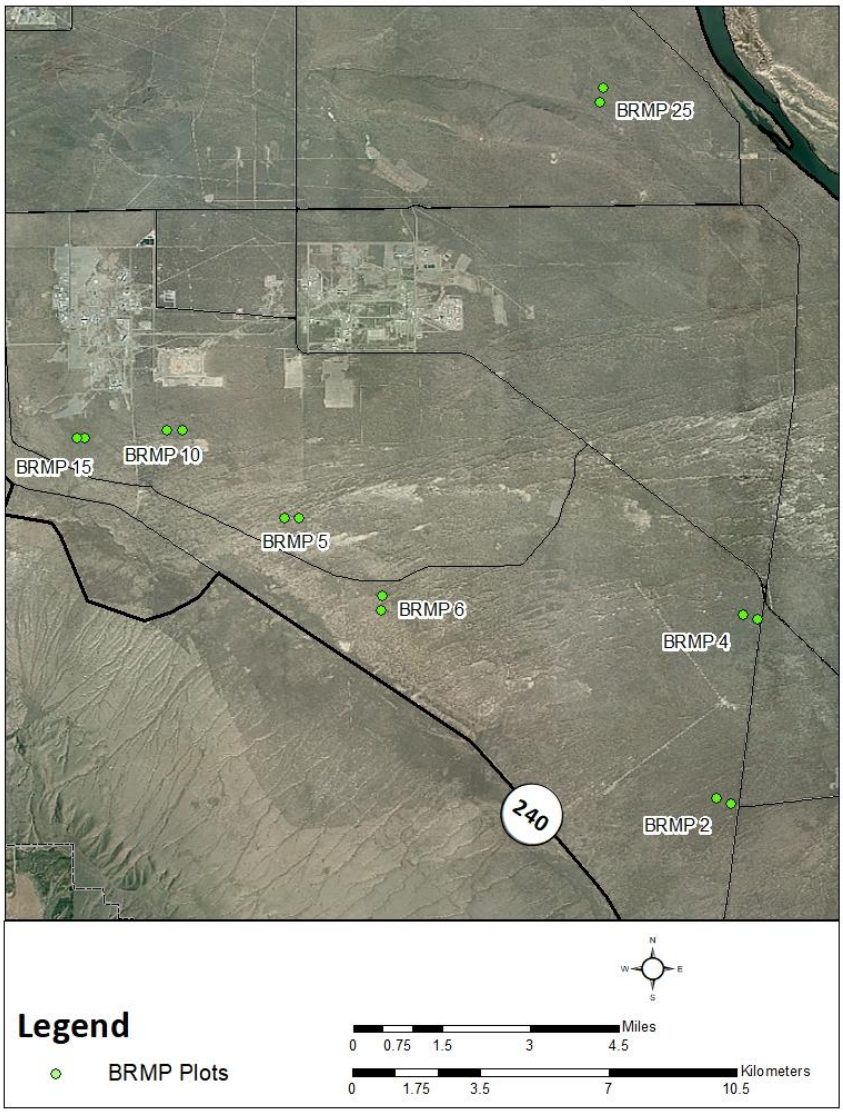

Figure 6. Locations of the BMRP Plots Monitored in 2021, with each Point Representing a Monitored PC Location.

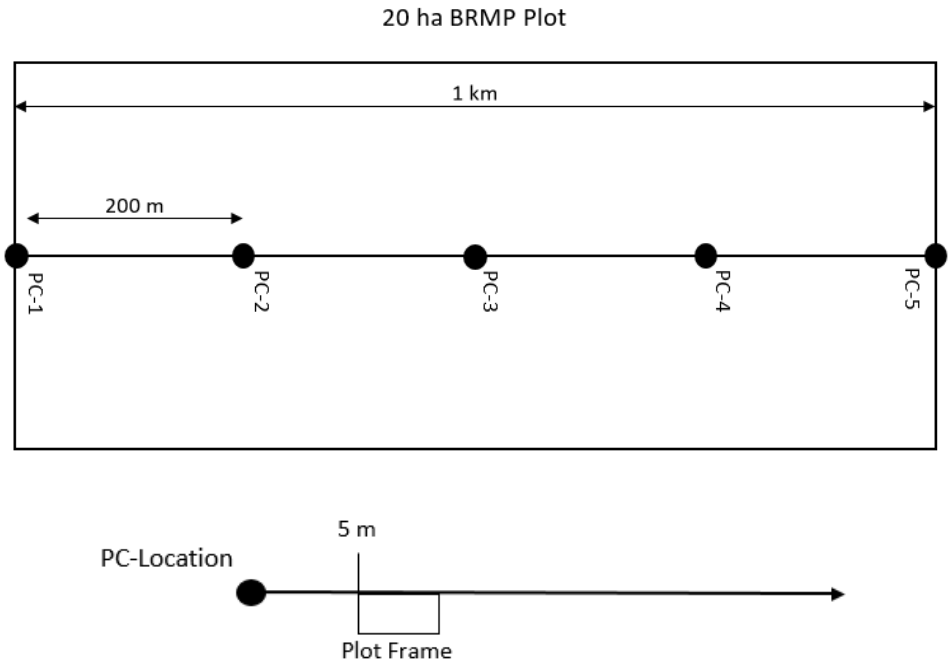

Figure 7. BRMP Plot Orientation and Transect Set Up.

4.0 RESULTS

This section reports results for the Gable Mountain Fire area and for the long-term BRMP plot monitoring. The Gable Mountain Fire area monitoring results includes data from immediate post-fire monitoring, short-term monitoring, and from the BMRP plot that burned in the Gable Mountain Fire. The long-term BMRP plot monitoring results includes data from plots that burned in the 24 Command Fire in summer 2000 and have been monitored once before the fire occurred and at least twice after. The implications of these results are discussed in Section 5.0.

4.1 GABLE MOUNTAIN FIRE AREA

Two distinct monitoring efforts occurred in the Gable Mountain Fire area: immediate post-fire monitoring and short-term monitoring. Both efforts measured vegetation on the same 15 transects, with immediate post-fire monitoring occurring in October 2020 and short-term monitoring occurring in April and May 2021. Between these two monitoring efforts, the Gable Mountain Fire area was reseeded with native grass and shrub seed, as described in Section 2.0. The 15 monitored transects are categorized into four areas: Gable Mountain, high-density sagebrush, low-density sagebrush, and reference areas. The monitoring transects have been categorized this way to develop a higher-level understanding of habitat recovery within the

Gable Mountain burn area. Additionally, it allows us to analyze the effectiveness of the three different seed mixes used in the restoration effort.

4.1.1 Gable Mountain Transects

The Gable Mountain transects are all located within the higher elevation section of the burned area, on and around Gable Mountain. This area was distinguished from the rest of the burned area due to the presence of bluebunch wheatgrass (*Pseudoroegnaria spicata*) as a dominant grass in the understory. Generally, the north slope of Gable Mountain saw far less damage both immediately and 1 year after the fire occurred than the south slope and appeared to be the only part of the burned area with a significant population of surviving sagebrush. The north slope of Gable Mountain was not surveyed due to timing and accessibility limitations. Transects 11, 13, and 14 are all within the Gable Mountain area, with Transect 12 on the boundary between the Gable Mountain area and the high-density shrub area. Transect 12 was analyzed within the Gable Mountain area due to the relatively high elevation of the site. Transects 13 and 14 are located on the higher elevation portion of Gable Mountain and Transects 11 and 12 are located on the south slope of the mountain.

This area is characterized by lithosols and Kiona silt loam soil. Prior to burning, the lithosols in the high elevation areas and the north slope of Gable Mountain supported sagebrush, scattered hopsage (*Grayia spinosa*), and purple sage (*Salvia dorii*) along with buckwheat species (*Eriogonum sphaerocephalum* and *E. microthecum*), rabbitbrush (*Ericameria nauseosa* and *Chrysothamnus viscidiflorus*), and a matrix of grasses including bluebunch wheatgrass, needle-and-thread grass, and Sandberg's bluegrass. The south slope supported similar vegetation, with a pattern of increasing cheatgrass and decreasing sagebrush southward.

Immediate post-fire monitoring in October 2020 found essentially no surviving vegetation on any of the Gable Mountain transects. Vegetation began to recover by short-term monitoring in April and May 2021. Across the four transects in the Gable Mountain area, native cover averaged 8.9% and invasive cover averaged 9.9%. Transect 12 and 13 had the highest native cover with 16.1% and 16.9% native cover, respectively. Transect 12 was surrounded by small patches of vegetation that had survived the fire. Both areas appeared to have a lower burn severity than Transects 11 and 14 immediately after the fire. Native cover at Transects 11 (Figure 8) and 14 (Figure 9) was quite low in May 2021, at 1.8% and 0.9%. Invasive species appeared to be recovering in those areas at a much faster rate than native species.

The species making up the majority of the native coverage in this area was Sandberg's bluegrass, which had been included in the restoration seed mix for this area. Bluebunch wheatgrass was present in the higher elevation areas but at a rate much lower than what had been observed pre-fire. Cheatgrass was the dominant invasive species at all transects within this area and had greater coverage on the transects on the south slope of the mountain, similar to pre-fire distribution. Another notable invasive species on the south slope of the mountain was tall tumblemustard (*Sisymbrium altissimum*).

Figure 8. Transect 11 in October 2020 (left) and May 2021 (right).

Figure 9. Transect 14 in October 2020 (left) and May 2021 (right).

4.1.2 High-Density Sagebrush Transects

The high-density sagebrush transects are all located within the lower elevation area surrounding Gable Mountain. This area was distinguished from the rest of the burned area due to the presence of a dense sagebrush overstory before the fire. This area included habitat previously designated as an element occurrence by the Washington Department of Natural Resources Natural Heritage Program due to its high quality, which is where Transect 1 is located. With the exception of a few patches in this area, the Gable Mountain Fire completely removed the sagebrush overstory. Sagebrush seed was added to the seed mix in this area to account for the loss of sagebrush plants. Transects 1, 2, 3, 4, 7, 8, 9, and 15 are all within the high-density sagebrush area. These transects span a variety of habitats with changing soil types.

The high-density sagebrush area lacks the lithosols and silt loam that characterize the Gable Mountain transect area. Soils in the high-density sagebrush area ranged from Burbank loamy sand to Quincy sand. Prior to burning, the soils in this area supported sagebrush and rabbitbrush species, along with scattered buckwheat. Grasses found in this area prior to burning included

Sandberg's bluegrass, needle-and-thread grass, and Indian ricegrass. Cheatgrass was a dominant component of this area before the fire and likely contributed to the fire having sufficient fuel to completely destroy the sagebrush overstory. Sandy habitats within the high-density sagebrush area had less cheatgrass prior to the fire and more patches of surviving vegetation.

Immediate post-fire monitoring in October 2020 found little to no surviving vegetation on any of the high-density sagebrush transects. The only transect with significant vegetation cover was Transect 4, where needle-and-thread grass covered approximately 1% of the area. Transect 4 was distinguished from the other transects with fairly active sandy soils, leading to some blowouts and gaps in vegetative cover. Lower cheatgrass coverage before the fire may have led to a lesser burn intensity in this area, resulting in more surviving native grasses. Vegetation recovered in certain areas by short-term monitoring in April and May 2021. Across the eight transects in the high-density sagebrush area, native cover averaged 5.8% and invasive cover averaged 5.5%. Transect 7 had the highest native cover at 12.6%, mostly made up of slender phlox and Sandberg's bluegrass. Transect 7 was one of the few transects with surviving sagebrush in the immediate area, and was notably diverse, hosting many forbs both on the transect and in the immediate area. Needle-and-threadgrass coverage continued to grow at Transect 4, increasing to 3.7% in spring monitoring. Transect 1 and 9 had the lowest native coverage, with 1.1% and 0.4% coverage, respectively. These areas saw high burn intensity and had no surviving sagebrush overstory. Cheatgrass was the dominant invasive species in these transects, with Transect 2, 7, and 9 having the highest invasive species coverage at 11.6%, 10%, at 9.6% coverage, respectively.

The species making up the majority of the native coverage in this area was Sandberg's bluegrass, which had been the major component of the restoration seed mix for this area. Though bunchgrass seedlings were detected at Transect 2 (Figure 10), 4 (Figure 11), and 15, they were too small to identify to the species level and were suspected to be either needle-and-thread grass or Indian ricegrass, both of which were included in the restoration seed mix. Notably, no sagebrush seedlings were detected at any transect in the high-density transect area or in the entire Gable Mountain burn area, despite sagebrush seed being included in the high-density sagebrush seed mix.

Figure 10. Transect 2 in October 2020 (left) and May 2021 (right).

Figure 11. Transect 4 in October 2020 (left) and May 2021 (right).

4.1.3 Low-Density Sagebrush Transects

The low-density sagebrush transects are all located within the lower elevation area east of the historic railroad track traversing the Gable Mountain Fire area. This area is bordered by Route 2 North, which was used as a firebreak during the firefighting process. The low-density sagebrush area was distinguished from the rest of the burned area due to the lack of a sagebrush overstory before the fire and general dominance of weedy species, including cheatgrass and tumblemustard. Transects 5, 6, and 10 are within the low-density sagebrush area.

The low-density sagebrush area contains a range of soil types, including Burbank loamy sand, Quincy sand, and Ephrata sandy loam. Prior to burning, soils in this area supported a grassland community made up of needle-and-thread grass, sand dropseed, Sandberg's bluegrass, and cheatgrass. Cheatgrass was a dominant component of this area before the fire, and large swaths of burned and matted cheatgrass were present throughout this section of the burned area leading to little exposed soil. In addition to the grasses, patches of rabbitbrush characterized the overstory with occasional sagebrush plants along the western boundary of the area.

Immediate post-fire monitoring in October 2020 found little to no surviving vegetation on any of the low-density sagebrush transects. Vegetation began to regrow in by short-term monitoring in April and May 2021. Native cover in this area was the lowest of the three areas, averaging 5% across the three transects. Invasive cover was by far the highest of the three areas, averaging 19.3%. Each of these transects were distinct in their native and invasive cover patterns. Transect 5 had 4.5% native and 28.5% invasive cover, with native cover consisting solely of Sandberg's bluegrass and invasive cover containing tumblemustard, cheatgrass, and chickweed (Figure 12). Transect 6 had higher native cover at 10.4%, which mainly consisted of western tansymustard and needle-and-thread grass. Invasive cover at Transect 6 totaled 8% and was made up of mainly cheatgrass and tumblemustard. Transect 10 had no detectable native cover and 21.5% invasive cover, which mainly consisted of bulbous bluegrass and cheatgrass. All of these areas contained matted, burned cheatgrass that left little available open soil.

Sandberg's bluegrass was common at Transect 5 and 6 and was the major component of the restoration seed mix for this area. Also included in the seed mix were prairie junegrass and sand dropseed, which were detected in the low-density sagebrush area. Species included in the seed mix that were not detected in the low-density transects were Indian ricegrass and bottlebrush squirreltail; however, there were many areas of the low-density sagebrush section that were not surveyed.

Figure 12. Transect 5 in October 2020 (left) and April 2021 (right).

4.1.4 Reference Area Transects

The Reference Area transects are located around the perimeter of the burned area in sections that resemble the vegetative community within the burned area prior to the fire. The purpose of these transects is to establish what the baseline vegetative community consisted of prior to the fire and to compare how the burned area recovers over time to the vegetative communities in the reference area. This area will not have to be monitored annually as the vegetation is not expected to significantly change. Five reference transects were established for this study, depicted as "RA" in Figure 5.

Reference Area 1 (RA 1) is representative of the low-elevation area north of Gable Mountain, where Transect 7 and Transect 8 are located. RA 1 had 4.5% native cover, mainly made up of sagebrush and Sandberg's bluegrass. RA 1 had 44.0% invasive cover, nearly completely made up of cheatgrass. It is characterized as a mature sagebrush habitat with a highly disturbed understory. Reference Area 2 (RA 2) is representative of the invasive dominated habitat with little overstory that is transitional between the high-density and low-density sagebrush areas of the burned area. It is located near Transect 9, both transects are near a firebreak created during the process of fighting the Gable Mountain Fire. RA 2 had 1.6% native cover, mainly made up of Sandberg's bluegrass and slender phlox. Invasive cover totaled 34.2%, with the majority of that cover being cheatgrass.

Reference Area 3 (RA 3) is located on the west side of the fire boundary and is representative of pre-fire conditions for Transect 1 and Transect 2. RA 3 is within the element occurrence that spanned over Transect 1 prior to the fire. RA 3 had 17.9% native cover, with 14.4% of that native cover made up by mature sagebrush. Hoary tansyaster, slender phlox, and Sandberg's bluegrass also made up significant coverage native understory. RA 3 had 23.3% invasive cover, with 21.9% of that made up by cheatgrass. Reference Area 4 (RA 4) is located south of the fire boundary in an area similar to pre-fire conditions for Transect 15 and Transect 4. RA 4 had 15.6% native cover, with 10.8% of the cover made up of sagebrush. This area had a higher cover of Sandberg's bluegrass compared to other reference area sites at 4.4% cover. RA 4 had 31.8% invasive cover, with 28.1% of that made up by cheatgrass.

Reference Area 5 (RA 5) is located on the east side of the fire boundary and is representative of pre-fire conditions for Transect 5, Transect 6, and Transect 10. RA 5 had no native species cover on the transect, though sand dropseed and tarweed fiddleneck were observed in the area. Invasive cover totaled 42.4%, which was made up by cheatgrass (34.3%), tall tumblemustard (4.4%), and jagged chickweed (3.8%).

Figure 13. The Transect for Reference Area 1, Showing High Cheatgrass Density in the Understory Typical of the Reference Area Transects.

4.1.5 BRMP Plot 25

BRMP Plot 25 (referred to as BRMP 25) is located in an area classified by HNF-61417 as a Big sagebrush/Sandberg's bluegrass – Cheatgrass habitat. This plot is included in the Gable Mountain Fire Area results because it was seeded in the January 2020 restoration effort and will be evaluated with the established Gable Mountain Fire transects. It is characterized by having an overstory dominated by sagebrush, with lower coverage of bitterbrush and hopsage interspersed. The understory is co-dominated by Sandberg's bluegrass and cheatgrass, with low coverage of needle-and-thread grass. This classification was done before the area burned in 2020 and stands

as a pre-fire representation of the area. The soil in this area is characterized as Burbank loamy sand and Quincy sand. Data from 1996 and 2009 monitoring efforts were evaluated to determine the pre-fire vegetative composition; this plot was monitored in 2021 to determine the post-fire composition. Two PC locations were evaluated for this study: PC-1 and PC-3. Figure 14 shows the change in vegetative composition over time and Figure 15 shows the change in the dominant grass coverage over time at BRMP 25.

Average native cover in 1996 was 44.1%. This was mainly made up of sagebrush and Sandberg's bluegrass, which were the two main components of the habitat. Bottlebrush squirreltail, longleaf phlox, and small fescue were other common native species in the plot. Invasive cover averaged 37.3%, with the majority of that coverage coming from cheatgrass. Jagged chickweed and spring draba also contributed to the high invasive coverage. Monitoring in 2009 found 32.6% native cover. Sagebrush and Sandberg's bluegrass still made up the majority of the native cover with forbs like Jacob's ladder, longleaf phlox, and slender phlox also providing coverage. Invasive cover averaged 18.9% and was mainly made up of cheatgrass.

Post-fire monitoring in 2021 found significant decreases in all species. Native cover decreased to 2.6%, with the majority of the native cover coming from Sandberg's bluegrass and needle-and-threadgrass. Invasive cover also decreased significantly, averaging only 3.3% after the fire. Cheatgrass made up the majority of the invasive species coverage in 2021.

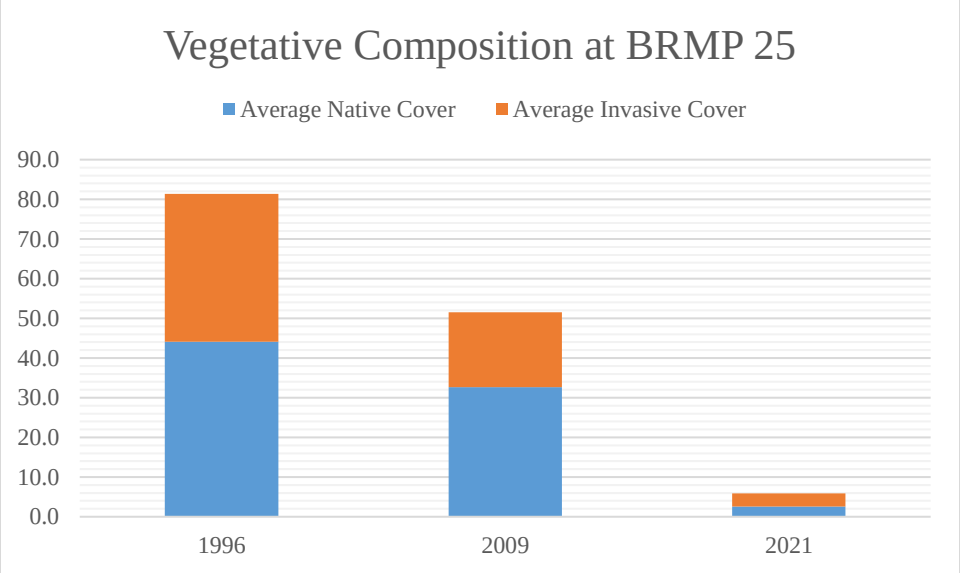

Figure 14. The Average Vegetative Composition at BRMP 25 over Time.

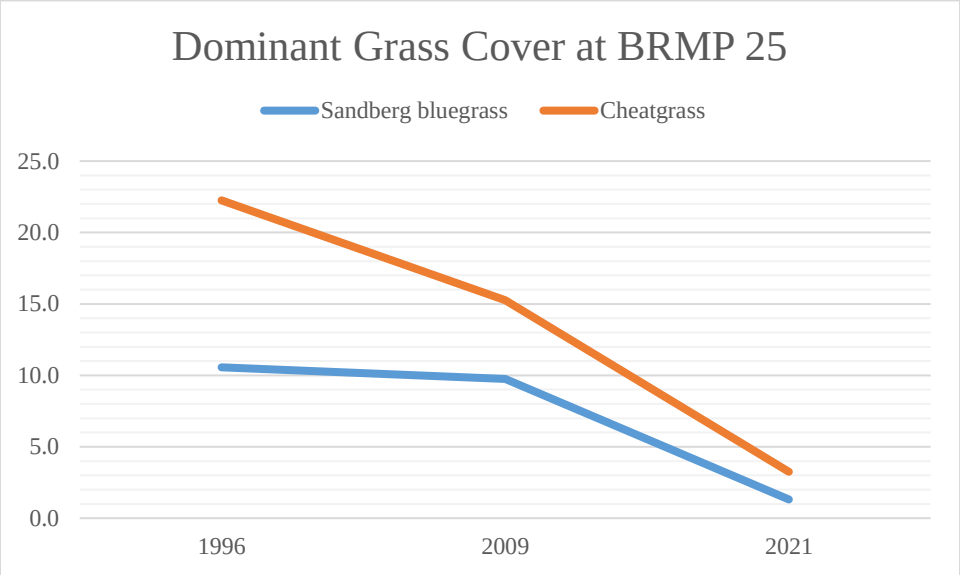

Figure 15. Changes in Dominant Grass Cover at BRMP 15 over Time.

4.2 LONG-TERM BRMP PLOT MONITORING

Long-term post-fire monitoring occurred at seven BRMP plots. Six of those plots had burned in the 24 Command Fire in 2000. The BRMP plots selected had all been monitored once prior to the fire and at least once between the fire and the 2021 monitoring effort. The goal of long-term BRMP plot monitoring in these areas was to evaluate vegetation recovery over time with no post-fire restoration. The seventh plot burned in the Gable Mountain Fire and provides pre-fire vegetation data from 1996 and 2009. Results from BRMP plot monitoring are reported by plot rather than by individual PC locations. BRMP plot monitoring occurred June 7 to June 10, 2021.

4.2.1 BRMP Plot 2

BRMP Plot 2 (referred to as BRMP 2) is located in an area classified by HNF-61417 as a Bitterbrush/Sandberg's bluegrass – Cheatgrass-dominated habitat with a low cover of bitterbrush, grey rabbitbrush, and green rabbitbrush in the overstory and Sandberg's bluegrass, and cheatgrass co-dominant in the understory along with low coverage of Indian ricegrass and needle-and-thread grass. The soil in this area varies between Quincy sand and Burbank loamy sand. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-3. Figure 16 shows the change in vegetative composition over time and Figure 17 shows the change in the dominant grass coverage over time at BRMP 2.

Average native cover at BRMP 2 in 1996 was 25.9%, made up mainly of Sandberg's bluegrass and dune scurfpea. No shrubs were detected in the overstory in either location in 1996. Invasive species averaged 54.4% cover, with cheatgrass as the dominant invasive species. BRMP 2 was monitored for vegetative cover for a second time in 2009, 9 years after the 24 Command Fire. Monitoring in 2009 saw an increase in native species cover, with native cover averaging 30.6%. Sandberg's bluegrass, dune scurfpea, pale-evening primrose, hoary tansyaster, and needle-and-

thread grass made up the majority of the native cover in 2009. Invasive cover had decreased significantly since 1996 monitoring, averaging 12.8% in 2009 but still dominated by cheatgrass.

BRMP Plot 2 was monitored for a third time on June 7, 2021. Average native cover had decreased to 18.7%, below pre-fire levels. Sandberg's bluegrass and dune scurfpea made up the majority of the native cover in the area, with fiddleneck tarweed and needle-and-thread grass present as minor components of the understory. Invasive cover had increased to 19.7% since 2009 monitoring but was still significantly less than pre-fire levels. Cheatgrass was the most common invasive species, with Russian thistle and tall tumblemustard as minor components of the understory. No shrubs or shrub seedlings were detected on either transect in 2021.

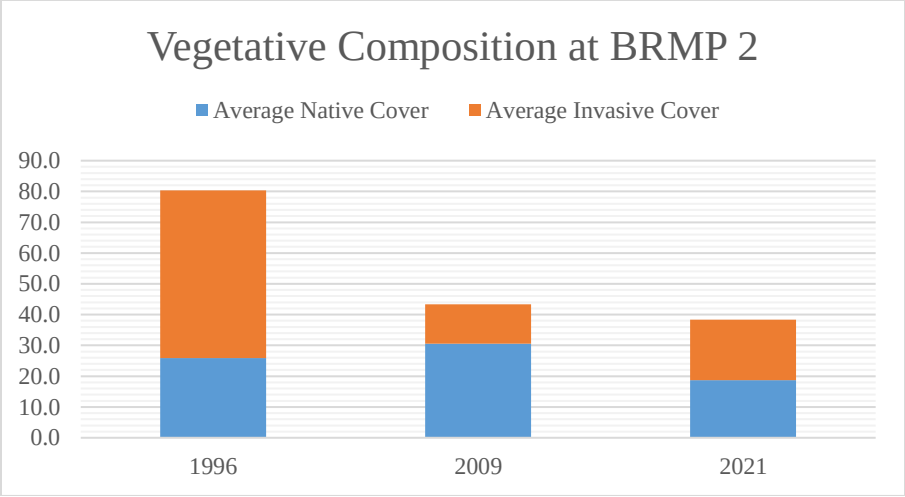

Figure 16. The Average Vegetative Composition at BRMP 2 over Time.

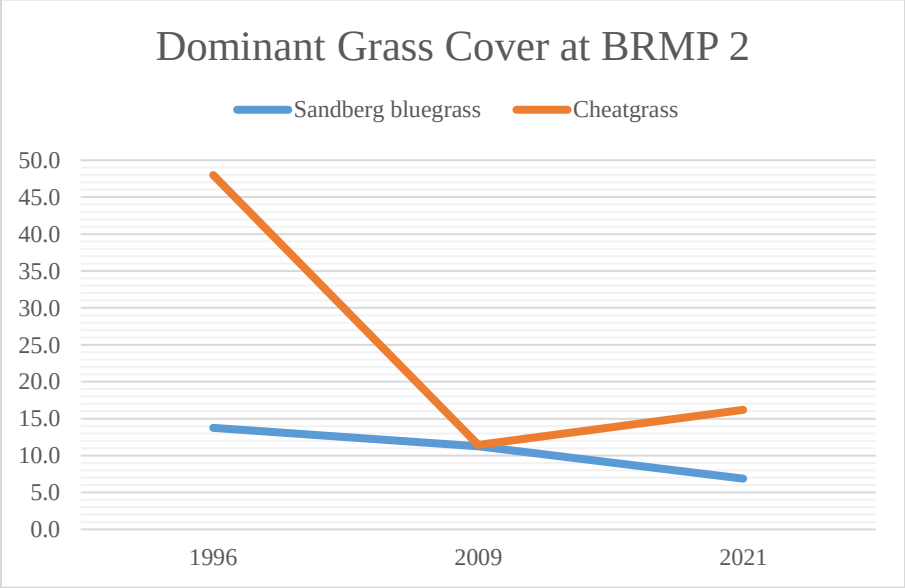

Figure 17. Changes in Dominant Grass Cover at BRMP 2 over Time.

4.2.2 BRMP Plot 4

BRMP Plot 4 (referred to as BRMP 4) is located in an area classified by HNF-61417 as a Bitterbrush/Bunchgrass and Bitterbrush/Sandberg's bluegrass – Cheatgrass-dominated habitat with a low cover of bitterbrush, sagebrush, and green rabbitbrush in the overstory and Sandberg's bluegrass and cheatgrass co-dominant in the understory with needle-and-thread grass ranging from a minor component to co-dominant and low coverage of Indian ricegrass. The soil in this area varies between Quincy sand and Ephrata sandy loam. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-3, over 3 years (1996, 2002, and 2021). Figure 18 shows the change in vegetative composition over time and Figure 19 shows the change in the dominant grass coverage over time at BRMP 4.

Average native cover in 1996 monitoring was 10.4% at BRMP 4. Sandberg's bluegrass and dune scurfpea made up the majority of the native cover in this area. Invasive cover averaged 49.5%, with the majority of that coverage made up by cheatgrass. BRMP 4 was monitored for a second time in 2002, 2 years after the 24 Command Fire. Monitoring after the fire found lowered native and invasive cover at 3.8% and 30.2% cover, respectively. Native cover mainly consisted of Sandberg's bluegrass. Bitterbrush was recorded within the transect in 2002. Invasive cover was made up of cheatgrass and early spring annuals such as jagged chickweed and spring draba.

BRMP 4 was monitored on June 7, 2021. Average native cover had increased since the fire and was measured at 13.3%. Bitterbrush, needle-and-thread grass, and dune scurfpea made up the majority of the native cover. Minor native components of the understory included Sandberg's bluegrass and fiddleneck tarweed. Invasive cover had decreased below pre-fire levels, with an average cover of 21% that mainly consisted of cheatgrass and rush skeletonweed. Spring annuals jagged chickweed and spring draba were minor invasive components of the understory.

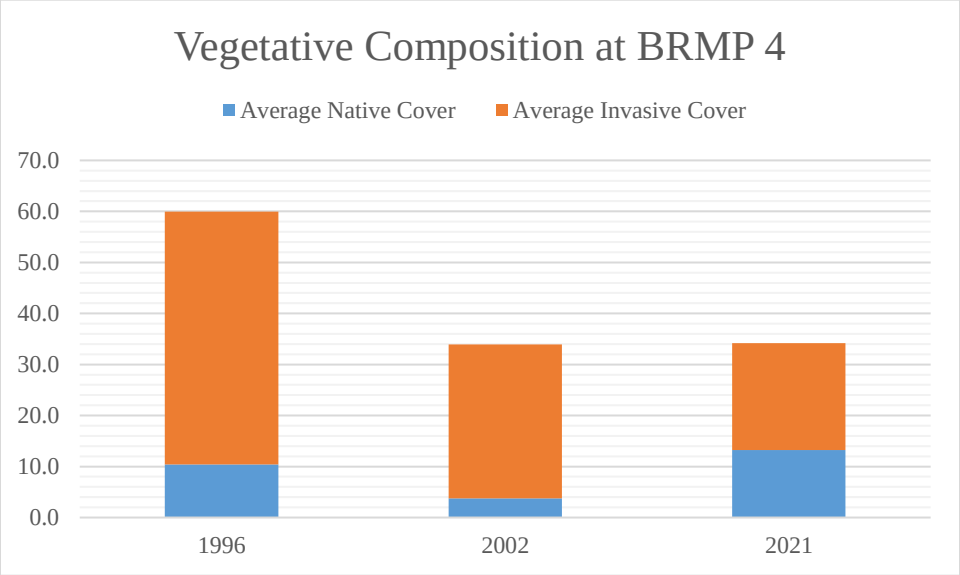

Figure 18. The Average Vegetative Composition at BRMP 4 over Time.

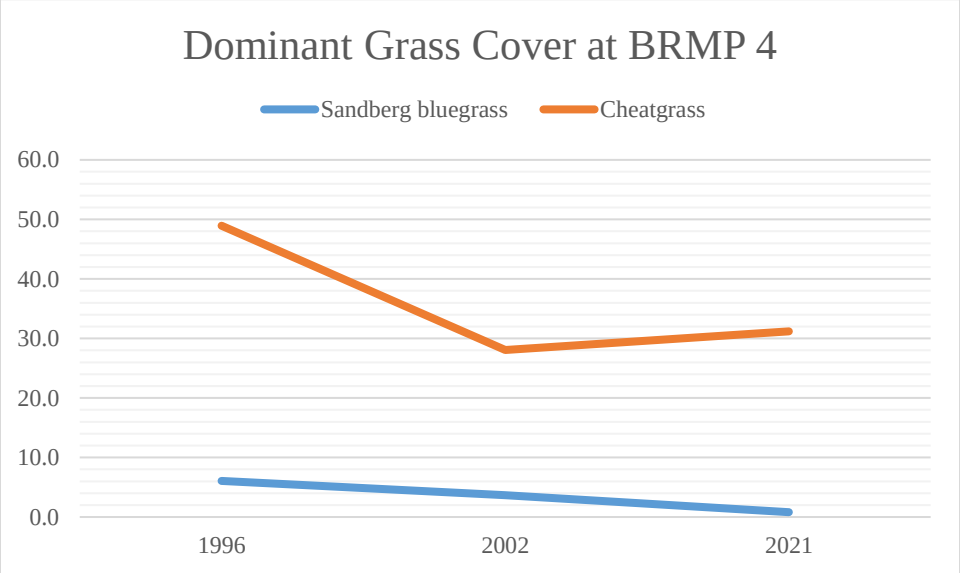

Figure 19. Changes in Dominant Grass Cover at BRMP 4 over Time.

4.2.3 BRMP Plot 5

BRMP Plot 5 (referred to as BRMP 5) is located in an area classified by HNF-61417 as a Bitterbrush/Bunchgrasses-dominated habitat. It was characterized as having 0 to 3% cover of sagebrush, bitterbrush, green rabbitbrush, and grey rabbitbrush in the overstory and co-dominant needle-and-thread grass, Sandberg's bluegrass, and cheatgrass with low cover of Indian ricegrass in the understory. The soil in this area is characterized as Hezel sand. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-3. Figure 20 shows the change in vegetative composition over time and Figure 21 shows the change in the dominant grass coverage over time at BRMP 5.

Average native cover measured in 1996 before the 24 Command Fire was 33.3%. This included sagebrush, which was present at over 10% cover, and spiny hopsage as a minor component of the native overstory. Other dominant native species included long-leafed phlox, Sandberg's bluegrass, desert parsley, and dune scurfpea. Invasive cover averaged 31% and was heavily dominated by cheatgrass. BRMP 5 was monitored again in 2005, 5 years after the fire. Average native cover decreased to 12.5%, with Sandberg's bluegrass, shy gilia, and long-leafed phlox as the dominant components of the understory. The only shrub detected in the overstory in 2005 was green rabbitbrush. Average invasive cover was 20.7% and was dominated by both cheatgrass and tall tumblemustard, which had not been present in significant quantities before the fire.

BRMP Plot 5 was monitored on June 10, 2021. The area had a variety of forbs and grasses but was dominated by cheatgrass. Average native cover had decreased again to 8.8%. Sandberg's bluegrass, needle-and-thread grass, Indian ricegrass, fiddleneck tarweed, and Carey's balsamroot were dominant components of the understory. Sagebrush was detected on one transect but was

not present at significant levels. Average invasive cover had increased since 2005 monitoring to 25.6%, dominated by cheatgrass and with Russian thistle as a minor component.

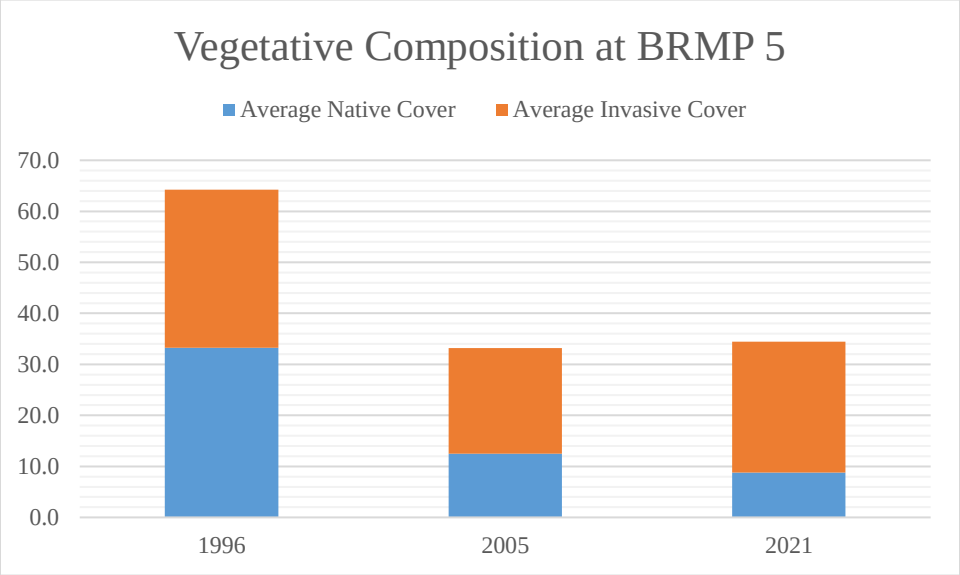

Figure 20. The Average Vegetative Composition at BRMP 5 over Time.

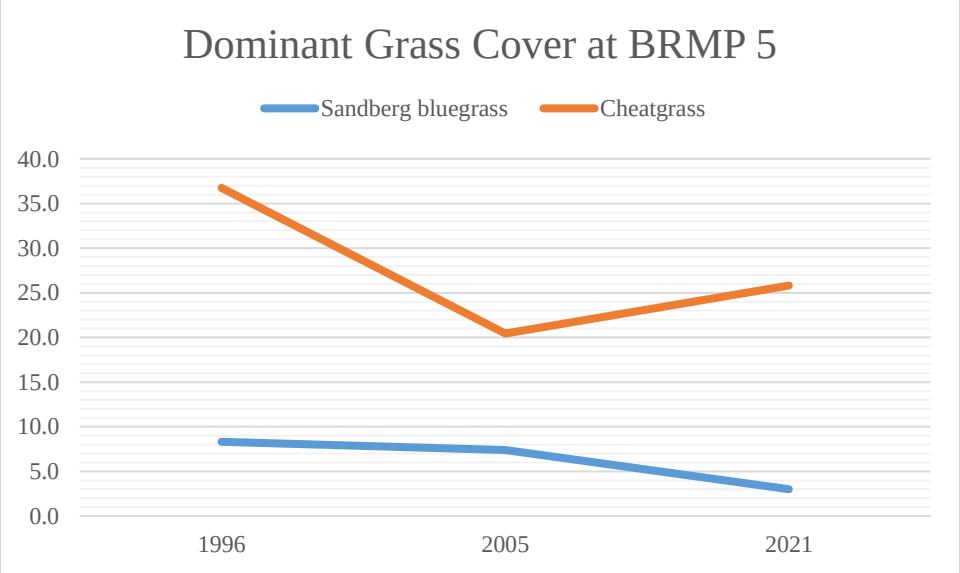

Figure 21. Changes in Dominant Grass Cover at BRMP 5 over Time.

4.2.4 BRMP Plot 6

BRMP Plot 6 (referred to as BRMP 6) is located in an area classified by HNF-61417 as a mix of Bitterbrush/Bunchgrasses and Sandberg's bluegrass – Cheatgrass-dominated habitat. It was characterized as having 0 to 3% cover of sagebrush, bitterbrush, green rabbitbrush, and grey rabbitbrush in the overstory and co-dominant needle-and-thread grass, Sandberg's bluegrass, and cheatgrass with low cover of Indian ricegrass in the understory. The soil in this area is

characterized as Hezel sand. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-3. Figure 22 shows the change in vegetative composition over time and Figure 23 shows the change in the dominant grass coverage over time at BRMP 6.

Average native cover at BRMP 6 in 1996 was 28.4%, which was mainly composed of Sandberg's bluegrass. Native plants that were minor components of the environment included sagebrush and grey rabbitbrush. Average invasive cover was 34.4%, which was composed mainly of cheatgrass with jagged chickweed, spring draba, and Russian thistle as minor components of the understory. Monitoring was performed at BRMP 6 again in 2005, 5 years after the 24 Command Fire. Native cover had not changed significantly and was measured at 29.6%. Sandberg's bluegrass still made up the majority of the native cover but sagebrush and grey rabbitbrush were no longer present and there was no overstory component. Invasive cover had decreased and measured 12.0%. Invasive cover was still dominated by cheatgrass and tall tumblemustard had significant cover compared to 1996 levels.

BRMP Plot 6 was monitored on June 9, 2021. Native cover averaged only 7.1%. The understory was dominated by needle-and-thread grass and Sandberg's bluegrass. A wide variety of forbs were detected on this transect but not at levels providing significant coverage. The forb with the highest cover was pale-evening primrose. Invasive coverage increased slightly in 2021 over 2005 levels to 13.8%; however, this was still below the pre-fire invasive coverage of 34.4%. Invasive coverage was dominated by cheatgrass, and Russian thistle and tall tumblemustard made up a minor component of the coverage.

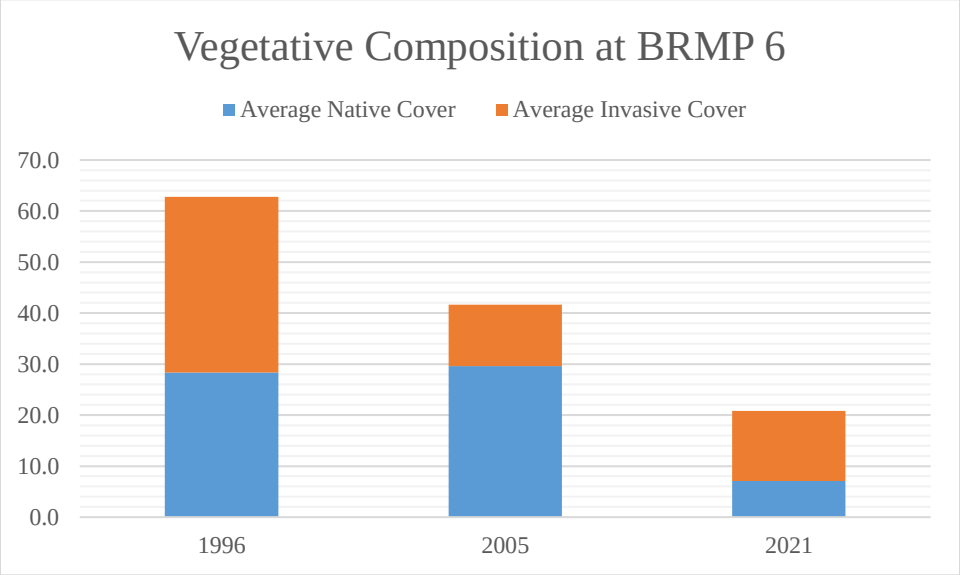

Figure 22. The Average Vegetative Composition at BRMP 6 over Time.

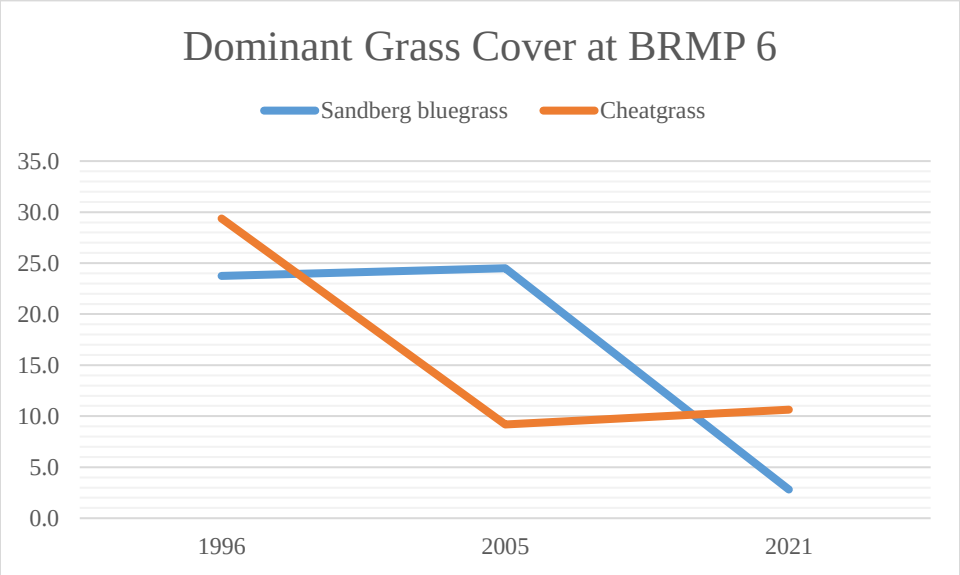

Figure 23. Changes in Dominant Grass Cover at BRMP 6 over Time.

4.2.5 BRMP Plot 10

BRMP Plot 10 (referred to as BRMP 10) is located in an area classified by HNF-61417 as a Bunchgrasses habitat. It is characterized by having a low coverage of sagebrush and grey and green rabbitbrush overstory along with needle-and-thread grass, Sandberg's bluegrass, and cheatgrass, all co-dominant in the understory. Indian ricegrass also makes up a minor component of the understory. The soil in this area is characterized as Quincy sand. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-3. Figure 24 shows the change in vegetative composition over time and Figure 25 shows the change in the dominant grass coverage over time at BRMP 10.

Average native cover at BRMP 10 in 1996 was 32.8%. Native cover was dominated by needle-and-thread grass, which had 20.8% coverage within PC-1. Other high-coverage native species included Sandberg's bluegrass, sagebrush, and fescue species. Average invasive cover totaled 37.4%, which was almost completely dominated by cheatgrass. Vegetative cover was measured again in 2009, 9 years after the 24 Command Fire. Native cover averaged 12.3% and was dominated by needle-and-thread grass, Indian ricegrass, and Sandberg's bluegrass. Sagebrush was not recorded on either PC transect in 2009. Invasive cover averaged 21.4% and was dominated by cheatgrass.

BRMP 10 was monitored on June 9, 2021. Native cover averaged 9.4% and was dominated by needle-and-thread grass and Sandberg's bluegrass. A number of forbs were detected in the understory, with hoary tansyaster and desert parsley providing some native coverage. Sagebrush was detected at 0.1% cover in PC-1. Invasive cover averaged 27.1%, more than what was detected in 2009 but still below pre-fire levels. Cheatgrass dominated the area, averaging 23.3% coverage throughout BRMP 10. Russian thistle was also present at significant levels at this site.

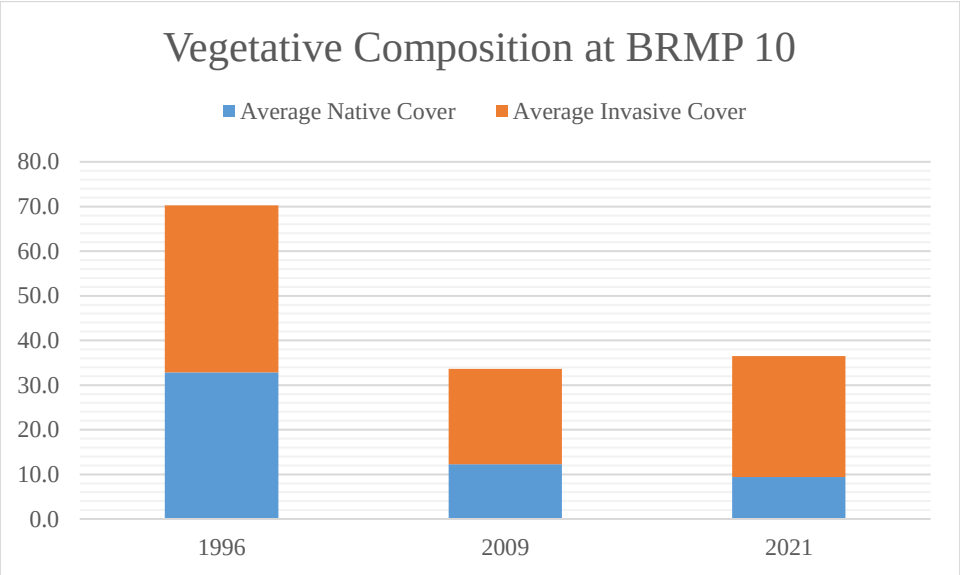

Figure 24. The Average Vegetative Composition at BRMP 10 over Time.

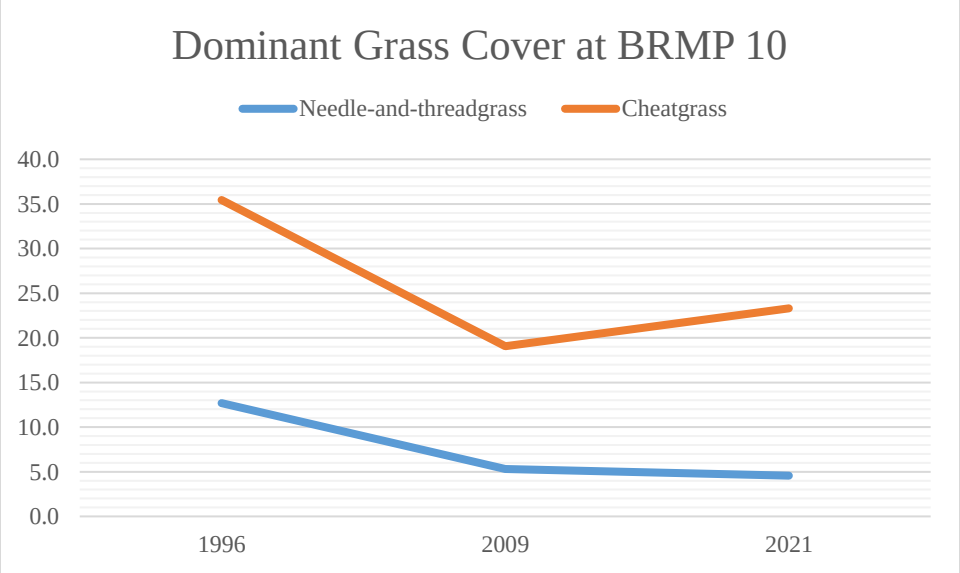

Figure 25. Changes in Dominant Grass Cover at BRMP 10 over Time.

4.2.6 BRMP Plot 15

BRMP Plot 15 (referred to as BRMP 15) is located in an area classified by HNF-61417 as a Bunchgrasses habitat. It is characterized by having a low coverage of grey and green rabbitbrush overstory with needle-and-thread grass dominant in the understory. Also present in the understory is Sandberg's bluegrass and cheatgrass with a patchy distribution. The soil in this area is characterized as Quincy sand. This plot was established and first monitored in 1996, 4 years prior to the 24 Command Fire. Two PC locations were evaluated for this study: PC-1 and PC-2.

Figure 26 shows the change in vegetative composition over time and Figure 27 shows the change in the dominant grass coverage over time at BRMP 15.

Average native cover at BRMP 15 in 1996 was 23.7%. Sagebrush made up the majority of the native coverage with an average cover of 17.3%. Following sagebrush, desert parsley had significant coverage in this area. Invasive cover averaged 43.6% and was heavily dominated by cheatgrass. BRMP 15 was monitored again in 2009, 9 years after the 24 Command Fire. Native cover had decreased to 9.4%, mainly due to the loss of the sagebrush overstory. Forbs, including desert parsley, common yarrow, and long-leafed phlox, dominated the native understory. Needle-and-thread grass was the dominant grass with some Sandberg's bluegrass interspersed. Invasive cover decreased to 28.1% with cheatgrass dominating the area. Tall tumblemustard, which had not been recorded in significant levels in 1996, was also present and averaged 2.8% cover.

BRMP 15 was monitored on June 8, 2021. Native cover averaged 6.0%, marking a steady decline in native cover since 1996 monitoring. Desert parsley and needle-and-thread grass were the dominant native species with Sandberg's bluegrass and Indian ricegrass as minor components of the understory. Grey rabbitbrush was the only shrub detected at either transect, no sagebrush or sagebrush seedlings were found. Invasive species had 17.9% cover and had also steadily decreased since 1996 monitoring. Cheatgrass was the dominant invasive species; this was the only site where cheatgrass coverage had declined gradually since 1996 monitoring.

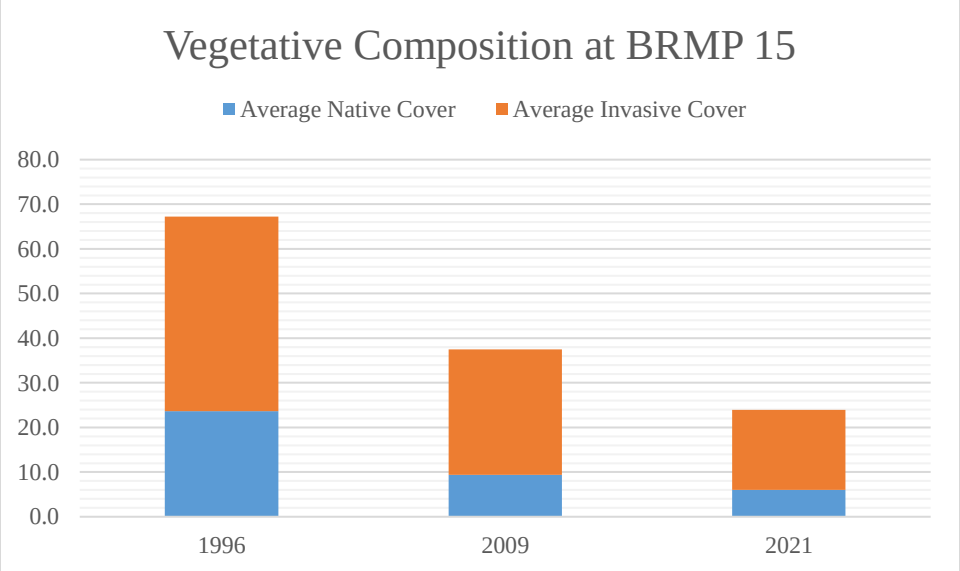

Figure 26. The Average Vegetative Composition at BRMP 15 over Time.

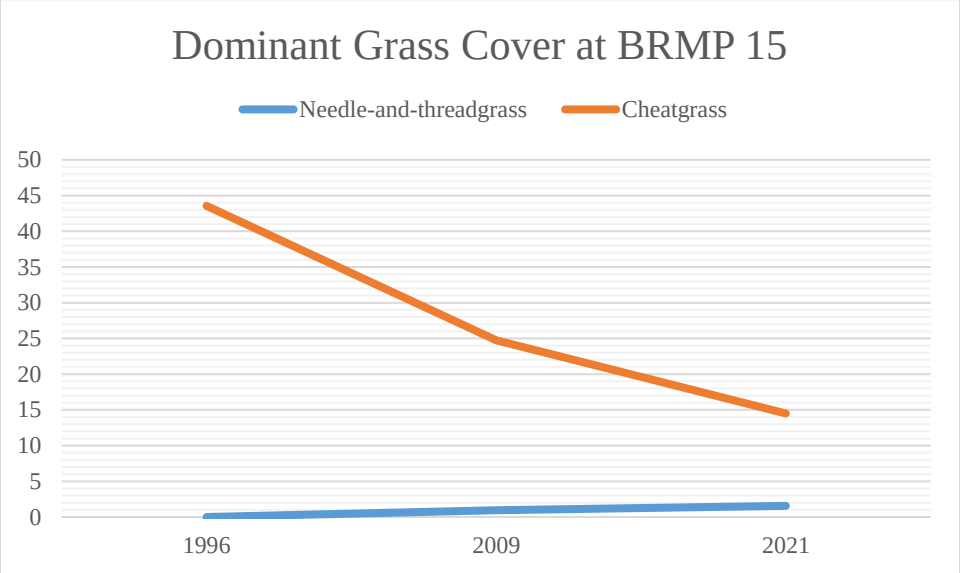

Figure 27. Changes in Dominant Grass Cover at BRMP 15 over Time.

4.2.7 BRMP Plot Trends

The data from BRMP Plots 2, 4, 5, 6, 10, and 15 were analyzed as a unit to identify potential trends in vegetation recovery after the 24 Command Fire. Native and invasive species coverage over time, dominant grass coverage, and shrub survival and recovery were all evaluated.

Native and invasive species coverage and dominant grass coverage over time followed similar patterns, as shown in Figure 28 and 29. Data from 1996 showed relatively high levels of invasive species before the fire, mainly consisting of cheatgrass coverage that averaged 35% across all sites. Both invasive and native cover dropped post-fire, with invasive species seeing an average decrease of 21% and native species decreasing by 9%. When looking at only the dominant native grass at each post-fire site, the dominant native grass cover dropped by 3%, significantly less than the steep decline in cheatgrass coverage of 20%. Despite this decrease in invasive species cover in the years immediately following the 24 Command Fire, by 2021, cheatgrass cover had begun to increase while native species cover continued decreasing. Native species decreased by 6% from less than 10 years after the fire to 2021 monitoring, and the dominant native grass decreased by 5%. Over the same period, cheatgrass cover increased by 5%. Invasive species cover did not vary over this period, likely due to increases in cheatgrass being offset by decreases in early successional weeds like tall tumblemustard and Russian thistle.

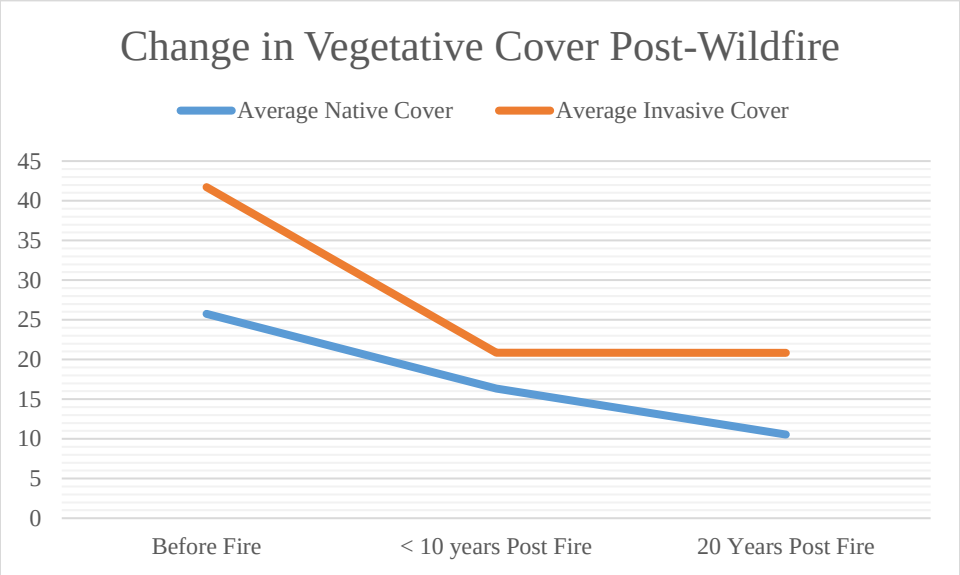

Figure 28. Change in Vegetative Cover at BRMP Plots Burned in the 24 Command Fire.

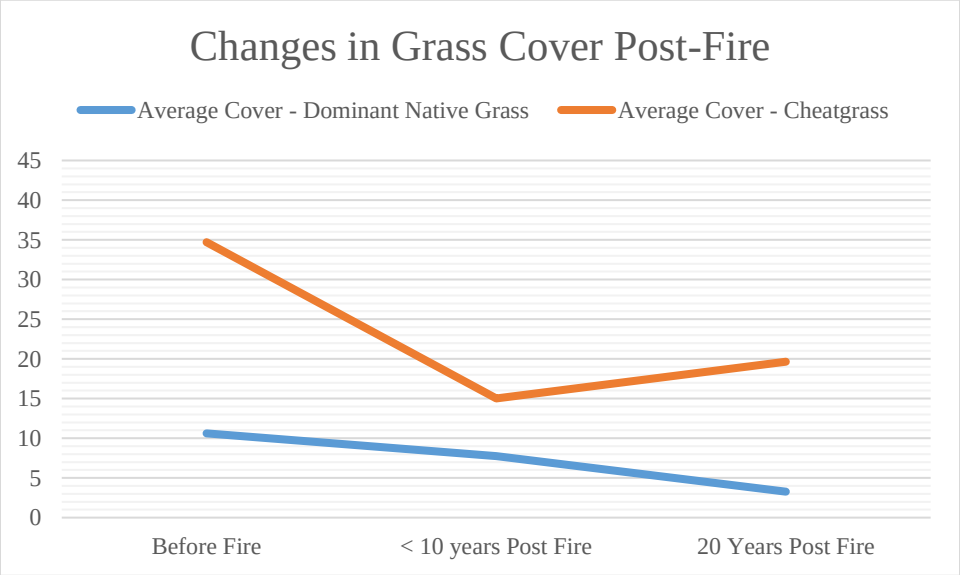

Figure 29. Change in Grass Cover in BRMP Plots Burned in the 24 Command Fire.

An additional noteworthy trend is the decrease in shrub cover after fire, as shown in Figure 30 (considering sagebrush, spiny hopsage, and antelope bitterbrush). Four of the BRMP Plots (BRMP 5, BRMP 6, BRMP 10, and BRMP 15) had significant coverage of sagebrush or spiny hopsage before the 24 Command Fire. In the monitoring window that occurred less than 10 years after the fire, sagebrush and/or spiny hopsage cover was insignificant at all of these sites. In 2021 monitoring, sagebrush was detected at low levels within 3 of the 4 plots that previously contained high sagebrush coverage. BRMP 5 contained sagebrush seedlings and established sagebrush. BRMP 6 had sagebrush seedlings and scattered established sagebrush. BRMP 10 had

low coverage of established sagebrush on the transect. BRMP 15, which had the highest average sagebrush coverage before the fire (17.3%), had no sagebrush detected on either transect.

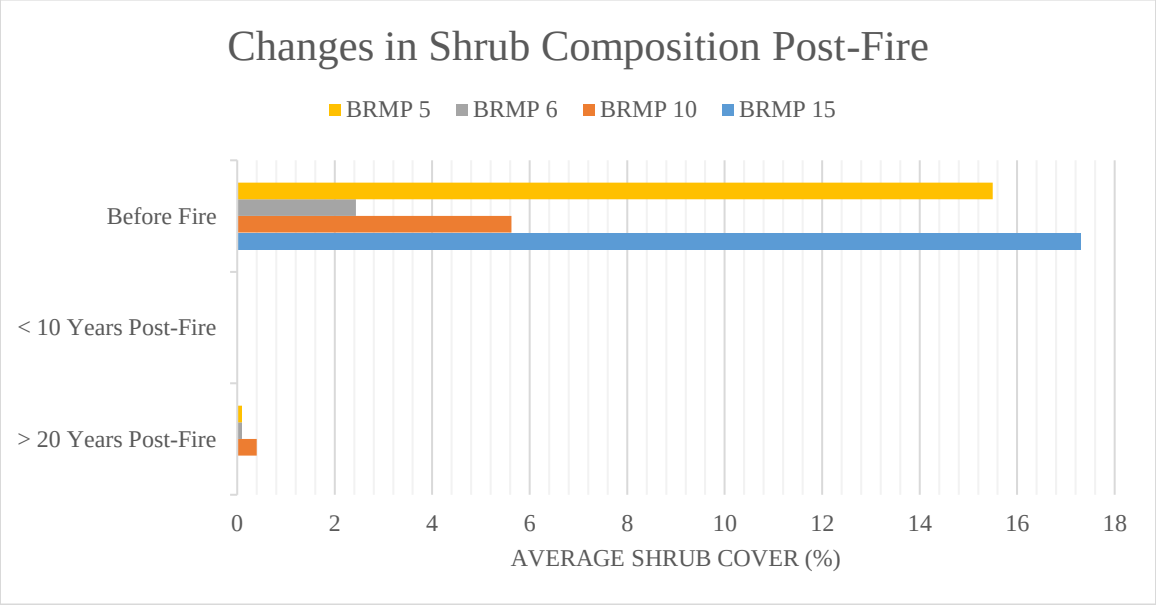

Figure 30. Changes in Shrub Composition at BMRP Plots after the 24 Command Fire.

5.0 DISCUSSION

This section analyzes the results and examines how the data collected from the post-fire vegetation monitoring effort can be used to inform the management approach to areas affected by wildfire. It assesses the Gable Mountain restoration effort and BMRP Plot monitoring results separately but uses conclusions from both of those monitoring efforts together to inform future management.

5.1 GABLE MOUNTAIN FIRE MONITORING

The immediate post-fire monitoring that occurred after the Gable Mountain Fire in October 2020 showed little surviving vegetation throughout the majority of the burned area, with the exception of the north slope of Gable Mountain. In an area once dominated by a mature sagebrush overstory, habitat was reduced to ashes and matted cheatgrass. Though this area was considered high quality habitat prior to the Gable Mountain Fire, the unburned Reference Area transects contained high quantities of cheatgrass in the understory with average cheatgrass cover totaling 31.4%. This suggests that cheatgrass was dominant in the understory of the Gable Mountain Fire area prior to burning and likely fueled the fire to burn hotter, resulting in high mortality of the native plants in the area. Pre-fire cheatgrass levels in the 24 Command Fire BRMP plots were

also high, averaging 35%, resulting in a fire that eliminated the majority of the shrub overstory in that area. Monitoring at BRMP plots suggest that cheatgrass cover will be temporarily reduced in the years following fire but will gradually increase over time.

The Gable Mountain Fire area was seeded with native grass species and sagebrush in January 2021 in an attempt to replenish the native seed bank and prevent cheatgrass from increasing beyond pre-fire coverage levels in the area. As there was no supplemental water added to the seeded area, this effort was heavily dependent on precipitation for success. Precipitation from January 1 to June 30, 2021, totaled 1.76 in., well below the expected level of 2.74 in. for that time period. Not only was rainfall at only 64% of normal levels, an early spring and above average temperatures left native and invasive plants at lower coverages than expected. This is expected to have negatively influenced germination of both the species seeded in the restoration effort and germination of species in the seed bank that survived the fire. Seed from the restoration effort that did not germinate in 2021 can potentially germinate in 2022 with favorable weather conditions. Increased precipitation in the winter and spring 2022 would likely lead to an increase in seeded native species cover.

Despite the abnormally low precipitation in spring 2021, bunchgrass seedlings were observed throughout the burn area. Sandberg's bluegrass was the major component of native coverage throughout the transects and had been included as a main component of the restoration seed mix in most areas. The majority of unidentified bunchgrass seedlings were believed to be needle-and-thread grass and Indian ricegrass. Germination of bunchgrasses throughout the burned area suggests that the seeding effort had a beneficial impact or that native seed in the seed bank persisted through the fire. This germination occurred despite low precipitation, suggesting increased germination will be seen within a year with average or high precipitation. Bunchgrasses, including bluebunch wheatgrass, sand dropseed, Sandberg's bluegrass, needle-and-thread grass, and Indian ricegrass were all observed growing from partially burned clumps throughout the burned area. This was mainly observed in areas with lower burn severity and remnants of surviving vegetation.

Sagebrush was present throughout the western and central portions of the burned area prior to the Gable Mountain Fire. Sagebrush decreases significantly in the seed bank following fire (Allen et al. 2008). Native sagebrush was seeded over the high-density sagebrush area in an attempt to replenish the sagebrush overstory that had been decimated in the fire. With the exception of patches of sagebrush that survived the fire, no sagebrush seedlings were observed within the high-density sagebrush area or within the Gable Mountain area, where sagebrush had also been dominant pre-fire. Sagebrush seed remains viable in the seed bank for 1 to 2 years when buried or under litter and decreases in viability over time (Wijayratne and Pyke 2009). Typical restoration efforts increase seed to soil contact to increase seed viability, but the Gable Mountain restoration effort did not obtain authorization to perform ground-disturbing activities. Sagebrush seed that remains in the seed bank and re-seeded sagebrush seed that was protected by litter has a chance to germinate the next growing season.

Monitoring in spring 2021 showed little vegetative coverage, likely due to both the recency of the fire and the low precipitation for the year. Depending on winter and spring 2022 precipitation patterns, the second monitoring season may see drastic changes in native and invasive species

cover. More data is needed before evaluating the effectiveness of the restoration seed mix and trending the recovery of the Gable Mountain Fire area. The seed bank within the burned area contains both seed from the restoration effort and native seed that may require an average to high precipitation year to germinate and push forward the recovery of the burned area.

5.2 BMRP PLOT MONITORING

Results from long-term BRMP plot monitoring help increase understanding of vegetation recovery post-fire. Spring 2021 monitoring of BRMP plots revealed a number of significant trends among the plots that will be critical in understanding how areas of the Hanford Site recover post-fire.

Cheatgrass coverage was evaluated for BRMP plots that burned in the 24 Command Fire. Pre-fire coverage was relatively high at 35%. That coverage decreased in the first monitoring effort after the fire, then increased when monitored in 2021. It is expected that cheatgrass coverage will continue to increase at these sites. Cheatgrass coverage percentages in 2021 are likely lower than normal due to the low precipitation and corresponding lack of significant vegetative growth in 2021. Native species followed a different trend and decreased across the BRMP plots after the 24 Command Fire. Pre-fire native cover averaged 26%, decreasing to 16% less than 10 years after the fire and to 11% in 2021. This gradual decrease is concerning and reflects a gradual conversion of habitats dominated by native species to invasive species after fire. This conversion can be combatted by reseeding areas with native species after fire in an attempt to replenish the native seed bank and outcompete invasive species.

Four of the six BRMP plots burned in the 24 Command Fire contained sagebrush as a dominant overstory plant prior to the fire. Within these four sites, sagebrush coverage did not begin to increase significantly until 2021 monitoring where sagebrush cover still averaged less than 1%. The slow to non-existent recovery of the sagebrush overstory in burned areas has been observed after multiple fires on the Hanford Site, where a lack of sagebrush, decrease in native species, and increase in invasive species results in fire-converting sagebrush habitat to cheatgrass monocultures. This increases future fire danger as cheatgrass provides increased fuel loads for fire and perpetuates a destructive fire cycle (Knapp 1996).

Recovery of the BMRP Plots after the 24 Command Fire provide trends that can be used to interpret the recovery of the Gable Mountain Fire area. Without restoration actions, the recovery of the Gable Mountain Fire area would be expected to look similar to the 24 Command Fire area, especially in the BRMP plots with high sagebrush and cheatgrass cover prior to the fire (BMRP 5, 10, 15). If restoration actions are successful, the decreases in native cover would not be as pronounced at the Gable Mountain Fire area compared to the 24 Command Fire BRMP plots. The initial results of BRMP plot monitoring support re-seeding after fire, especially for species like sagebrush that do not naturally recover well after fire.

5.3 FUTURE ACTIONS

The results of the Gable Mountain Fire and 24 Command Fire monitoring provide an initial dataset that can be used to track the recovery of a restored burned area versus an unrestored burned area. Future monitoring will help develop the Gable Mountain Fire dataset and will provide needed information about continued recovery after fire. Monitoring frequency in the Gable Mountain Fire area should be maintained at an annual basis, with effort made to repeat the monitoring activity around the same time each year. BRMP plot vegetative composition is not expected to change significantly on an annual basis, and it is recommended the BRMP plots burned in the 24 Command Fire be revisited in 5 years to collect additional trend data. BRMP Plot 25, which is located within the Gable Mountain burn area, should be monitored with the Gable Mountain Fire transects on an annual basis to evaluate the immediate effects of the fire.

Based on the results of BRMP plot monitoring, it is recommended that restoration action be taken within burned areas on the Hanford Site. Both supplementing native grasses and returning the shrub overstory is crucial to restoring a pre-fire habitat. Where sagebrush is a critical component of the ecosystem, sagebrush seed should be included within the restoration mix, and efforts should be made to increase seed to soil contact. Continued monitoring of the Gable Mountain Fire area will help restoration practitioners refine the Hanford Site post-fire seed mix and determine the best restoration for an area.

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