Great Group DD: [MLRA 24/27] Winterfat

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group DD – Ecological sites:

MLRA 24 DRG 4 (Modal)	
Silty 4-8" P.Z. (Modal)	024XY004NV
Saline Terrace 6-8" P.Z.	024XY012NV
Coarse Silty 4-8" P.Z.	024XY014NV
Silty 8-10" P.Z.	024XY059NV
MLRA 27 DRG 15	
Coarse Silty 4-8" P.Z.	024XY014NV

Description of Great Group DD:
Great Group DD consists of two DRGs and five ecological sites. The precipitation zone for these sites ranges from 4 to 10 inches. Soils correlated to this group are deep to very deep and occur on fan piedmonts, alluvial flats, stream terraces and lake plains. They formed in mixed alluvium influenced by loess high in volcanic ash or lacustrine sediments. Some soils formed in loess high in volcanic ash on summits of plateaus. Slopes range from 0 to 30 percent. Elevation ranges from 4000 to 6000 feet. Drainage ranges from somewhat excessive to well. Surface layers are free of salt and sodium accumulation. In some soils concentrations of salts and sodium in the lower substratum is common. Where these soils occur on lake plains, drainage is moderately well with seasonal saturation at a depth greater than 5 feet. Capillary movement of water in these areas contributes to high salt and sodium accumulations below 10 inches of the surface. Ponding is common in areas of less than 1 percent slopes following high rainfall or snowmelt events. Soil temperature regime is mesic. Production is less than 700 lbs/ac with the average production for a normal year being 440 lbs/ac. The potential native plant community for 3 of the sites is dominated by winterfat (*Krascheninnikovia lanata*) with an herbaceous understory of Indian ricegrass (*Achnatherum hymenoides*) and bottlebrush squirreltail (*Elymus elymoides*). Needleandthread (*Hesperostipa comata*) and Sandberg bluegrass (*Poa secunda*) are also present on these sites. The remaining site is dominated by sickle saltbush (*Atriplex falcata*) with Indian ricegrass and bottlebrush squirreltail dominating the herbaceous understory.

Ecological Dynamics and Disturbance Response:
An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

Winterfat is a long-lived, drought tolerant, native shrub typically about 30 cm tall (Mozingo 1987). It has a woody base from which annual branchlets grow (Welsh et al. 1987). The most common variety is a low growing dwarf form (less than 38.1 cm), which is most often found on desert valley floors (Stevens et al. 1977). Total winter precipitation is a primary growth driver and lower than average spring precipitation can reverse the impact of plentiful winter precipitation. While summer rainfall has a limited impact, heavy August-September rain can cause a second flowering in winterfat (West and Gasto 1978). Winterfat reproduces from seed and primarily pollinates via wind (Stevens et al. 1977). Seed production, especially in desert regions, is dependent on precipitation (West and Gasto 1978) with good seed years occurring when there is appreciable summer precipitation and little browsing (Stevens et al. 1977).Winterfat has multiple dispersal mechanisms: diaspores are shed in the fall or winter, dispersed by wind, rodent-cached, or carried on animals (Majerus 2003). Diaspores take advantage of available moisture, tolerating freezing conditions as they progress from imbibed seeds to germinants to nonwoody seedlings (Booth 1989). Under some circumstances, the degree of reproduction may be dependent on mature plant density (Freeman and Emlen 1995).

These communities often exhibit the formation of microbiotic crusts within the interspaces between shrubs. These crusts influence the soils on these sites and their ability to reduce erosion and increase infiltration; they may also alter the soil structure and possibly increase soil fertility (Fletcher and Martin 1948, Williams 1993). Finer textured soils such as silts tend to support more microbiotic cover than coarse texture soils (Anderson 1982). Disturbance such as hoof action from inappropriate grazing and cheatgrass (*Bromus tectorum*) invasion can reduce biotic crust integrity (Anderson 1982, Ponzetti et al. 2007) and increase erosion.

Drought and/or inappropriate grazing will initially favor shrubs but prolonged drought can cause a decrease in the winterfat, bud sagebrush and other shrubs, while bare ground increases. Indian ricegrass will decrease with inappropriate grazing management. Squirreltail may maintain or also decline within the community. Repeated spring and early summer grazing will have an especially detrimental effect on winterfat and bud sagebrush (*Artemisia tridentata*). Cheatgrass and other non-native annual weeds increase with excessive grazing. Abusive grazing during the winter may lead to soil compaction and reduced infiltration. Prolonged abusive grazing during any season leads to abundant bare ground, desert pavement and active wind and water erosion. Repeated, frequent fire will promote cheatgrass dominance and elimination of the native plant community. These sites frequently attract recreational use, primarily by off highway vehicles (OHV). Annual non-native species increase where surface soils have been disturbed. Three alternative stable states have been identified for this site.

Fire Ecology:
Winterfat tolerates environmental stress, extremes of temperature and precipitation, and competition from other perennials but not the disturbance of fire or overgrazing (Ogle 2001). Fire is rare within these communities due to low fuel loads. There are conflicting reports in the literature about the response of winterfat to fire. In one of the first published descriptions, Dwyer and Pieper (1967) reported that winterfat sprouts vigorously after fire. This observation was frequently cited in subsequent literature, but recent observations have suggested that winterfat can be completely killed by fire (Pellant and Reichert 1984). The response is apparently dependent on fire severity. Winterfat is able to sprout from buds near the base of the plant. However, if these buds are destroyed, winterfat will not sprout. Research has shown that winterfat seedling growth is depressed in growth by at least 90% when growing in the presence of cheatgrass (Hild et al. 2007). Repeated, frequent fires will increase the likelihood of conversion to a non-native, annual plant community with trace amounts of winterfat.

Bud sagebrush (*Picrothamnus desertorum*), a minor shrub to this ecological site, is a native, summer-deciduous shrub. It is low growing, spinescent, aromatic shrub with a height of 4 to 10 inches and a spread of 8 to 12 inches (Chambers and Norton 1993). Bud sagebrush is fire intolerant and must reestablish from seed (Banner 1992, West 1994).

Indian ricegrass, the dominant grass within this site, is a hardy, cool-season, densely tufted, native perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). Indian ricegrass has been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983). Thus the presence of surviving, seed producing plants is necessary for reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Bottlebrush squirreltail, another cool-season, native perennial bunchgrass is common to this ecological site. Bottlebrush squirreltail is considered more fire tolerant than Indian ricegrass due to its small size, coarse stems, and sparse leafy material (Britton et al. 1990). Postfire regeneration occurs from surviving root crowns and from on- and off-site seed sources. Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and ability to grow at low temperatures contribute to the persistence of bottlebrush squirreltail among cheatgrass dominated ranges (Hironaka and Tisdale 1972).

Livestock and Wildlife Grazing Interpretations:
Winterfat is a valuable forage species with an average of 10% crude protein during winter when there are few nutritious options for livestock and wildlife (Welch 1989). However, excessive grazing throughout the west has negatively impacted survival of winterfat stands (Hilton 1941; Statler 1967; Stevens et al. 1977). Time of grazing is critical for winterfat with the active growing period being most critical (Romo 1995). Stevens et al. (1977) found that both vigor and reproduction of winterfat were reduced in Steptoe Valley, Nevada by improper season of use, and he recommended no more than 25% utilization during periods of active growth and up to 75% utilization during dormant season use. Rasmussen and Brotherson (1986) found significantly greater foliar cover and density of winterfat in areas ungrazed for 26 years versus winter grazed areas in Utah. In exclosures protected from grazing for between 5 and 16 years, Rice and Westoby (1978) found that winterfat increased in foliar cover but not in density where it was dominant, and in both foliar cover and density in shadscale-perennial grass communities where it was not dominant.

In addition to grazing by cattle, winterfat is browsed by rabbits, antelope, and other wildlife species (Stevens et al. 1977, Ogle et al. 2001). Winterfat and perennial grasses average 80% of jackrabbits' diet in southeastern Idaho, with shrubs being grazed in fall and winter particularly (Johnson and Anderson 1984). Pronghorn and rabbits browse stems, leaves, and seed stalks of winterfat year round, especially during periods of active growth (Stevens et al. 1977). Management of wildlife browse is difficult and browse may be harmful to winterfat reestablishment as seed production and regrowth are curtailed if grazing occurs as the plant begins to grow (Eckert 1954).

Heavy spring grazing has been found to sharply reduce the vigor of Indian ricegrass and decrease the stand (Cook and Child 1971). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended.

Bottlebrush squirreltail generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced bottlebrush squirreltail seedling emergence compared to untrampled conditions. Heavy trampling however was found to significantly reduce germination sites (Eckert et al. 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to over utilization within the growing season.

Bud sagebrush is also a palatable, nutritious forage for upland game birds, small game, big game and domestic sheep in winter, particularly late winter (Johnson 1978), however it can be poisonous or fatal to calves when eaten in quantity (Stubbendieck et al. 1992). Bud sagebrush is highly susceptible to effects of browsing. It decreases under browsing due to year-long palatability of its buds and is particularly susceptible to browsing in the spring when it is physiologically most active (Chambers and Norton 1993). Heavy browsing (>50%) may kill bud sagebrush rapidly (Wood and Brotherson 1986).

State and Transition Model Narrative—Great Group DD

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group DD.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. This state has two community phases, one co-dominated by shrubs and grass, and the other dominated by shrubs. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. This site is very stable, with little variation in plant community composition. Plant community changes would be reflected in production in response to drought or inappropriate grazing management. Wet years will increase grass production, while drought years will reduce production. Shrub production will also increase during wet years; however, recruitment of winterfat is episodic.

Community Phase 1.1:
This community is dominated by winterfat and Indian ricegrass. Bottlebrush squirreltail and bud sagebrush are also important species on this site. Community phase changes are primarily a function of chronic drought. Fire is infrequent and patchy due to low fuel loads.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Long term drought and/or herbivory. Fires would also decrease vegetation on these sites but would be infrequent and patchy due to low fuel loads.

Community Phase 1.2:
Drought will favor shrubs over perennial bunchgrasses. However, long term drought will result in an overall decline in the plant community, regardless of functional group.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time, lack of disturbance and recovery from drought would allow the vegetation to increase and bare ground would eventually decrease.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:
Trigger: This transition is caused by the introduction of non-native annual plants, such as halogeton and cheatgrass.
Slow variables: Over time the annual non-native species will increase within the community.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:
This state is similar to the Reference State 1.0. This state has the same two general community phases. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community is dominated by winterfat and Indian ricegrass. Bottlebrush squirreltail and bud sagebrush are also important species on this site. Community phase changes are primarily a function of chronic drought. Fire is infrequent and patchy due to low fuel loads. Non-native annual species are present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Drought will favor shrubs over perennial bunchgrasses. However, long term drought will result in an overall decline in the plant community, regardless of functional group. Inappropriate grazing management will favor unpalatable shrubs such as shadscale, and cause a decline in winterfat and bud sagebrush.

Community Phase 2.2:

This community is dominated by winterfat. The perennial grass component is significantly reduced.

Silty 4-8" (024XY004NV) Phase 2.2 T. Stringham July 2010

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Release from long term drought and/or growing season grazing pressure allows recovery of bunchgrasses, winterfat, and bud sagebrush.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:
Trigger: Inappropriate, long term grazing of perennial bunchgrasses during the growing season and/or long term drought will favor shrubs and initiate a transition to Community phase 3.1.
Slow variables: Long-term decrease in deep-rooted perennial grass density.
Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:
Trigger: Severe fire/ multiple fires and/or soil disturbing treatments would transition to Community Phase 4.1. Long term inappropriate grazing management in the presence of non-native annual species would transition to Community Phase 4.2.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community. Increased, continuous fine fuels from annual non-native plants modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0:
This state consists of one community phase. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased.

Community Phase 3.1:
Perennial bunchgrasses, like Indian ricegrass are reduced and the site is dominated by winterfat. Rabbitbrush and shadscale may be significant components or dominant shrubs. Annual non-native species increase. Bare ground has increased.

Silty 4-8" (024XY004NV) Phase 3.1 T. Stringham April 2010

Silty 4-8" (024XY004NV) Phase 3.1 T. Stringham June 2010

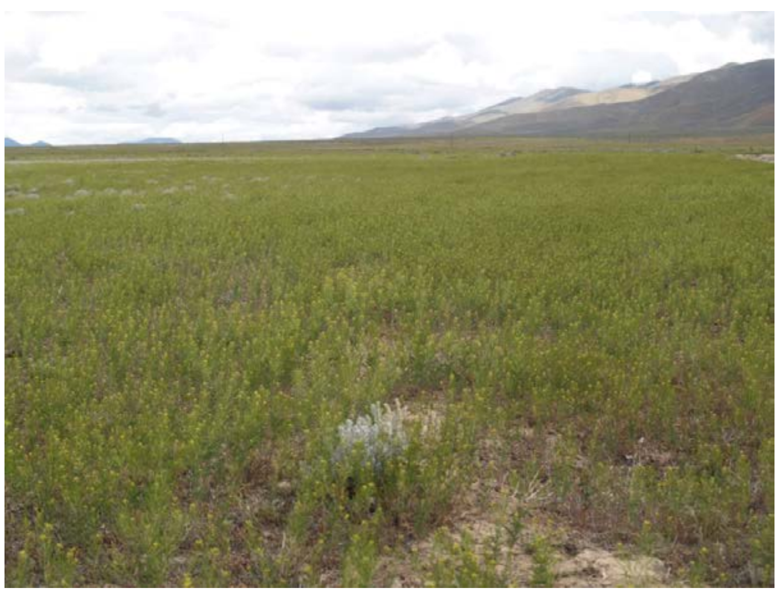
T3A: Transition from Shrub State 3.0 to Annual State 4.0:
Trigger: Severe fire/ multiple fires, long term inappropriate grazing management, and/or soil disturbing treatments such as plowing.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

Annual State 4.0:

This state consists of two community phases. This state is characterized by the dominance of annual non-native species such as halogeton and cheatgrass. Rabbitbrush, shadscale, sickle saltbush and other sprouting shrubs may dominate the overstory.

Community Phase 4.1:
This community is dominated by annual non-native species. Trace amounts of winterfat and other shrubs may be present, but are not contributing to site function. Bare ground may be abundant, especially during low precipitation years. Soil erosion, soil temperature and wind are driving factors in site function.

Silty 4-8" (024XY004NV) Phase 4.1 T. Stringham June 2010



Silty 4-8" (024XY004NV) Phase 4.1 T. Stringham July 2010

Coarse Silty 4-8" (024XY014NV) Phase 4.1 T. Stringham August 2010

Silty 4-8" (024XY004NV) or Saline Terrace 6-8" (024XY012NV) Phase 4.1 T. Stringham August 2010

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Reestablishment of winterfat. This pathway is unlikely due to the impact of annual non-native species on the establishment and growth of winterfat seedlings.

Community Phase 4.2:
This community is dominated by winterfat with an understory of non-native annual species. Perennial bunchgrasses may be a minor component or missing. Bare ground may be abundant.

Silty 4-8 (024XY004NV) Phase 4.2 T. Stringham July 2010

Community Phase Pathway 4.2a, from Phase 4.2 to 4.1:
Fire

Potential Resilience Differences with other Ecological Sites:

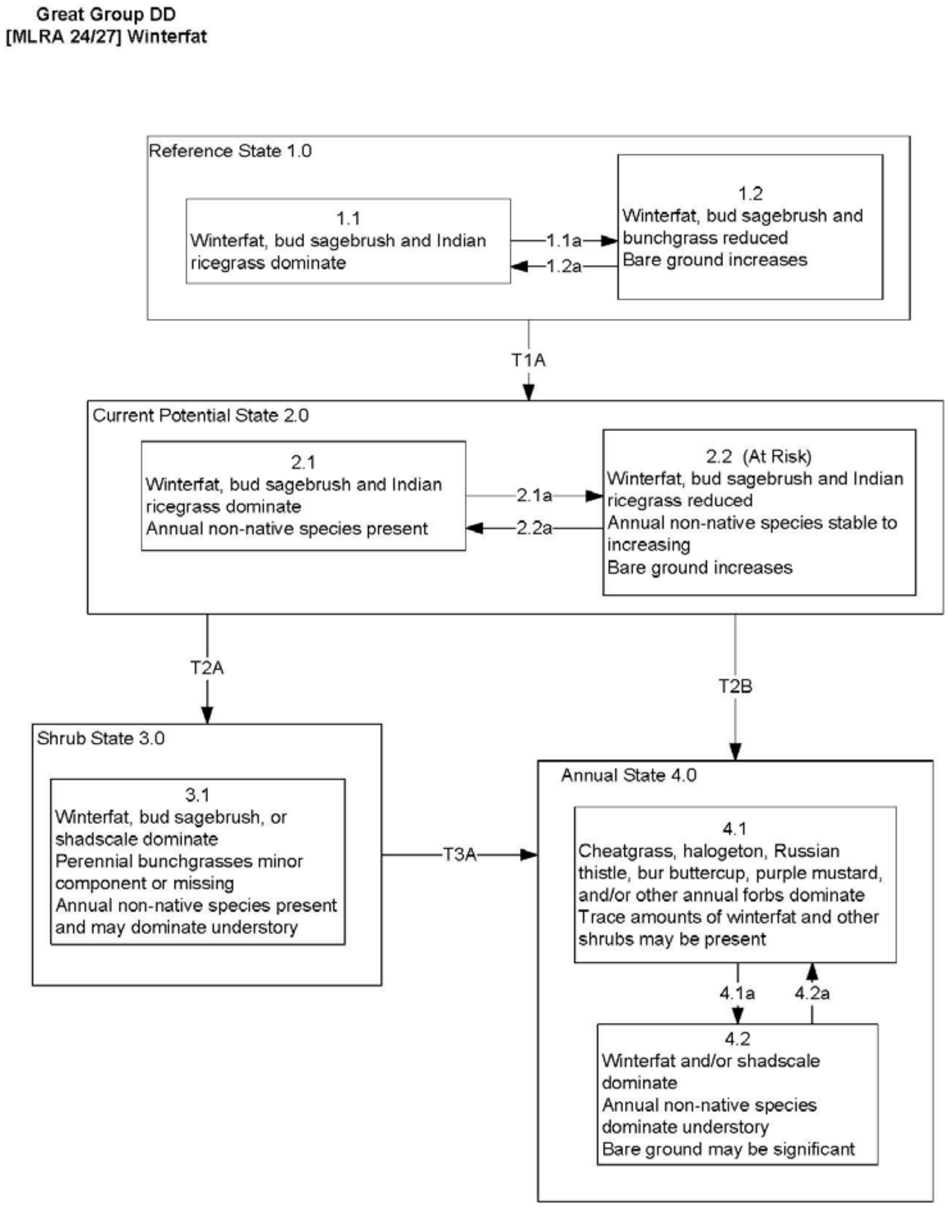
Saline Terrace 6-8" (024XY012NV):
The soils of this site are very deep. Surface soils are medium textured and less than 10 inches thick. These soils are moderately well drained with a seasonally high water table at a depth of greater than 5 feet. The soils are strongly saline and moderately to strongly sodium affected. The greatest concentration of salts is below 10 inches of the surface where dissolved salts accumulate at the upper limits of capillary movement. These sites are dominated by sickle saltbush with an understory of Indian ricegrass. Black greasewood is a minor component on these sites but may dominate the aspect. Production for a normal year is 400 lbs/ac. This site was only seen in the shrub state on the field visits. However it likely has a similar state-and-transition model with 4 alternative states.

Coarse Silty 4-8" (024XY014NV):
The soils of this site are deep to very deep and are well drained. Surface soils are moderately coarse textured and less than 10 inches thick. Soil reaction increases with soil depth. Moderate to strong concentrations of salt and sodium occur within 20 inches of the surfaces. Some soils are modified with a high volume of gravel in the lower profile. Rock fragments in the soil profile and/or high salt concentration in the lower profile reduce the available water capacity of these soils. This plant community is dominated by winterfat and bud sagebrush. Indian ricegrass and shadscale are also common on these sites. Production for this site in a normal year is 500 lbs/acre. This site was only seen in an annual state with a shrub overstory on the field visits. However it likely has a similar state-and-transition model with 4 alternative states.

Silty 8-10" (024XY059NV):
The soils in this site are very deep and moderately well drained. Surface soils are typically silt loams and normally less than 10 inches thick. The surface layers are free of salt and sodium. Moderate to strong concentrations of salts and sodium are common in the lower substratum in some pedons. Due to their

silty textures, the surface layer of these soils will normally crust and bake upon drying, inhibiting water infiltration and seedling emergence. This site is dominated by Indian ricegrass and winterfat. Production for this site in a normal year is 500 lbs/acre. This site was not seen on the field visits but is similar to the modal site with four alternative states in the state-and-transition model.

Modal State and Transition Model for Great Group DD



Great Group DD
[MLRA 24/27] Winterfat

Reference State 1.0 Community Phase Pathways:
1.1a: Drought and/or excessive herbivory during the growing season will reduce both shrub and perennial bunchgrass production and/or cover. Fire would be infrequent and patchy due to low fuel loads.
1.2a: Time, lack of disturbance and release from drought will allow for perennial grass production to increase and/or cover, especially with an increase in spring precipitation.

Transition T1A: Introduction of non-native annual species such as cheatgrass, halogeton and mustards.

Current Potential State 2.0 Community Phase Pathways:
2.1a: Drought and/or inappropriate grazing management.
2.2a: Release from drought combined with appropriate grazing management would allow for both the shrubs and perennial grasses to recover.

Transition T2A: Inappropriate grazing management.

Transition T2B: Catastrophic fire, and/or soil disturbing treatments (4.1). Inappropriate grazing management in the presence of non-native species (4.2).

Shrub State 3.0 Community Phase Pathways:
None.

Transition T3A: Catastrophic fire, long term inappropriate grazing management, and/or soil disturbing treatments.

Annual State 4.0 Community Phase Pathways:
4.1a: Time and lack of disturbance. Winterfat and/or shadscale may reestablish after many years.
4.2a: Fire.

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Great Group E: Sandy/Dune

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group E – Ecological Sites:

MLRA 23 DRG 14 (Modal)
Dunes 8-10" (Modal) 023XY011NV

Description of Great Group E:
Great Group E consists of one DRG and one ecological site: Dunes 8-10" (023XY011NV). The precipitation zone for this site ranges from 8 to 10 inches. The elevation range for this group is from 4,500 to 5,000 ft. Slopes range from 2 to 30 percent. The soils of this site are windblown, fine and very fine sands, typically more than 40 inches in depth. Soils are very susceptible to wind erosion and may have small "blow out" areas. The soil profile is excessively drained and free of salts. Because of rapid soil intake and deep percolation of water, the loss of soil moisture due to evaporation is reduced and runoff is negligible. These conditions allow deep rooted plants to grow vigorously under arid climatic conditions. The potential native plant community for this site varies depending on precipitation, elevation and landform. The shrub overstory component is dominated by basin big sagebrush (*Artemisia tridentata ssp. tridentata)* and spiny hopsage (*Grayia spinosa*). The understory is dominated by Indian ricegrass (*Achnatherum hymenoides*), basin wildrye (*Leymus cinereus*), thickspike wheatgrass (*Elymus lanceolatus*), and needle and thread (*Hesperostipa comata*). The production on this site ranges from 400 to 900 lbs/acre, with 700 lb/ac in normal years.

Ecological Dynamics and Disturbance Response:
An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).
The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (Dobrowolski et al. 1990). Root length of mature sagebrush reached a depth of 2 meters in alluvial soils in Utah (Richards and Caldwell 1987). However, community types with low sagebrush as the dominant shrub were found to have soil depths and thus available rooting depths of 71 to 81 cm in a study in northeast Nevada

(Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons (MacMahon 1980). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance (Whisenant 1999, Miller et al. 2013). The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Beckstead and Augspurger 2004, Chambers et al. 2007, Johnson et al. 2011).

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and have been ongoing in Nevada since 2004 (Longland and Young 1995, Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975). When sagebrush stands are decadent and even-aged, aroga investations are more likely to be a stand-replacing event (Longland and Young 1995).

Indian ricegrass is the dominant grass on this site. Indian ricegrass is a deep-rooted, cool season perennial bunchgrass that is adapted primarily to sandy soils. Grasses generally have shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m, but taper off more rapidly than shrubs. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation, and increased nutrient availability. Four possible states have been identified for this DRG.

Annual Invasive Grasses:

The species most likely to invade these sites are cheatgrass and medusahead, however medusahead is more commonly found in clayey soils, so it may never become dominant on this sandy dune site. This narrative will focus on cheatgrass. Both species are cool-season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increase with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Medusahead and cheatgrass originated from Eurasia and both were first reported in North America in the late 1800s (Mack and Pyke, 1983; Furbush 1953). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011). Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by increasing fire frequency.

Methods to control medusahead and cheatgrass include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead cover near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. Spraying with herbicide (Imazapic or Imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating medusahead and cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of medusahead or cheatgrass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015). Butler et al. (2011) tested four herbicides (Imazapic, Imazapic + glyphosate, rimsulfuron and sulfometuron + Chlorsulfuron) only treatments for suppression of cheatgrass, medusahead, and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011), however caution in using these results is advised, as only one year of data was reported.

Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (Cercocarpus montanus), antelope bitterbrush, and multiple sagebrush species to three rates of Imazapic and the same rates with methylated seed oil as a surfactant. They found a cheatgrass control program in an antelope bitterbrush community should not exceed Imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad scale herbicide application is initiated.

Fire Ecology:

In many basin big sagebrush communities, changes in fire frequency occurred along with fire suppression, livestock grazing and OHV use. Few if any fire history studies have been conducted on basin big sagebrush; however, Sapsis and Kauffman (1991) suggest that fire return intervals in basin big sagebrush are intermediate between mountain big sagebrush (15 to 25 years) and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) (50 to 100 years). Fire severity in big sagebrush communities is described as "variable" depending on weather, fuels, and topography. However, fire in basin big sagebrush communities are typically stand replacing (Sapsis and Kauffman 1991). Basin big sagebrush does not sprout after fire. Because of the time needed to produce seed, it is eliminated by frequent fires (Bunting et al. 1987). Basin big sagebrush reinvades a site primarily by off-site seed or seed from plants that survive in unburned patches. Approximately 90% of big sagebrush seed is dispersed within 30 feet (9 m) of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 feet (33 m) from the parent shrub (Shumar and Anderson 1986). Therefore regeneration of basin big sagebrush after stand replacing fires is difficult and dependent upon proximity of residual mature plants and favorable moisture conditions (Johnson and Payne 1968, Humphrey 1984).

Spiny hopsage is a sprouting shrub (Daubenmire 1970) that is fairly tolerant of fire due its dormancy during the summer months (Rickard and McShane 1984). After fire, these sprouting shrubs can produce significant new growth if there is enough moisture available (Shaw 1992). Other environmental conditions also determine the level of re-establishment that occurs, such as the salinity and temperature of soil. In order to germinate, seeds need moist conditions (Monsen et al. 2004). They do not compete well with annual invasives (Monsen et al. 2004).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface, providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Indian ricegrass has been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus the presence of surviving, seed producing plants is necessary for reestablishment of Indian ricegrass. It is important to manage grazing following fire in a way that promotes seed production and establishment of seedlings.

Basin wildrye is relatively resistant to fire, particularly dormant season fire, as plants sprout from surviving root crowns and rhizomes (Zschaechner 1985). Miller et al. (2013) reported increased total shoot and reproductive shoot densities in the first year following fire, although by year two there was little difference between burned and control treatments.

The grasses likely to invade this site are cheatgrass and medusahead. These invasive grasses displace desirable perennial grasses, reduce livestock forage, and accumulate large fuel loads that foster frequent fires (Davies and Svejcar 2008). Invasion by annual grasses can alter the fire cycle by increasing fire size, fire season length, rate of spread, numbers of individual fires, and likelihood of fires spreading into native or managed ecosystems (D'Antonio and Vitousek 1992, Brooks et al. 2004). While historical fire return intervals are estimated at 15 to 100 years, areas dominated with cheatgrass are estimated to have a fire return interval of 3-5 years (Whisenant 1990). The mechanisms by which invasive annual grasses alter fire regimes likely interact with climate. For example, cheatgrass cover and biomass vary with climate (Chambers et al. 2007) and are promoted by wet and warm conditions during the fall and spring. Invasive annual species have been shown able to take advantage of high N availability following fire through higher growth rates and increased seedling establishment relative to native perennial grasses (Monaco et al. 2003).

Livestock/Wildlife Grazing Interpretations:

Personius et al. (1987) found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable).

Spiny hopsage is palatable to livestock, especially sheep, during the spring and early summer (Phillips et al. 1996, Simmons and Rickard 2003). However, the shrub goes to seed and loses its leaves in July and August so its usefulness in the fall and winter is limited (Sanderson and Stutz 1994). Two studies showed little to no utilization by sheep during the winter (Harrison and Thatcher 1970, Green et al. 1951). Some scientists are concerned about the longevity of the species. One study showed no change in cover or density when excluded from livestock and wildlife grazing for 10+ years (Rice and Westoby 1978), while another seldom observed seedling establishment (Daubenmire 1970). With poor recruitment rates, some are concerned that with repeated fires and overgrazing, local populations of spiny hopsage may be lost (Simmons and Rickard 2003).

Indian ricegrass is a deep-rooted, cool season perennial bunchgrass that is adapted primarily to sandy soils. Indian ricegrass is a preferred forage species for livestock and wildlife (Booth et al. 1980, Cook 1962). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) note that the plant does well when utilized in winter and spring. However, Cook and Child (1971) found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Cook and Child 1971, Pearson 1964); however, utilization of less than 60% is recommended.

Basin wildrye is valuable forage for livestock (Ganskopp et al. 2007) and wildlife, but is intolerant of heavy, repeated, or spring grazing (Krall et al. 1971). Basin wildrye is used often as a winter feed for livestock and wildlife; not only providing roughage above the snow but also cover in the early spring months (Majerus 1992).

Inappropriate grazing practices can be tied to the success of medusahead, however, eliminating grazing will not eradicate medusahead if it is already present (Wagner et al. 2001). Sheley and Svejcar (2009) reported that even moderate defoliation of bluebunch wheatgrass resulted in increased medusahead density. They suggested that disturbances such as plant defoliation limit soil resource capture, which creates an opportunity for exploitation by medusahead. Avoidance of medusahead by grazing animals allows medusahead populations to expand. This creates seed reserves that can infest adjoining areas and cause changes to the fire regime. Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by an increase in fire frequency. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008).

State and Transition Model Narrative of Great Group E:

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group E.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has two general community phases: a shrub-grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
The community is dominated by Indian ricegrass and basin big sagebrush. Spiny hopsage, basin wildrye, thickspike wheatgrass, needle and thread grass, and perennial forbs are also common on this site.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Time and lack of disturbance allows shrubs to increase. Chronic drought reduces grass production.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Big sagebrush, spiny hopsage and other shrubs increase. Perennial grasses are reduced.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Low severity fire results in a mosaic pattern with an increase in grasses. Release from drought may allow Indian ricegrass to increase in production. Fall and/or winter herbivory may cause mechanical damage to shrubs and reduce shrub density.

Dunes 8-10 (023XY011NV) Phase 1.2 T.K. Stringham August 2014

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual weeds, such as cheatgrass, mustard (*Descurainia* sp.) and halogeton (*Halogeton glomeratus*).
Slow variables: Over time, the annual non-native plants will increase within the community.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. This state has the same two general community phases. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces state resilience because these species can promote fire where historically fire has been infrequent leading to positive feedbacks that further the degradation of the system.

Community Phase 2.1:
The community is dominated by Indian ricegrass and basin big sagebrush. Spiny hopsage, basin wildrye, thickspike wheatgrass, needle and thread grass, and perennial forbs are also common on this site. Annual non-native species present.

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Time and lack of disturbance allows shrubs to increase. Chronic drought reduces grass production.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early seral community phase. Big sagebrush, spiny hopsage and other shrubs increase. Perennial grasses are reduced. Annual non-native species are present.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Low severity fire resulting in a mosaic pattern, with an increase in grasses. Release from drought may allow Indian ricegrass to increase in production. Fall and/or winter herbivory may cause mechanical damage to shrubs and reduce shrub density.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during growing season would favor shrubs and initiate transition to Community Phase 3.1. Fire would cause a transition to Community Phase 3.2.
Slow variables: Long-term decrease in deep-rooted perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.
Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0
Trigger: Fire in the presence of annual grasses leads to plant community phase 4.1.
Slow variables: Increased production and cover of non-native annual species. The change in dominance from perennial grasses to annual grasses reduces decreasing organic matter inputs from deep-rooted perennial bunchgrasses root turnover, resulting in reductions in soil water availability for perennial bunchgrasses.
Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community. Increased, continuous fine fuels from annual non-native plants modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0

This state has two community phases: a Basin big sagebrush dominated phase and a sprouting shrub dominated phase. This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sagebrush dominates the overstory and other shrubs may be a significant component. Sagebrush canopy cover is high and sagebrush may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1:
Big sagebrush dominates. Indian ricegrass and other perennial grasses in the understory are reduced. Annual non-native species are present to increasing. Understory may be sparse, with bare ground increasing.

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire and/or brush treatment would decrease or eliminate the overstory of sagebrush.

Community Phase 3.2:
Sprouting shrubs dominate the overstory. Perennial bunchgrasses may be a minor component. Annual non-native species are present to increasing.

Dunes 8-10" (023XY011NV) Shrub State 3.0 T.K. Stringham, August 2014

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Absence of disturbance over time would allow sagebrush and spiny hopsage to recover.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Fire in the presence of annual grasses eliminates the shrub overstory and transition to community phase 4.1.
Slow variable: Increased seed production and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

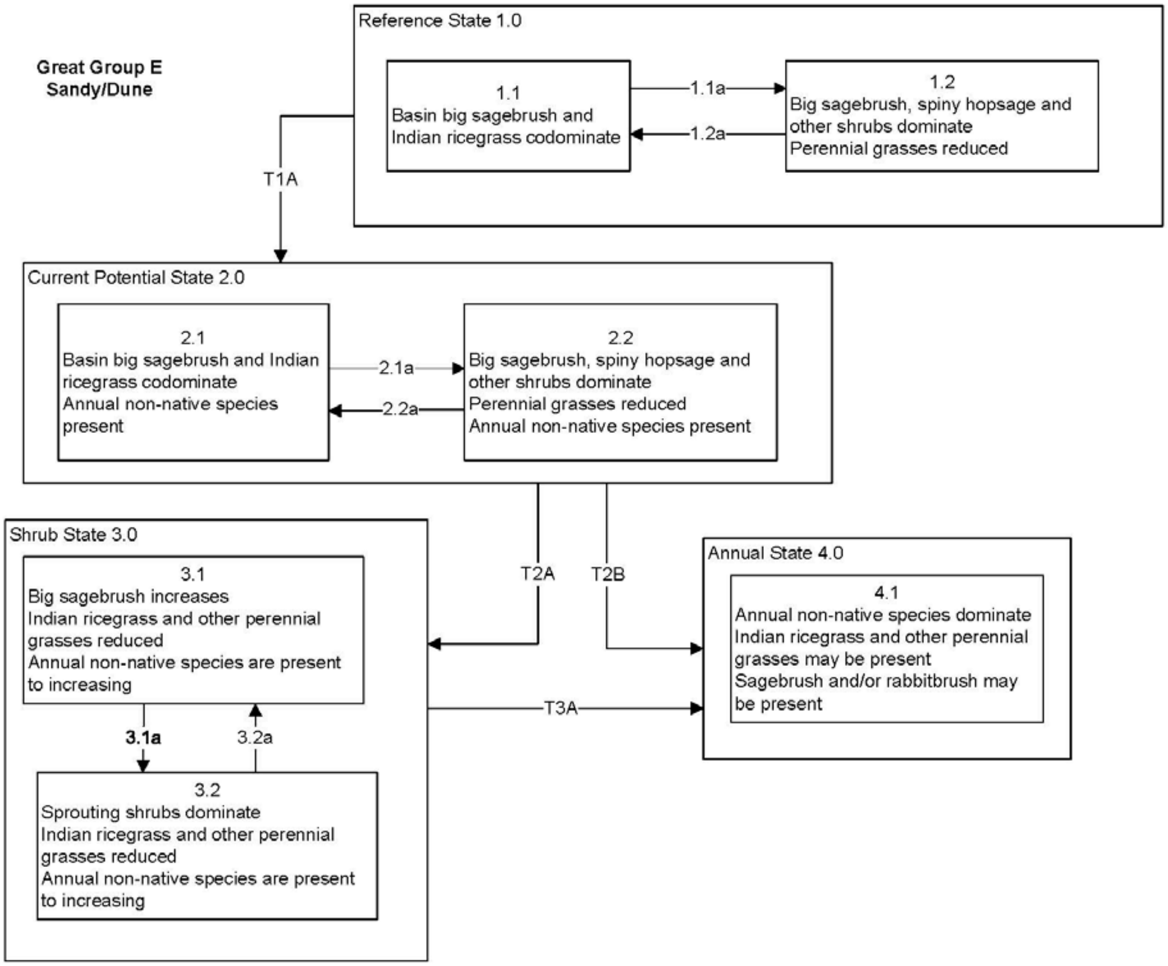
Annual State 4.0

This state has one community phase dominated by annual non-native species. This state is characterized by the dominance of annual non-native species such as cheatgrass and tansy mustard in the understory. Sagebrush and/or rabbitbrush may dominate the overstory. Annual non-native species and squirreltail dominate the understory.

Community Phase 4.1:
Annual non-native plants such as cheatgrass dominate the site. This phase may have seeded species present if resulting from a failed seeding attempt. Sagebrush and/or rabbitbrush may be present.

Dunes 8-10” (R023XY011NV) Annual State 4.0 T.K. Stringham, June 2017

Modal State and Transition Model for Great Group E:



Great Group E
Sandy/Dune

Reference State 1.0 Community Phase Pathways
1.1a: Time and lack of disturbance, may be coupled with drought.
1.2a: Low severity fire resulting in a mosaic pattern, fall/winter herbivory may cause mechanical damage to shrubs and reduce shrub density.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Time and lack of disturbance, may be coupled with drought.
2.2a: Low severity fire resulting in a mosaic pattern, fall/winter herbivory may cause mechanical damage to shrubs and reduce shrub density.

Transition T2A: Inappropriate grazing management (3.1), fire and/or brush treatment may be coupled with inappropriate grazing management (3.2).
Transition T2B: Fire in the presence of non-native annual species.

Shrub State 3.0 Community Phase Pathways
3.1a: Fire and/or brush treatment.
3.2a: Time and lack of disturbance.

Transition T3A: Fire.

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Great Group EE: [MLRA 24/27] Sandy/Dune

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group EE – Ecological Sites:

MLRA 24 DRG 7 (Modal)

Sandy 8-10” P.Z. (Modal)	024XY017NV
Dune 6-10” P.Z.	024XY001NV
Sandy 5-8” P.Z.	024XY055NV
Sodic Dune	024XY066NV

MLRA 27 DRG 11

Sandy 5-8” P.Z. (Modal)	027XY009NV
Sandy 3-5” P.Z.	027XY060NV
Outwash Plain	027XY078NV

MLRA 27 DRG 17

Sodic Dunes (Modal)	027XY016NV
Sodic Sands	027XY012NV

MLRA 27 DRG 19

Dunes 4-8” P.Z. (Modal)	027XY023NV
Dunes 8-10” P.Z.	027XY053NV

Description of Great Group EE:
Great Group EE consists of four DRGs and eleven ecological sites. The precipitation zone is 8 to 10 inches. The soils correlated to this site occur on sand sheets that cover middle and lower piedmont slopes or erosional fan remnants and alluvial fans, on beach terraces, and on partially stabilized dunes adjacent to playas. Parent materials consist of coarse textured alluvium or aeolian deposits from mixed rock sources. Slopes range from 2 to 30 percent, but 2 to 15 percent is typical. Elevations range from 4000 to 6000 feet. Soil temperature regime is mesic. These soils are porous and are somewhat excessively to excessively drained. If soils are not protected by plant cover, they are highly susceptible to wind erosion. Little to no runoff is expected, as moisture penetrates the soil rapidly. Average production is 500 lbs/ac, with a range between 200 to 900 lbs/ac. The potential native plant community for these sites is dominated by Indian ricegrass. Wyoming (*Artemisia tridentate* spp. *wyomingensis)*, basin big sagebrush (*Artemisia tridentata* spp. *tridentata*), black greasewood (*Sarcobatus vermiculatus*), and spiny hopsage (*Grayia spinosa*) are the dominant shrub species. Needleandthread (*Hesperostipa comata*), basin wildrye (*Leymus cinereus*), and fourwing saltbush (*Atriplex canescens)* are common species found throughout these sites.

Ecological Dynamics and Disturbance Response:
An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m. (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 meters in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990)
In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al 2006).
Wyoming big sagebrush, the most drought tolerant of the big sagebrushes, is generally long-lived; therefore it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (Aroga websteri). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and have been ongoing in Nevada since 2004 (Bentz, et al 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Perennial bunchgrasses generally have somewhat shallower root systems than shrubs in these systems, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m but taper off more rapidly than shrubs. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems. The perennial bunchgrasses that are sub-dominant with the shrubs include Indian ricegrass and needle and thread. The dominant grass within this site, is Indian ricegrass a hardy, cool-season, densely tufted, native perennial bunchgrass that grows from 4 to 24 inches in height (Blaisdell and Holmgren 1984). These species generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of the shrubs in the upper 0.5m of the soil profile. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation, both among years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The moisture resource supporting the greatest amount of plant growth is usually the water stored in the soil profile during the winter. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007). The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency. Conversely, as fire frequency decreases, sagebrush will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

The ecological sites within this DRG may experience high wind erosion, especially with a decrease in vegetative cover. This can be caused by inappropriate grazing practices, drought, Aroga moth infestation, off-road vehicle use and/or fire. As ecological condition declines, the dunes become mobile and recruitment and establishment of sagebrush and perennial grasses is reduced. This can cause an increase in sprouting shrubs such as rabbitbrush and horsebrush which are more adapted to disturbed sites. Annual non-native species invade these sites where competition from perennial species is decreased.

The ecological sites in this DRG have low resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Three alternative states have been identified for this ecological site but an annual state has been noted in other MLRA's and may be possible within this DRG.

Fire Ecology:

In many basin big sagebrush communities, changes in fire occurrence have occurred along with fire suppression, livestock grazing and OHV use. Reduction in plant cover or changes in plant community composition and structure, on ecological sites characterized by sandy soils, increases risk of active soil movement and dune creation or flattening. Few if any fire history studies have been conducted on basin big sagebrush; however, Sapsis and Kauffman (1991) suggest that fire return intervals in basin big sagebrush are intermediate between mountain big sagebrush (5 to 15 years) and Wyoming big sagebrush (10 to 70 years). It is likely the fire return interval for this site with average production of 700 lbs per acre was greater than those reported for mountain big sagebrush communities. Fire severity in big sagebrush communities is described as "variable" depending on weather, fuels, and topography. However, fire in basin big sagebrush communities are typically stand replacing (Sapis and Kauffman 1991). Basin big sagebrush does not sprout after fire. Because of the time needed to produce seed, it is eliminated by frequent fires (Bunting et al. 1987). Basin big sagebrush reinvades a site primarily by off-site seed or seed from plants that survive in unburned patches. Approximately 90% of big sagebrush seed is dispersed within 30 feet (9 m) of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 feet (33 m) from the parent shrub (Shumar and Anderson 1986).

Therefore regeneration of basin big sagebrush after stand replacing fires is difficult and dependent upon proximity of residual mature plants and favorable moisture conditions (Johnson and Payne 1968, Humphrey 1984). Reestablishment after fire may require 50-120 or more years (Baker 2006). However, the introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013), therefore altering restoration potential of big sagebrush communities (Evans and Young 1978). Sites with low abundances of native perennial grasses and forbs typically have reduced resiliency following disturbance and are less resistant to invasion or increases in cheatgrass (Miller et al 2013).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Needle and thread is a fine leaf grass and is considered sensitive to fire (Akinsoji 1988, Bradley et al. 1992, Miller et al. 2013). In a study by Wright and Klemmedson (1965), season of burn rather than fire intensity seemed to be the crucial factor in mortality for needle-and-thread grass. Early spring burning was found to kill the plants while August burning had no effect. Thus, under wildfire scenarios needle-and-thread is often present in the post-burn community.

Spiny hopsage is generally top-killed by fire (Daubenmire 1970), but often sprouts after plants are damaged by fire or mechanical injury (Shaw 1992). Fires in spiny hopsage sites generally occur in late summer when plants are dormant, and sprouting generally does not occur until the following spring (Daubenmire 1970). Spiny hopsage is reported to be least susceptible to fire during summer dormancy (Rickard and McShane 1984). Plants often survive fires that kill adjacent sagebrush (Blauer et al. 1976).

Invasion of cheatgrass, mustards and other annual weeds decreases site resilience, increases the risk of stand replacing fire and decreases the potential for sagebrush and Indian ricegrass reestablishment. Soil movement associated with fire and other activities such as OHV use or brush treatment has been observed. Twelve years after stand replacing fires near Winnemucca, NV reestablishment of sagebrush stands has not occurred. Spiny hopsage, a minor component in the reference community, has increased on burned areas due to the ability to resprout. Repeated fire within a 10 to 20 year timeframe has the potential to convert this site to an annual weed dominated system.

Seeding of this site following fire has not proven effective and rehabilitation methods are not known due to active soil movement following fire (M. Zielinski, personal communication, 2010)

Livestock/Wildlife Grazing Interpretations:

Inappropriate grazing leads to an increase in sagebrush and a decline in understory plants like Indian ricegrass and needle and thread grass. Invasion of annual weedy forbs and cheatgrass could occur with further grazing degradation, leading to an increase in bare ground. A combination of overgrazing and prolonged drought leads to soil erosion, increased bare ground and a loss in plant production. Without management cheatgrass and annual forbs are likely to invade and dominate the site, especially after fire.

Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). It is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al. (2006) note that the plant does well when utilized in winter and spring. Cook and Child (1971) however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. Additionally, heavy early spring grazing reduces plant vigor and stand density (Stubbendieck 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use in the desert ranges of Utah. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended.

Needle and thread grass is most commonly found on warm/dry soils (Miller et al. 2013). It is not grazing tolerant and will be one of the first grasses to decrease under heavy grazing pressure (Smoliak et al. 1972, Tueller and Blackburn 1974). Heavy grazing is likely to reduce basal area of these plants (Smoliak et al. 1972).

Spiny hopsage is considered one of the most palatable of the salt desert shrubs, particularly during the spring. However, overall value is limited in most areas since leaves and fruits are shed by early summer (Shaw 1992). Spiny hopsage is used as forage to at least some extent by domestic sheep and goats, deer, pronghorn, and rabbits (Wassar 1982). It is somewhat tolerant of browsing, but heavy use will reduce cover. Webb and Stielstra (1979) reported mean cover of individual spiny hopsage plants decreased 29% in response to heavy domestic sheep grazing in the western Mojave Desert.

State and Transition Model Narrative – Great Group EE:

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group EE.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic long term drought and/or insect or disease attack.

Community Phase 1.1:

Big sagebrush and Indian ricegrass dominate the site. Fourwing saltbush, spiny hopsage and other shrubs are also common. Needle and thread grass, basin wildrye and other perennial grasses are also present in the understory. Forbs are present but not abundant.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:

Fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to dispersed fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:

Long term drought, time and/or herbivory favor an increase in Wyoming and basin big sagebrush over deep-rooted perennial bunchgrasses. Combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. Bottlebrush squirreltail and thickspike wheatgrass may increase in density depending on herbivory impacts.

Community Phase 1.2:

This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass, needle and thread grass, basin wildrye and other perennial grasses dominate. Wyoming and basin big sagebrush are killed by fire, therefore decreasing within the burned community. Sagebrush could still be present in unburned patches. Forbs may increase post-fire but will likely return to pre-burn levels within a few years.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:

Absence of disturbance over time allows for the sagebrush to recover.

Community Phase 1.3:

Wyoming and basin big sagebrush increase in the absence of disturbance or with herbivory that favors shrubs. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from herbivory.

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:

A low severity fire and/or a moderate Aroga moth infestation may reduce sagebrush overstory and allow perennial bunchgrasses to increase.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:

Severe fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0:

Trigger: This transition is caused by the introduction of non-native annual weeds, such as cheatgrass, mustards and Russian thistle.

Slow variables: Over time the annual non-native plants will increase within the community.

Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. This state has the same three general community phases. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal.

Community Phase 2.1:

Big sagebrush and Indian ricegrass dominate the site. Needle and thread grass, basin wildrye and other perennial grasses may be significant components; other shrubs such as spiny hopsage and fourwing saltbush are also present. Forbs make up a smaller percentage by weight of the understory. Non-native annual species are present.

Sandy 8-10 (024XY017NV) Phase 2.1 T. Stringham June 2010

Sandy 8-10 (024XY017NV) Phase 2.1 T. Stringham April 2010

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:

Fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.1b, from Phase 2.2 to 2.1:

Time, long term drought, grazing management that favors shrubs or combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. However bottlebrush squirreltail and thickspike wheatgrass may increase in the understory depending on the grazing management. Heavy spring grazing will favor an increase in sagebrush. Annual non-native species may be stable or increasing within the understory.

Community Phase 2.2:

This community phase is characteristic of a post-disturbance, early seral community phase. Indian ricegrass and other perennial grasses dominate. Wyoming and basin big sagebrush are killed by fire, therefore decreasing within the burned community. Sagebrush could still be present in unburned patches. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Annual non-native species generally respond well after fire and may be stable or increasing within the community. Rabbitbrush and other sprouting shrubs may dominate the aspect for a number of years following fire.

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:

Absence of disturbance over time allows for the sagebrush to recover.

Community Phase 2.3 (at risk):

Wyoming and basin big sagebrush increase and the perennial understory is reduced. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from grazing management. Other shrubs such as spiny hopsage and rabbitbrush may also increase in the overstory. Annual non-native species are present.

Sandy 8-10 (024XY017NV) Phase 2.3 T. Stringham April 2010

Sandy 8-10 (024XY017NV) Phase 2.3 T. Stringham April 2010

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:

Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance, likely aerial herbicide application; late-fall/winter grazing causing mechanical damage to sagebrush can also reduce sagebrush overstory and allow an increase in perennial bunchgrasses or thickspike wheatgrass.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:

High severity fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during the growing season, and/or long term drought would favor shrubs and initiate transition to Community Phase 3.1. Fire would cause a transition to Community Phase 3.2.

Slow variables: Long-term decrease in deep-rooted perennial grass density.

Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during the growing season, in the presence of non-native annual species will transition to Community Phase 4.2; this may be combined with higher than normal spring precipitation. Catastrophic fire would cause a transition to Community Phase 4.1.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Shrub State 3.0:

This state consists of two community phases one which is dominated by big sagebrush and one that is dominated by sprouting shrubs such as rabbitbrush and horsebrush. This site has crossed a biotic threshold and site processes are being controlled by shrubs. Bare ground has increased and dunes may become active.

Community Phase 3.1:

Perennial bunchgrasses, like Indian ricegrass and needle and thread are reduced and the site is dominated by big sagebrush and rabbitbrush. Thickspike wheatgrass may be present. Bare ground has increased. Annual non-native species are present.

Sandy 8-10 (024XY017NV) Phase 3.1 T. Stringham June 2010

Dune 6-10 (024XY001NV) Phase 3.1 T. Stringham April 2010

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:

Fire, Aroga moth infestation, late-fall/winter grazing or brush management would decrease or eliminate the overstory of sagebrush. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to forbs and sprouting shrubs.

Community Phase 3.2:

Sprouting shrubs such as rabbitbrush, horsebrush or spiny hopsage may dominate aspect following disturbance for a number of years. Wind erosion may be significant and lead to soil redistribution and potential dune flattening, significantly reducing safe sites for sagebrush reestablishment. Trace amounts of sagebrush may be present. Annual non-native species are present.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:

Time and lack of disturbance allows for regeneration of sagebrush. This may take many years.

T3A: Transition from Shrub State 3.0 to Annual State 4.0

Trigger: Severe fire will transition to 4.1. Inappropriate grazing management in the presence of annual non-native species may be in combination with higher than normal spring precipitation will transition to 4.2.

Slow variables: Increased production and cover of non-native annual species.

Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Annual State 4.0

This state has crossed both a biotic and abiotic threshold. Annual invasive weeds, primarily cheatgrass and mustard, dominate the plant community. Sprouting shrubs may be present in trace amounts; sagebrush is missing. Ecological processes are controlled by the annual weed community during the spring growing season and by the physical process of wind movement of soil after the annual plant cover has senesced. In extremely degraded sites wind erosion of soil may progress to dune formation or flattening (depending on landscape position) and near elimination of the annual plant community.

Community Phase 4.1:

Annual species, primarily mustards and cheatgrass, dominate the site. Trace amounts of perennial grasses or sprouting shrubs may be present. Fire occurs often enough in this state to eliminate the reestablishment of sagebrush or dominance of sprouting shrubs.

Sandy 8-10 (024XY017NV) Phase 4.1 T. Stringham June 2010

Sandy 8-10 (024XY017NV) Phase 4.1 T. Stringham June 2010

Sandy 8-10 (024XY017NV) Phase 4.1 T. Stringham June 2010

Sandy 8-10 (024XY017NV) Phase 4.1 T. Stringham April 2010

Sandy 8-10 (024XY017NV) Phase 4.1 T. Stringham June 2010

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:

Time and lack of disturbance allows for regeneration of sagebrush. This pathway is unlikely due to the competitive advantages of cheatgrass over sagebrush seedlings.

Community Phase 4.2 (at risk):

Sagebrush and/or sprouting shrubs dominate the overstory. Cheatgrass, annual mustards and other non-native annual species dominate the understory. This phase is very at risk of fire and conversion to an annual dominated site.

Sandy 8-10 (024XY017NV) Phase 4.2 T. Stringham June 2010

Community Phase 4.2a, from Phase 4.2 to 4.1:

Fire

Potential Resilience Difference with other Ecological Sites

Dune 6-10" (024XY001NV):

This ecological site occurs on thick sand sheets that cover middle and lower piedmont slopes and on beach terraces (sand dunes or pama dunes). It is characterized by undulating to rolling, low and partially stabilized sand dunes, with intervening depressions. Slopes range from 2 to 30 percent, with some micro-slopes to 60 percent. Elevations are 4000 to 5000 feet. This site has two community phases within the reference 1.0 and current potential 2.0 states. The primary ecological driver in this system is drought; with drought perennial bunchgrasses decrease. Basin big sagebrush can codominate with spiny hopsage in microsites with more stable soil. This site also has a shrub state and with the introduction of annual non-native species and fire will likely go to an annual state. Lack of perennial cover will leave this site open to wind erosion which can cause the dunes to destabilize. As dunes "flatten" and soils redistribute even annual species may decrease on this site.

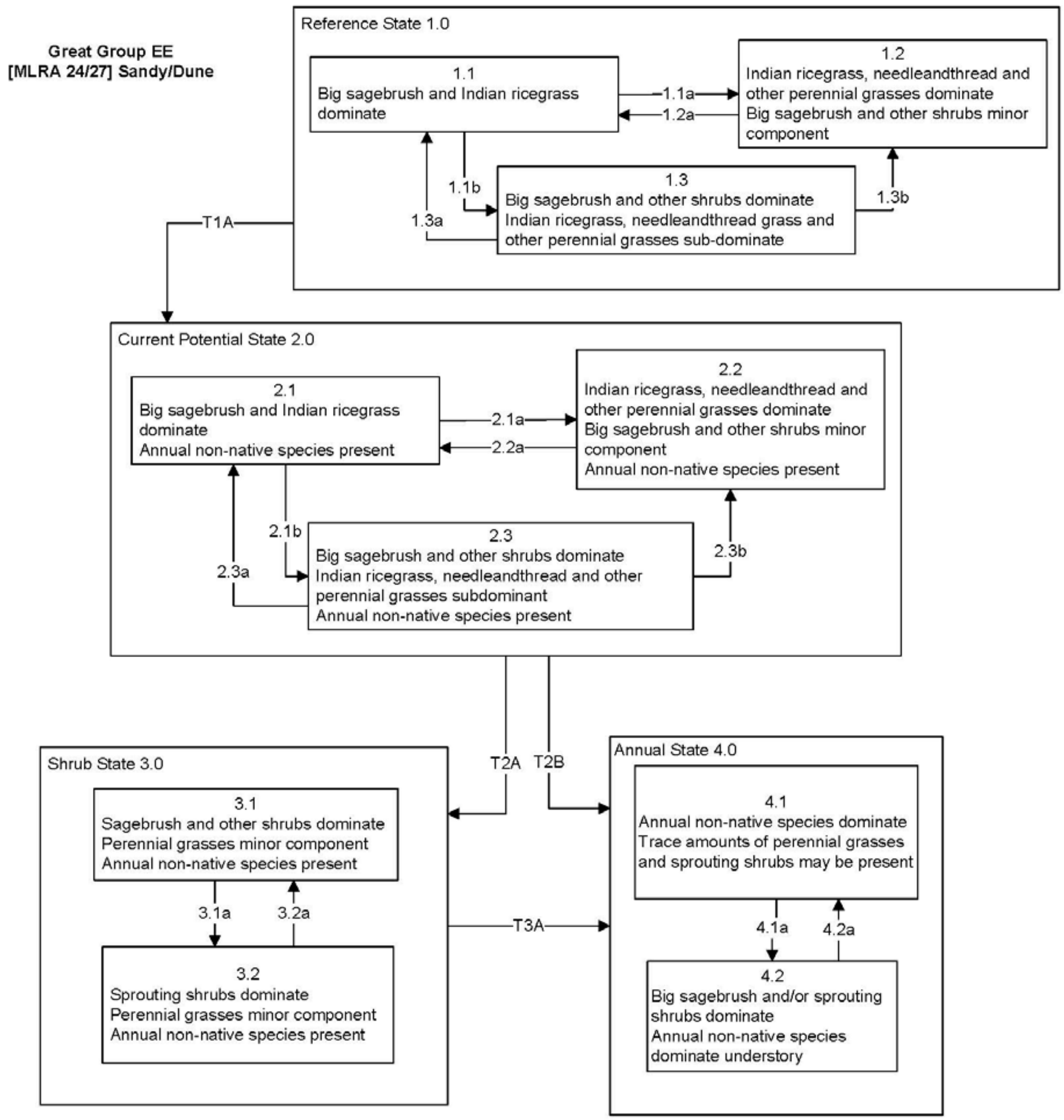
Sandy 5-8" (024XY055NV):

This site occurs on sand sheets that cover lower erosional fan remnants and alluvial fans. The soils of this site have formed in coarse textured alluvium or Aeolian deposits from mixed rock sources. Some soils have a thick layer of overblown or alluvial sand. These soils have rapid infiltration and percolation rates, low available water capacity and are excessively drained with low to no runoff. The potential for wind erosion on these sites is high. The potential native plant community is dominated by Indian ricegrass and spiny hopsage. This site is similar to the modal site with 4 alternative states in the state-and-transition model.

Sodic Dune (024XY066NV):

This site occurs on partially stabilized sand dunes that typically occur adjacent to, and on the leeward side of large playas. Black greasewood tends to be the dominant shrub on this site. Soils on this site exhibit minimal characteristics associated with soil development. The soils are windblown fine sands typically more than 40 inches in depth. The soil profile is excessively drained and available water capacity is low. Underground water occurs within the rooting depth of black greasewood. Because of rapid intake and deep percolation of water, surface runoff is very low. The extremely loose and unstable surface soils and low fertility of these soils are not favorable to uniform stands of perennial herbaceous plants. These soils are extremely susceptible to wind erosion. The potential native plant community is dominated by Indian ricegrass and black greasewood. Production for a normal year is 400 lbs/acre. Like the other sites in this group management should focus on maintaining perennial plant cover in order to reduce wind erosion and soil redistribution. This site is similar to the modal site with 4 alternative states in the state-and-transition model.

Modal State and Transition Model for Great Group EE



Great Group EE
[MLRA 24/27] Sandy/Dune

Reference State 1.0 Community Phase Pathways:
1.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory and/or drought will reduce perennial bunchgrasses.
1.2a: Time and lack of disturbance allows for sagebrush regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire and/or severe Aroga moth infestation significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species such as cheatgrass, mustards and Russian thistle.

Current Potential State 2.0 Community Phase Pathways:
2.1a: Low severity fire and/or Aroga moth infestation creates grass/sagebrush mosaic; annual non-native species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing and/or drought will reduce perennial bunchgrasses.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush management (aerial herbicide application), late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire and/or severe Aroga moth infestation significantly reduces sagebrush cover leading to early mid-seral community.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses and/or drought (3.1). Fire leads to 3.2.

Transition T2B: Catastrophic wildfire (4.1). Inappropriate grazing management in the presence of non-native annual species and/or higher than normal spring precipitation could increase the non-native annual species in the understory (4.2).

Shrub State 3.0 Community Phase Pathways:
3.1a: Fire, Aroga moth, brush management (aerial herbicide application), and/or late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance (an unlikely/slow transition).

Transition T3A: Fire (4.1). Inappropriate grazing management, may be combined with higher than normal spring precipitation could increase annual non-native species in the understory (4.2).

Annual State 4.0 Community Phase Pathways:
4.1a: Time and lack of disturbance allows for the shrubs to sprout/increase.
4.2a: Fire.

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Great Group F: Palatable Lahontan Sagebrush

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group F - Ecological Sites:

MLRA 23 DRG 1 (Modal)	
Claypan 10-14" P.Z. (Modal)	023XY031NV
Clay Slope 8-12" P.Z.	023XY037NV
Gravelly Claypan 10-12" P.Z.	023XY059NV
Gravelly Clay 10-12" P.Z.	023XY093NV
Scabland 10-14" P.Z.	023XY021NV
Cobbly Claypan 8-12" P.Z.	023XY060NV
Shallow Stony Loam 9-12" P.Z.	023XF081CA
Shallow Stony Clay Loam 9-12" P.Z.	023XF083CA
MLRA 23 DRG 4	
Very Cobbly Claypan (Modal)	023XY044NV
Churning Clay	023XY001NV
Shallow Clay 9-16" P.Z.	023XF093CA
MLRA 26 DRG 1	
Gravelly Clay 10-12" P.Z. (Modal)	026XY050NV
Claypan 8-10" P.Z.	026XY025NV
Gravelly Clay 8-10" P.Z.	023XY041NV
Gravelly Clay 10-12" P.Z.	023XY093NV
Scabland 10-14" P.Z.	023XY021NV
Cobbly Claypan 8-12" P.Z.	023XY060NV
Shallow Stony Loam 9-12" P.Z.	023XF081CA
Shallow Stony Clay Loam 9-12" P.Z.	023XF083CA

Description of Great Group F:

Great Group F consists of three DRGs and 19 ecological sites. The California sites, Shallow Stony Loam 9-12" (023XF081CA) and Shallow Stony Clay Loam 9-12" (023XF083CA), correlate with the Nevada ecological sites Cobbly Claypan 8-12" (023XY060NV) and Clay Slope 8-12" (023XY037NV), respectively. The precipitation zone for these sites ranges from 8 to 16 inches. The elevation range for this group is 4500 to 7000 feet. Slopes range from 2 to 50 percent but slopes of 2 to 30 percent are most typical. Annual production in a normal year ranges from 200 to 1200 lbs/acre for the group. The potential native plant community for these sites varies depending on precipitation, elevation and landform. The shrub component is dominated by Lahontan sagebrush (*Artemisia arbuscula* ssp. *longicaulis)*, low sagebrush (*Artemisia arbuscula)*, or early or alkali sagebrush (*Artemisia arbuscula* ssp. *longiloba*). The understory is dominated by deep rooted cool season perennial bunchgrasses; primarily bluebunch wheatgrass (*Pseudoroegneria spicata)* and Thurber's needlegrass (*Achnatherum thurberianum)*. Bluegrasses (*Poa* sp.), Webber's needlegrass and other bunchgrasses are also common on these sites. Forbs make up a small component of the annual production. Soils in this group have a moderate to strong-structured clayey subsoil that exhibits shrink-swell behavior and become saturated during the springtime.

Many of the ecological sites in this group are described as having low sagebrush as the dominant shrub. During our visits to these sites for this project, we used the black light test (Winward and Tisdale 1969, Rosentreter 2005) to verify sagebrush species. Almost all sites visited, including some NRCS Type Locations, had Lahontan sagebrush as the dominant shrub. Lahontan sagebrush was only recently identified as a unique species of sagebrush (Winward and McArthur 1995), so it may not have been apparent at the time some of these ecological sites were established. Due to the differences in palatability between low sage and Lahontan, as well as potential soil differences, we recommend a reevaluation of the low sagebrush ecological sites in MLRA 23.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (Dobrowolski et al. 1990). However, community types with low sagebrush as the dominant shrub may only have available rooting depths of 71 to 81 cm (Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Low sagebrush is fairly drought tolerant but also tolerates periodic wetness during some portion of the growing season (Fosberg and Hironaka 1964, Blackburn et al. 1968a and b, 1969). It grows on soils that have a strongly-structured B2t (argillic) horizon close to the soil surface (Winward 1980, Fosberg and Hironaka 1964, Zamora and Tueller 1973). Low sagebrush is also susceptible to the sagebrush defoliator, Aroga moth. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but research is inconclusive of the damage sustained by low sagebrush populations.

Lahontan sagebrush was only recently identified as a unique species of sagebrush (Winward and McArthur 1995). Lahontan sagebrush is a cross between low sagebrush and Wyoming sagebrush

(*Artemisia tridentata ssp. wyomingensis*) and is typically found near the old shorelines of Lake Lahontan from the Pleistocene epoch. This subspecies grows on soils similar to low sagebrush with shallow depths and low water holding capabilities (Winward and McArthur 1995).

Early sagebrush (also known as alkali sagebrush) is a unique subspecies of *Artemisia arbuscula* that is differentiated because it blooms in mid-June to July. While originally named alkali sagebrush because it was found on alkaline limestone soils (Beetle 1960), a body of research has challenged this claim across the species' range (Passey and Hughie 1962, Robertson et al. 1966, Zamora and Tueller 1973). It is found on soils similar to low sagebrush, with a restrictive horizon close to the soil surface (Robertson et al. 1966, Zamora and Tueller 1973).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons (MacMahon 1980). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance changes resource uptake and increases nutrient availability, often to the benefit of non-native species; native species are often damaged and their ability to use resources is depressed for a time, but resource pools may increase from lack of use and/or the decomposition of dead plant material following disturbance (Whisenant 1999, Miller et al. 2013). The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Beckstead and Augspurger 2004, Chambers et al. 2007, Johnson et al. 2011).

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible stable states have been identified for this DRG.

Annual Invasive Grasses:

The species most likely to invade these sites are cheatgrass and medusahead. Both species are cool-season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increase with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Medusahead and cheatgrass originated from Eurasia and both were first reported in North America in the late 1800s (Mack and Pyke 1983; Furbush 1953). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead. By 2003, medusahead occupied approximately 2.3 million acres in 17 western states (Rice 2005). In the Intermountain West, the exponential increase in dominance by medusahead has largely been at the expense of cheatgrass (Harris 1967, Hironaka 1994).

Medusahead matures 2-3 weeks later than cheatgrass (Harris 1967) and recently, James et al. (2008) measured leaf biomass over the growing season and found that medusahead maintained vegetative growth later in the growing season than cheatgrass. Mangla et al. (2011) also found medusahead had a longer period of growth and more total biomass than cheatgrass and hypothesized this difference in relative growth rate may be due to the ability of medusahead to maintain water uptake as upper soils dry compared to co-occurring species, especially cheatgrass. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008). Harris (1967) reported medusahead roots have thicker cell walls compared to those of cheatgrass, allowing it to more effectively conduct water, even in very dry conditions.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011). Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by increasing fire frequency.

Methods to control medusahead and cheatgrass include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead cover near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. Spraying with herbicide (Imazapic or Imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating medusahead and cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of medusahead or cheatgrass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015). Butler et al. (2011) tested four herbicides (Imazapic, Imazapic + glyphosate, rimsulfuron and sulfometuron + Chlorsulfuron) only treatments for suppression of cheatgrass, medusahead and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011), however caution in using these results is advised, as only one year of data was reported. Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (Cercocarpus montanus), antelope bitterbrush, and multiple sagebrush species to three rates of Imazapic and the same rates with methylated seed oil as a surfactant. They found a cheatgrass control program in an antelope bitterbrush community should not exceed Imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad scale herbicide application is initiated.

Fire Ecology:

Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Fire risk is greatest following a wet, productive year when there is greater production of fine fuels (Beardall and Sylvester 1976). Fire return intervals are not well understood because these ecosystems rarely coincide with fire-scarred conifers, however a wide range of 20 to well over 100 years has been estimated (Miller and Rose 1995, Miller and Rose 1999, Baker 2006, Knick et al. 2005). Historically, fires were probably patchy due to the low productivity of these sites (Beardall and Sylvester 1976, Ralphs and Busby 1979, Wright et al. 1979, Smith and Busby 1981). Fine fuel loads generally average 100 to 400 pounds per acre (110- 450 kg/ha) but are occasionally as high as 600 pounds per acre (680 kg/ha) in low sagebrush habitat types (Bradley et al. 1992). Reestablishment occurs from off-site wind-dispersed seed (Young 1983). Recovery time of low sagebrush following fire is variable (Young 1983). After fire, if regeneration conditions are favorable, low sagebrush recovers in 2 to 5 years, however on harsh sites where cover is low to begin with and/or erosion occurs after fire, recovery may require more than 10 years (Young 1983). Slow regeneration may subsequently worsen erosion (Blaisdell et al. 1982). We were unable to find any substantial research on success of seeding low sagebrush after fire. To date, we have not been able to find specific research on the fire response of Lahontan sagebrush.

Antelope bitterbrush, a minor component on these sites, is moderately fire tolerant (McConnell and Smith 1977). It regenerates by seed and resprouting (Blaisdell and Mueggler 1956, McArthur et al. 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Bitterbrush sprouts from a region on the stem approximately 1.5 inches above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). Low intensity fires and springtime fires may allow bitterbrush to sprout; however, community response also depends on soil moisture levels at time of fire (Murray 1983, Busse et al. 2000, Kerns et al. 2006).). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956).If cheatgrass is present, bitterbrush seedling success is much lower; the factor that most limits establishment of bitterbrush seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The two dominant grasses on this site, bluebunch wheatgrass and Thurber’s needlegrass, have different responses to fire. Bluebunch wheatgrass has coarse stems with little leafy material, therefore the plant’s aboveground biomass burns rapidly and little heat is transferred downward into the crowns (Young 1983). Bluebunch wheatgrass was described as fairly tolerant of burning, other than in May in eastern Oregon (Britton et al. 1990). Uresk et al. (1976) reported burning increased vegetative and reproductive vigor of bluebunch wheatgrass. Bluebunch wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983).

Conversely, Thurber’s needlegrass is very susceptible to fire caused mortality. Burning has been found to decrease the vegetative and reproductive vigor of Thurber’s needlegrass (Uresk et al. 1976). Fire can cause high mortality, in addition to reducing basal area and yield of Thurber’s needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influences the response and mortality of Thurber’s needlegrass, smaller bunch sizes are less likely to be damaged by fire (Wright and Klemmedson 1965). However, Thurber’s needlegrass often survives fire and will continue growth when conditions are favorable (Koniak 1985). Thus, the initial condition of the bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response.

Sandberg bluegrass, a minor component of this ecological site, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975) and may retard reestablishment of deeper rooted bunchgrasses.

The grasses likely to invade this site are cheatgrass and medusahead. These invasive grasses displace desirable perennial grasses, reduce livestock forage, and accumulate large fuel loads that foster frequent fires (Davies and Svejcar 2008). Invasion by annual grasses can alter the fire cycle by increasing fire size, fire season length, rate of spread, numbers of individual fires, and likelihood of fires spreading into native or managed ecosystems (D'Antonio and Vitousek 1992, Brooks et al. 2004). While historical fire return intervals are estimated at 15 to 100 years, areas dominated with cheatgrass are estimated to have a fire return interval of 3-5 years (Whisenant 1990). The mechanisms by which invasive annual grasses alter fire regimes likely interact with climate. For example, cheatgrass cover and biomass vary with climate (Chambers et al. 2007) and are promoted by wet and warm conditions during the fall and spring. Invasive annual species have been shown able to take advantage of high N availability following fire through higher growth rates and increased seedling established relative to native perennial grasses (Monaco et al. 2003).

Livestock/Wildlife Grazing Interpretations:

Domestic sheep and, to a much lesser degree, cattle consume low sagebrush, particularly during the spring, fall, and winter (Sheehy and Winward 1981). Heavy dormant season grazing by sheep will reduce sagebrush cover and increase grass production (Laycock 1967). Trampling damage, particularly from cattle or horses, in low sagebrush habitat types is greatest in areas with high clay content soils during spring snowmelt when surface soils are saturated. In drier areas with more gravelly soils, trampling is less of a problem (Hironaka et al. 1983). Bunchgrasses, in general, best tolerate light grazing after seed formation. Britton et al. (1990) observed the effects of clipping date on basal area of five bunchgrasses in eastern Oregon, and found grazing from August to October (after seed set) has the least impact. Heavy grazing during the growing season will reduce perennial bunchgrasses and increase sagebrush (Laycock 1967). Abusive grazing by cattle or horses allows unpalatable plants like low sagebrush, rabbitbrush and some forbs such as arrowleaf balsamroot to become dominant on the site. Sandberg bluegrass is also grazing tolerant due to its short stature. Annual non-native weedy species such as cheatgrass, mustards, and medusahead may invade.

Throughout two years of site visits for this report, Lahontan sagebrush was observed in a heavily-browsed state on this ecological site and others in this DRG. This recently differentiated subspecies of low sagebrush (Winward and McArthur 1995) is moderately to highly palatable to browse species (McArthur 2005, Rosentreter 2005). Dwarf sagebrush species such as Lahontan sagebrush, low sagebrush, and black sagebrush are preferred by mule deer for browse among the sagebrush species.

Antelope bitterbrush a minor component on this site is a critical browse species for mule deer, antelope and elk and is often utilized heavily by domestic livestock (Wood et al. 1995). Grazing tolerance is dependent on site conditions (Garrison 1953) and the shrub can be severely hedged during the dormant season for grasses and forbs.

Bluebunch wheatgrass is moderately grazing tolerant and is very sensitive to defoliation during the active growth period (Blaisdell and Pechanec 1949, Laycock 1967, Anderson and Scherzinger 1975, Britton et al. 1990). Herbage and flower stalk production was reduced with clipping at all times during the growing season; however, clipping was most harmful during the boot stage (Blaisdell and Pechanec 1949). Tiller production and growth of bluebunch was greatly reduced when clipping was coupled with drought (Busso and Richards 1995). Mueggler (1975) estimated that low vigor bluebunch wheatgrass may need up to 8 years rest to recover. Although an important forage species, it is not always the preferred species by livestock and wildlife.

Thurber's needlegrass is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber's needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

Inappropriate grazing practices can be tied to the success of medusahead, however, eliminating grazing will not eradicate medusahead if it is already present (Wagner et al. 2001). Sheley and Svejcar (2009) reported that even moderate defoliation of bluebunch wheatgrass resulted in increased medusahead density. They suggested that disturbances such as plant defoliation limit soil resource capture, which creates an opportunity for exploitation by medusahead. Avoidance of medusahead by grazing animals allows medusahead populations to expand. This creates seed reserves that can infest adjoining areas and cause changes to the fire regime. Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by an increase in fire frequency. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008).

State and Transition Model Narrative Great Group F:

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group F.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases: a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
This community is dominated by Lahontan/low sagebrush, bluebunch wheatgrass and Thurber's needlegrass. Forbs and other grasses make up smaller components. Antelope bitterbrush may or may not be present.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires will typically be low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring may be more severe and reduce sagebrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early/mid-seral community. Bluebunch wheatgrass, Thurber's needlegrass and other perennial bunchgrasses dominate. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush and other sprouting shrubs may be sprouting. Perennial forbs may be a significant component for a number of years following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to increase.

Community Phase 1.3:
Sagebrush increases in the absence of disturbance. Mature and/or decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or from herbivory. Sandberg bluegrass may increase and become co-dominant with deep rooted bunchgrasses.

Gravelly Clay 10-12" (023XY093NV) Phase 1.3 T. K. Stringham, July 2015

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community.

T1A: Transition from the Reference State 1.0 to Current Potential State 2.0:

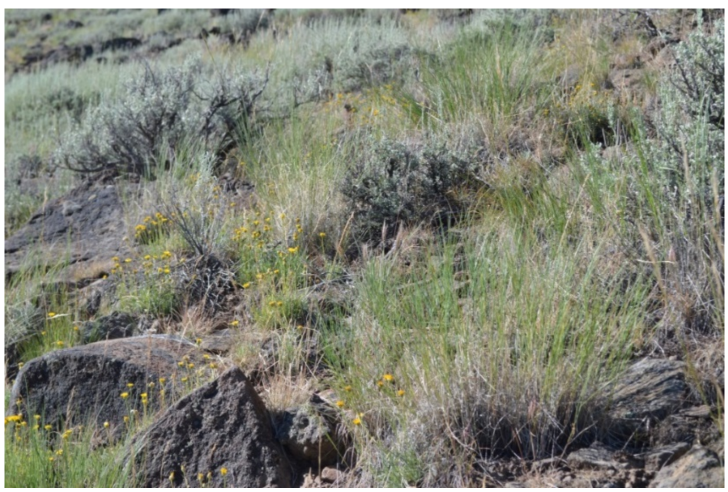
Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, medusahead, mustards, and bur buttercup.
Slow variables: Over time, the annual non-native plants will increase within the community. The change in dominance from perennial grasses to annual grasses reduces organic matter inputs from root turn-over, resulting in reductions in soil water availability.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. This state has four general community phases. These non-native species can be highly flammable, and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species in trace amounts. Lahontan/low sagebrush, bluebunch wheatgrass and Thurber's needlegrass dominate the site. Forbs and other shrubs and grasses make up smaller components of this site.

Gravelly Claypan 10-12" (023XY059NV) Phase 2.1 T. K. Stringham, August 2014



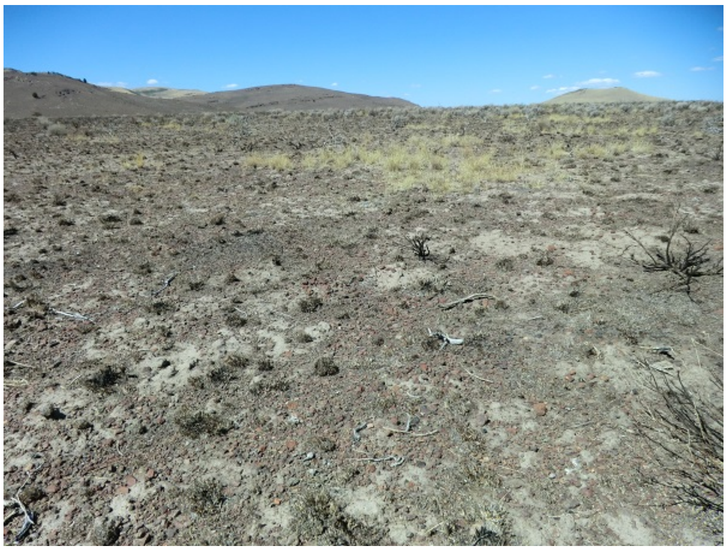
Clay Slope 8-12" (023XY037NV) Phase 2.1 T. K. Stringham, June 2015

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire reduces the shrub overstory and allows for perennial bunchgrasses to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allows for sagebrush to increase and become decadent. Long-term drought reduces fine fuels and leads to a reduced fire frequency, allowing Lahontan/low sagebrush to dominate the site. Inappropriate grazing management reduces the perennial

bunchgrass understory; conversely Sandberg bluegrass may increase in the understory depending on grazing management.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses dominate the site. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for a number of years following fire. Annual non-native species are stable or increasing within the community.



Claypan 10-14" (023XY031NV) Phase 2.2 P. Novak-Echenique, August 2014

Claypan 10-14" (023XY031NV) Phase 2.2 T. K. Stringham, June 2015

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of sagebrush can take many years.

Community Phase Pathway 2.2b, from Phase 2.2 to 2.4:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Higher than normal spring precipitation creates high annual production of annual grasses (Bradley et al. 2016). Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

Community Phase 2.3 (At Risk):
This community is at risk of crossing a threshold to another state. Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Sandberg bluegrass may increase and become co-dominant with deep rooted bunchgrasses. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Claypan 10-14" (023XY031NV) Phase 2.3 T. K. Stringham, August 2014

Scabland 10-14" (023XY021NV) Phase 2.3 T. K. Stringham, July 2015

Clay Slope 8-12" (023XY037NV) Phase 2.3 T.K. Stringham, May 2017

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A change in grazing management that reduces shrubs will allow the perennial bunchgrasses in the understory to increase. Heavy late-fall or winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. A low severity fire would decrease the overstory of sagebrush or leave patches of shrubs, and would allow the understory perennial grasses to increase. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire eliminates/reduces the overstory of sagebrush and allows the understory perennial grasses to increase. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community. Annual non-native species respond well to fire and may increase post burn.

Community Phase Pathway 2.3c, from Phase 2.3 to 2.4:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Higher than normal spring precipitation creates high annual production of annual grasses (Bradley et al. 2016). Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

Community Phase 2.4 (at risk):
This community is at risk of crossing to an annual state. Native bunchgrasses and forbs still comprise 50% or more of the understory annual production, however non-native annual grasses are nearly codominant. If this site originated from phase 2.3 there may be significant shrub cover as well. Annual production and abundance of these annuals may increase drastically in years with heavy spring precipitation. This site is susceptible to further degradation from grazing, drought and fire.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.3:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Depending on temperatures and precipitation in winter and spring, annual grass production may be reduced in favor of perennial bunchgrasses.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Depending on temperatures and precipitation in winter and spring, annual grass production may be reduced in favor of perennial bunchgrasses.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: To Community Phase 3.1: Inappropriate grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase Sandberg bluegrass and favor shrub growth and establishment. To Community Phase 3.2: Severe fire in community phase 2.3 will remove sagebrush overstory, decrease perennial bunchgrasses and enhance Sandberg bluegrass. Annual non-native species will increase.
Slow variables: Long term decrease in deep-rooted perennial grass density.
Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Tree State 4.0

Trigger: Time and lack of disturbance or management action allows for Utah juniper and/or western juniper to dominate. This may be coupled with grazing management that favors tree establishment by reducing understory herbaceous competition for site resources.
Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.
Slow variables: Over time the abundance and size of trees will increase.
Threshold: Trees dominate ecological processes and number of shrub skeletons exceed number of live shrubs. Minimal recruitment of new shrub cohorts.

T2C: Transition from Current Potential State 2.0 to Annual State 5.0

Trigger: Fire or soil disturbing treatment would transition to Community Phase 5.1.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. Increased, continuous fine fuels modify the fire regime by increasing frequency, size and spatial variability of fires.

Shrub State 3.0:

This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass will increase with a reduction in deep rooted perennial bunchgrass competition and become the dominant grass. Sagebrush dominates the overstory and rabbitbrush may be a significant component. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory and bluegrass understory dominate site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1 (At Risk):
Decadent sagebrush dominates the overstory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Sandberg bluegrass and annual non-native species increase. Bare ground is significant.

Gravelly Claypan 10-12” (023XY059NV) Phase 3.1 P. Novak-Echenique, May 2015

Very Cobbly Claypan (023XY044NV) Phase 3.1 T.K. Stringham, July 2015

Shallow Stony Loam 9-12" (023XF081CA) Phase 3.1 T.K. Stringham, October 2018

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, will greatly reduce the overstory shrubs to trace amounts and allow Sandberg bluegrass to dominate the site.

Community Phase 3.2:
Bluegrass dominates the site; annual non-native species may be present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of Lahontan/low sagebrush can take many years.

T3A: Transition from Shrub State 3.0 to Tree State 4.0:

Trigger: Absence of disturbance over time allows for Utah juniper or western juniper dominance.
Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.
Slow variables: Long-term increase in juniper and/or western juniper density.
Threshold: Trees overtop Lahontan/low sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts.

T3B: Transition from Shrub State 3.0 to Annual State 5.0

Trigger: Fire and/or treatments that disturb the soil and existing grass community. Further inappropriate grazing management transitions the site to phase 5.2.

Slow variables: Increased seed production (following a wet spring) and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing frequency, intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the temporal and spatial aspects of nutrient cycling and distribution.

Tree State 4.0:

This state is characterized by a dominance of Utah and/or western juniper in the overstory. Lahontan sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 4.1:
Utah juniper and/or western juniper dominates the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of bunchgrass may be found under tree canopies with trace amounts of Sandberg bluegrass and forbs in the interspaces. Sagebrush is stressed and dying. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Claypan 10-14" (023XY031NV) Phase 4.1 T. K. Stringham, August 2014

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance or management action allows for tree cover and density to further increase and trees to out-compete the herbaceous understory species for sunlight and water.

Community Phase 4.2:
Utah juniper /western juniper dominate overstory. Lahontan sagebrush is decadent and dying with numerous skeletons present or sagebrush may be missing from the system. Bunchgrasses present in trace amounts and annual non-native species may dominate understory. Herbaceous species may be located primarily under the canopy or near the drip line of trees. Bare ground interspaces are large and connected. Soil movement may be apparent.

T4A: Transition from Tree State 4.0 to Annual State 5.0:

Trigger: Catastrophic crown fire would reduce or eliminate trees to transition the site to 5.1. Tree removal when annual non-natives such as cheatgrass are present would also transition the site to state 5.0.
Slow variable: Increased seed production and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact nutrient cycling and distribution.

R4A: Restoration from Tree State 4.0 to Current Potential State 2.0:

Tree removal with minimum soil disturbance such as hand felling or mastication within community phase 4.1. This treatment may be combined with seeding for increased success when there is little understory.

Annual State 5.0:

An abiotic threshold has been crossed and state dynamics are driven by fire and time. The herbaceous understory is dominated by annual non-native species such as cheatgrass, medusahead, and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass and sprouting shrub plant community. The fire return interval is shortened due to the dominance of cheatgrass in the understory and frequent fire drives site dynamics.

Community Phase 5.1:
Annuals such as cheatgrass, medusahead, or tumblemustard dominate; Sandberg bluegrass and perennial forbs may still be present in trace amounts. Surface erosion may increase with summer convection storms and could be identified by increased pedestalling of plants, rill formation, or extensive water flow paths.

Clay Slope 8-12” (023XY037NV) Phase 5.1 T. K. Stringham, June 2014

Gravelly Claypan 10-12" (023XY059NV) Phase 5.1 T. K. Stringham, July 2015

Shallow Stony Loam 9-12" (023XF081CA) Phase 5.1 T.K. Stringham, October 2018

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:

Time and lack of disturbance allows sprouting shrubs and some sagebrush to recover after fire.

Community Phase 5.2:

Medusahead or cheatgrass dominate the understory. Lahontan or low sagebrush dominates the overstory and sprouting shrubs may be present.

Shallow Stony Clay Loam 9-12” (023XF083CA) Phase 5.2 T.K. Stringham, October 2018

Potential Resilience Differences with other Ecological Sites:

Clay Slope 8-12" (023XY037NV):

This site has a Lahontan sagebrush, bluebunch wheatgrass, and Thurber's needlegrass community that is very similar to the modal site, however with less precipitation and less production. Elevations range from 4500 to 6000 feet and production varies from 400 lbs/ac to 700 lbs/ac. This site is similar to the modal site, with five stable states. Upon further inspection the Claypan 10-14" site, written in 1963, may be more similar to this site concept with Lahontan sagebrush.

Gravelly Claypan 10-12" (023XY059NV):

The dominant grasses on this site are Thurber's and Webber's needlegrass. Like the modal site, Low sagebrush is the dominant shrub and spiny hopsage (*Grayia spinosa*) is a subdominant shrub. It is less productive than the modal site with 450 lbs/ac in a normal year. This site is found on convex summits and backslopes of low hills and erosional fan remnants, from 5000 to 6000 feet. The soils on this site have formed in alluvium or residuum derived from volcanic rock sources. These soils are generally shallow or moderately deep. There is a moderate to strong-structured, clay subsoil ranging from 8 to 12 inches in the soil profile. The soils have high amounts of gravel and/or small cobbles (over 65 percent ground cover) on the surface which provide a stabilizing effect on surface erosion conditions. This site has a four state model; it is unlikely to get a tree state or an eroded state. This site has been seen in a shrub state with no non-native annuals, indicating that it can transition from Reference to the Shrub State, Transition T1B: Long-term inappropriate grazing management favors shrubs and the shallow-rooted Sandberg bluegrass.

Gravelly Clay 10-12" (023XY093NV):

The soils in this site are typically moderately deep with depth to a moderate to strong-structure, clayey, subsoil ranging from 10 to 12 inches. Permeability is moderate and the soils are well drained. Available water capacity is low. Infiltration is restricted once these soils are wetted and they are subject to water loss by runoff. The soils have high amounts of gravels and/or cobbles on the surface which provide a stabilizing effect on surface erosion conditions. The plant community is dominated by Lahontan sagebrush and Thurber's needlegrass. It is less productive than the modal with 500 lbs/ac in a normal year. This site has a four state model without a tree state.

Scabland 10-14" (023XY021NV):

This site is dominated by Sandberg bluegrass, and is much less productive than the modal site with 200 lbs/ac in a normal year. It may have scattered juniper trees. The soils of this site have a very shallow effective rooting depth and are well drained. The soils are typically modified with over 50 percent gravels and other coarse fragments throughout the profile. These soils also have high amounts of gravels, cobbles, or stones on the surface which occupy plant growing space yet provide a stabilizing effect on surface erosion conditions. The available water capacity of these soils is very low. A surface cover of rock fragments helps to reduce evaporation and conserve the limited soil moisture. The harsh environment for plant growth presented by these soil properties restricts site productivity. Characteristic herbaceous plants have shallow root systems and the ability to make rapid early growth before evaporation depletes the limited supply of soil moisture. This site has a four state model without a tree state.

Cobbly Claypan 8-12” (023XY060NV):

This site has many cobbles on the soil surface, and is less productive than the modal site with 375 lbs/ac. The soils on this site have formed in alluvium or residuum derived from volcanic rock sources. These soils have a shallow effective rooting zone with depth to bedrock ranging from 10 to 20 inches. Depth to a dense, strong-structured, clay subsoil is less than 10 inches. Available water holding capacity is low. The soils have high amounts of cobbles and/or small stones (over 65 percent ground cover) on the surface which provides a stabilizing effect on surface erosion conditions. Pedestalling of some grass plants is common during the winter due to frost heave. The plant community is dominated by low sagebrush, bluebunch wheatgrass, and Thurber's needlegrass. This site is similar to the modal site; the model has five stable states.

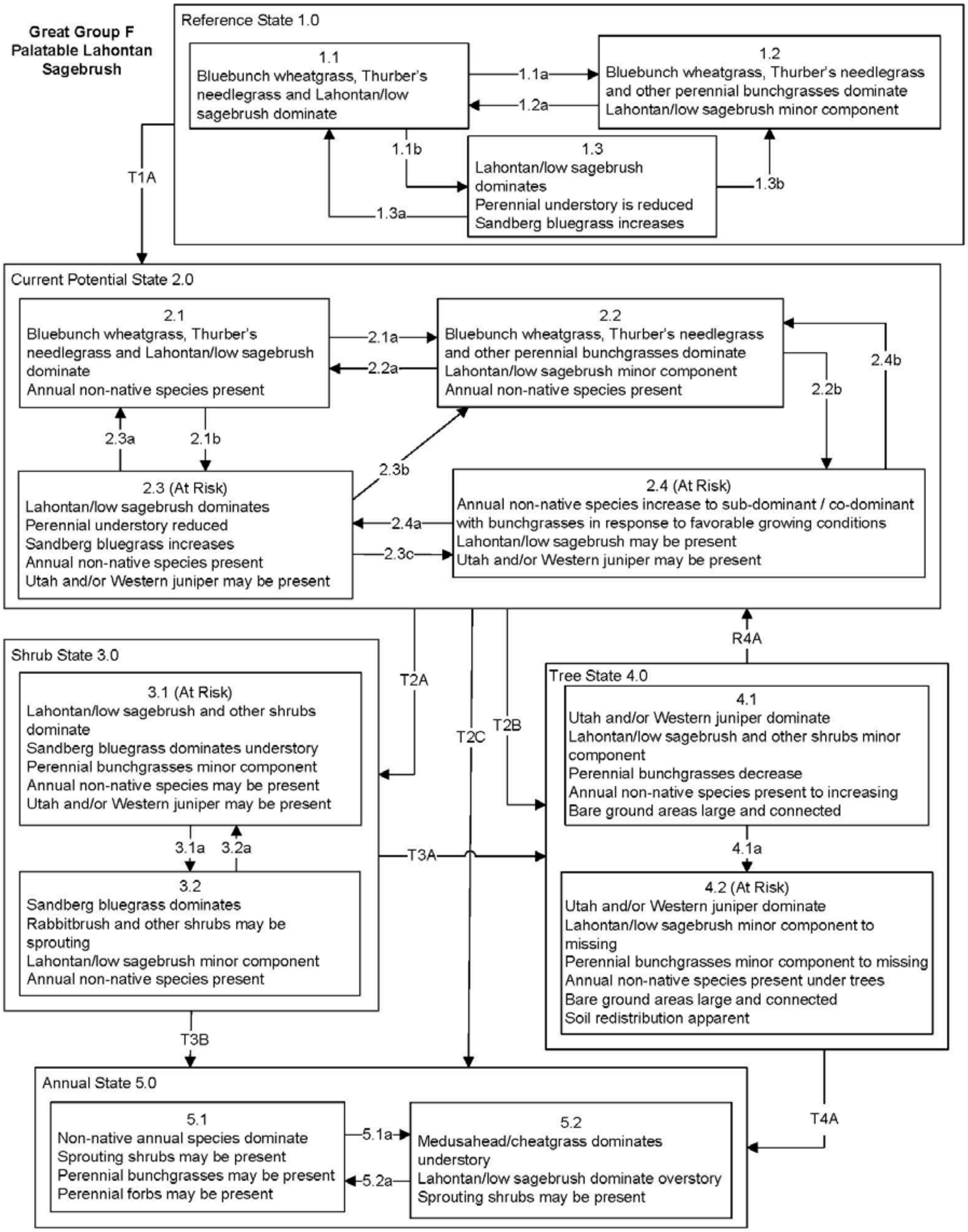
Shallow Stony Clay Loam 9-12” (023XF083CA):

This site has a similar plant community to the modal site, dominated by bluebunch wheatgrass, Lahontan sagebrush and Thurber’s needlegrass. Spiny hopsage (*Grayia spinosa*) may also be present. The soils have a shallow effective rooting depth and low soil moisture capacity. Production is lower than the modal site at 600 lbs/ac in a normal year. The soils in this site and Shallow Stony Loam (023XF081CA) are very similar, but are believed to have a higher amount or distribution of clay. This site is similar to the modal site; the model has five stable states.

Shallow Stony Loam 9-12” (023XF081CA):

This site is characterized by shallow effective rooting depth and low soil moisture capacity. The plant community is similar to the modal site with a Western juniper component. Production is also similar to the modal site at 700 lbs/ac in a normal year, but in favorable years can produce as much as 1000 lbs/ac. This site is similar to the modal site; the model has five stable states.

Modal State and Transition Model for Great Group F:



Great Group F
Palatable Lahontan Sagebrush

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory or combinations reduces sagebrush.
1.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs.

Transition T1A: Introduction of non-native annual species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for shrub reestablishment.
2.2b: Fall and spring growing conditions that favors the germination and production of non-native, annual grasses. Pathway typically occurs 3 to 5 years post-fire and 2.4 may be a transitory plant community.
2.3a: Low severity fire creates sagebrush/ grass mosaic, herbivory, or combination or brush management with minimal soil disturbance.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community or brush management with minimal soil disturbance reduces sagebrush.
2.3c: Fall and spring growing season conditions that favors the germination and production of non-native annual grasses. 2.4 may be a transitory plant community.
2.4a: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.
2.4b: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (to 3.1). Brush management of Community Phase 2.3 may result in Community Phase 3.2.
Transition T2B: Time and lack of fire allows Utah/Western juniper to establish and overtop the sagebrush, dominating site resources; may be coupled with inappropriate grazing management.
Transition T2C: Severe fire and/or multiple fires.

Shrub State 3.0 Community Phase Pathways
3.1a: High severity fire; brush management with minimal soil disturbance.
3.2a: Time and lack of disturbance (unlikely/may take many years).

Transition T3A: Time and lack of fire allows Utah/Western juniper to establish and dominate site resources; may be coupled with inappropriate grazing management that reduces perennial grass density and increases tree establishment.
Transition T3B: Invasive annual grasses increase under shrubs, or, high-severity fire or multiple fires and/or treatments that disturb the soil surface in the presence of non-native annual grasses. (to 5.1).

Tree State 4.0 Community Phase Pathways
4.1a: Time without disturbance allows maturation of the tree community.

Restoration R4A: Tree removal would decrease tree cover and allow for the understory to recover (to 4.1).
Transition T4A: Catastrophic fire and/or inappropriate tree removal practices (to 5.1).

Annual State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance.
5.2a: Fire.

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Great Group FF: [MLRA 24/27] Palatable Lahontan Sagebrush

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group FF - Ecological Sites:

MLRA 23 DRG 1 (Modal)	
Claypan 10-14" P.Z. (Modal)	023XY031NV
Clay Slope 8-12" P.Z.	023XY037NV
Gravelly Claypan 10-12" P.Z.	023XY059NV
Gravelly Clay 10-12" P.Z.	023XY093NV
Scabland 10-14" P.Z.	023XY021NV
Cobbly Claypan 8-12" P.Z.	023XY060NV
Shallow Stony Loam 9-12" P.Z.	023XF081CA
Shallow Stony Clay Loam 9-12" P.Z.	023XF083CA
MLRA 27 DRG 2	
Gravelly Claypan 8-10" P.Z. (Modal)	027XY079NV
Droughty Claypan 8-10" P.Z.	027XY070NV
Granitic Claypan 9-10" P.Z.	027XY068NV
Shallow Claypan 8-10" P.Z.	027XY020NV

Description of Great Group FF:

Great Group FF consists of two DRGs and twelve ecological sites. The California sites, Shallow Stony Loam 9-12" (023XF081CA) and Shallow Stony Clay Loam 9-12" (023XF083CA), correlate with the Nevada ecological sites Cobbly Claypan 8-12" (023XY060NV) and Clay Slope 8-12" (023XY037NV), respectively. The precipitation zone for these sites ranges from 8 to over 20 inches. The elevation range for this group is 4500 to 7000 feet. Slopes range from 2 to 50 percent but slopes of 2 to 30 percent are most typical. Annual production in a normal year ranges from 200 to 1200 lbs/acre for the group. The potential native plant community for these sites varies depending on precipitation, elevation and landform. The shrub component is dominated by Lahontan sagebrush (*Artemisia arbuscula* ssp. *longicaulis)*, low sagebrush (*Artemisia arbuscula)*, or early or alkali sagebrush (*Artemisia arbuscula* ssp. *longiloba*). The understory is dominated by deep rooted cool season perennial bunchgrasses; primarily bluebunch wheatgrass (*Pseudoroegneria spicata)* and Thurber's needlegrass (*Achnatherum thurberianum)*. Bluegrasses (*Poa* sp.), Webber's needlegrass and other bunchgrasses are also common on these sites. Forbs make up a small component of the annual production. Soils in this group have a moderate to strong-structured clayey subsoil that exhibits shrink-swell behavior and become saturated during the springtime.

Many of the ecological sites in this group are described as having low sagebrush as the dominant shrub. During our visits to these sites for this project, we used the black light test (Winward and Tisdale 1969, Rosentreter 2005) to verify sagebrush species. Almost all sites visited, including some NRCS Type Locations, had Lahontan sagebrush as the dominant shrub. Lahontan sagebrush was only recently identified as a unique species of sagebrush (Winward and McArthur 1995), so it may not have been apparent at the time some of these ecological sites were established. Due to the differences in palatability between low sage and Lahontan, as well as potential soil differences, we recommend a reevaluation of the low sagebrush ecological sites in MLRA 23.

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (Dobrowolski et al. 1990). However, community types with low sagebrush as the dominant shrub may only have available rooting depths of 71 to 81 cm (Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

Low sagebrush is fairly drought tolerant but also tolerates periodic wetness during some portion of the growing season (Fosberg and Hironaka 1964, Blackburn et al. 1968a and b, 1969). It grows on soils that have a strongly-structured B2t (argillic) horizon close to the soil surface (Winward 1980, Fosberg and Hironaka 1964, Zamora and Tueller 1973). Low sagebrush is also susceptible to the sagebrush defoliator, Aroga moth. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975), but research is inconclusive of the damage sustained by low sagebrush populations.

Lahontan sagebrush was only recently identified as a unique species of sagebrush (Winward and McArthur 1995). Lahontan sagebrush is a cross between low sagebrush and Wyoming sagebrush (*Artemisia tridentata ssp. wyomingensis*) and is typically found near the old shorelines of Lake Lahontan from the Pleistocene epoch. This subspecies grows on soils similar to low sagebrush with shallow depths and low water holding capabilities (Winward and McArthur 1995).

Early sagebrush (also known as alkali sagebrush) is a unique subspecies of *Artemisia arbuscula* that is differentiated because it blooms in mid-June to July. While originally named alkali sagebrush because it was found on alkaline limestone soils (Beetle 1960), a body of research has challenged this claim across the species' range (Passey and Hughie 1962, Robertson et al. 1966, Zamora and Tueller 1973). It is found on soils similar to low sagebrush, with a restrictive horizon close to the soil surface (Robertson et al. 1966, Zamora and Tueller 1973).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons (MacMahon 1980). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance changes resource uptake and increases nutrient availability, often to the benefit of non-native species; native species are often damaged and their ability to use resources is depressed for a time, but resource pools may increase from lack of use and/or the decomposition of dead plant material following disturbance (Whisenant 1999, Miller et al. 2013). The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Beckstead and Augspurger 2004, Chambers et al. 2007, Johnson et al. 2011).

The ecological sites in this DRG have low to moderate resilience to disturbance and resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible stable states have been identified for this DRG.

Annual Invasive Grasses:

The species most likely to invade these sites are cheatgrass and medusahead. Both species are cool-season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increase with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Medusahead and cheatgrass originated from Eurasia and both were first reported in North America in the late 1800s (Mack and Pyke 1983; Furbush 1953). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead. By 2003, medusahead occupied approximately 2.3 million acres in 17 western states (Rice 2005). In the Intermountain West, the exponential increase in dominance by medusahead has largely been at the expense of cheatgrass (Harris 1967, Hironaka 1994).

Medusahead matures 2-3 weeks later than cheatgrass (Harris 1967) and recently, James et al. (2008) measured leaf biomass over the growing season and found that medusahead maintained vegetative growth later in the growing season than cheatgrass. Mangla et al. (2011) also found medusahead had a longer period of growth and more total biomass than cheatgrass and hypothesized this difference in relative growth rate may be due to the ability of medusahead to maintain water uptake as upper soils dry compared to co-occurring species, especially cheatgrass. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008). Harris (1967) reported medusahead roots have thicker cell walls compared to those of cheatgrass, allowing it to more effectively conduct water, even in very dry conditions.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011). Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by increasing fire frequency.

Methods to control medusahead and cheatgrass include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead cover near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. Spraying with herbicide (Imazapic or Imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating medusahead and cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of medusahead or cheatgrass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015). Butler et al. (2011) tested four herbicides (Imazapic, Imazapic + glyphosate, rimsulfuron and sulfometuron + Chlorsulfuron) only treatments for suppression of cheatgrass, medusahead and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al. 2011), however caution in using these results is advised, as only one year of data was reported. Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (Cercocarpus montanus), antelope bitterbrush, and multiple sagebrush species to three rates of Imazapic and the same rates with methylated seed oil as a surfactant. They found a cheatgrass control program in an antelope bitterbrush community should not exceed Imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should install test plots before broad scale herbicide application is initiated.

Fire Ecology:

Low sagebrush is killed by fire and does not sprout (Tisdale and Hironaka 1981). Fire risk is greatest following a wet, productive year when there is greater production of fine fuels (Beardall and Sylvester 1976). Fire return intervals are not well understood because these ecosystems rarely coincide with fire-scarred conifers, however a wide range of 20 to well over 100 years has been estimated (Miller and Rose 1995, Miller and Rose 1999, Baker 2006, Knick et al. 2005). Historically, fires were probably patchy due to the low productivity of these sites (Beardall and Sylvester 1976, Ralphs and Busby 1979, Wright et al. 1979, Smith and Busby 1981). Fine fuel loads generally average 100 to 400 pounds per acre (110- 450 kg/ha) but are occasionally as high as 600 pounds per acre (680 kg/ha) in low sagebrush habitat types (Bradley et al. 1992). Reestablishment occurs from off-site wind-dispersed seed (Young 1983). Recovery time of low sagebrush following fire is variable (Young 1983). After fire, if regeneration conditions are favorable, low sagebrush recovers in 2 to 5 years, however on harsh sites where cover is low to begin with and/or erosion occurs after fire, recovery may require more than 10 years (Young 1983). Slow regeneration may subsequently worsen erosion (Blaisdell et al. 1982). We were unable to find any substantial research on success of seeding low sagebrush after fire. To date, we have not been able to find specific research on the fire response of Lahontan sagebrush.

Antelope bitterbrush, a minor component on these sites, is moderately fire tolerant (McConnell and Smith 1977). It regenerates by seed and resprouting (Blaisdell and Mueggler 1956, McArthur et al. 1982), however sprouting ability is highly variable and has been attributed to genetics, plant age, phenology, soil moisture and texture and fire severity (Blaisdell and Mueggler 1956, Blaisdell et al. 1982, Clark et al. 1982, Cook et al. 1994). Bitterbrush sprouts from a region on the stem approximately 1.5 inches above and below the soil surface; the plant rarely sprouts if the root crown is killed by fire (Blaisdell and Mueggler 1956). Low intensity fires and springtime fires may allow bitterbrush to sprout; however, community response also depends on soil moisture levels at time of fire (Murray 1983, Busse et al. 2000, Kerns et al. 2006).). Lower soil moisture allows more charring of the stem below ground level (Blaisdell and Mueggler 1956).If cheatgrass is present, bitterbrush seedling success is much lower; the factor that most limits establishment of bitterbrush seedlings is competition for water resources with the invasive species cheatgrass (Clements and Young 2002).

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The two dominant grasses on this site, bluebunch wheatgrass and Thurber’s needlegrass, have different responses to fire. Bluebunch wheatgrass has coarse stems with little leafy material, therefore the plant’s aboveground biomass burns rapidly and little heat is transferred downward into the crowns (Young 1983). Bluebunch wheatgrass was described as fairly tolerant of burning, other than in May in eastern Oregon (Britton et al. 1990). Uresk et al. (1976) reported burning increased vegetative and reproductive vigor of bluebunch wheatgrass. Bluebunch wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983).

Conversely, Thurber’s needlegrass is very susceptible to fire caused mortality. Burning has been found to decrease the vegetative and reproductive vigor of Thurber’s needlegrass (Uresk et al. 1976). Fire can cause high mortality, in addition to reducing basal area and yield of Thurber’s needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influences the response and mortality of Thurber’s needlegrass, smaller bunch sizes are less likely to be damaged by fire (Wright and Klemmedson 1965). However, Thurber’s needlegrass often survives fire and will continue growth when conditions are favorable (Koniak 1985). Thus, the initial condition of the bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response.

Sandberg bluegrass, a minor component of this ecological site, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975) and may retard reestablishment of deeper rooted bunchgrasses.

The grasses likely to invade this site are cheatgrass and medusahead. These invasive grasses displace desirable perennial grasses, reduce livestock forage, and accumulate large fuel loads that foster frequent fires (Davies and Svejcar 2008). Invasion by annual grasses can alter the fire cycle by increasing fire size, fire season length, rate of spread, numbers of individual fires, and likelihood of fires spreading into native or managed ecosystems (D'Antonio and Vitousek 1992, Brooks et al. 2004). While historical fire return intervals are estimated at 15 to 100 years, areas dominated with cheatgrass are estimated to have a fire return interval of 3-5 years (Whisenant 1990). The mechanisms by which invasive annual grasses alter fire regimes likely interact with climate. For example, cheatgrass cover and biomass vary with climate (Chambers et al. 2007) and are promoted by wet and warm conditions during the fall and spring. Invasive annual species have been shown able to take advantage of high N availability following fire through higher growth rates and increased seedling established relative to native perennial grasses (Monaco et al. 2003).

Livestock/Wildlife Grazing Interpretations:

Domestic sheep and, to a much lesser degree, cattle consume low sagebrush, particularly during the spring, fall, and winter (Sheehy and Winward 1981). Heavy dormant season grazing by sheep will reduce sagebrush cover and increase grass production (Laycock 1967). Trampling damage, particularly from cattle or horses, in low sagebrush habitat types is greatest in areas with high clay content soils during spring snowmelt when surface soils are saturated. In drier areas with more gravelly soils, trampling is less of a problem (Hironaka et al. 1983). Bunchgrasses, in general, best tolerate light grazing after seed formation. Britton et al. (1990) observed the effects of clipping date on basal area of five bunchgrasses in eastern Oregon, and found grazing from August to October (after seed set) has the least impact. Heavy grazing during the growing season will reduce perennial bunchgrasses and increase sagebrush (Laycock 1967). Abusive grazing by cattle or horses allows unpalatable plants like low sagebrush, rabbitbrush and some forbs such as arrowleaf balsamroot to become dominant on the site. Sandberg bluegrass is also grazing tolerant due to its short stature. Annual non-native weedy species such as cheatgrass, mustards, and medusahead may invade.

Throughout two years of site visits for this report, Lahontan sagebrush was observed in a heavily-browsed state on this ecological site and others in this DRG. This recently differentiated subspecies of low sagebrush (Winward and McArthur 1995) is moderately to highly palatable to browse species (McArthur 2005, Rosentreter 2005). Dwarf sagebrush species such as Lahontan sagebrush, low sagebrush, and black sagebrush are preferred by mule deer for browse among the sagebrush species.

Antelope bitterbrush a minor component on this site is a critical browse species for mule deer, antelope and elk and is often utilized heavily by domestic livestock (Wood et al. 1995). Grazing tolerance is dependent on site conditions (Garrison 1953) and the shrub can be severely hedged during the dormant season for grasses and forbs.

Bluebunch wheatgrass is moderately grazing tolerant and is very sensitive to defoliation during the active growth period (Blaisdell and Pechanec 1949, Laycock 1967, Anderson and Scherzinger 1975, Britton et al. 1990). Herbage and flower stalk production was reduced with clipping at all times during the growing season; however, clipping was most harmful during the boot stage (Blaisdell and Pechanec

1949). Tiller production and growth of bluebunch was greatly reduced when clipping was coupled with drought (Busso and Richards 1995). Mueggler (1975) estimated that low vigor bluebunch wheatgrass may need up to 8 years rest to recover. Although an important forage species, it is not always the preferred species by livestock and wildlife.

Thurber's needlegrass is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber's needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass or other weedy species. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

Inappropriate grazing practices can be tied to the success of medusahead, however, eliminating grazing will not eradicate medusahead if it is already present (Wagner et al. 2001). Sheley and Svejcar (2009) reported that even moderate defoliation of bluebunch wheatgrass resulted in increased medusahead density. They suggested that disturbances such as plant defoliation limit soil resource capture, which creates an opportunity for exploitation by medusahead. Avoidance of medusahead by grazing animals allows medusahead populations to expand. This creates seed reserves that can infest adjoining areas and cause changes to the fire regime. Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by an increase in fire frequency. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008).

State and Transition Model Narrative Great Group FF:

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group FF.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases: a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:
This community is dominated by Lahontan/low sagebrush, bluebunch wheatgrass and Thurber's needlegrass. Forbs and other grasses make up smaller components. Antelope bitterbrush may or may not be present.

Community Phase Pathway 1.1a, from Phase 1.1 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires will typically be low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring may be more severe and reduce sagebrush cover to trace amounts.

Community Phase Pathway 1.1b, from Phase 1.1 to 1.3:
Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these will cause a decline in perennial bunchgrasses and fine fuels leading to a reduced fire frequency and allowing sagebrush to dominate the site.

Community Phase 1.2:
This community phase is characteristic of a post-disturbance, early/mid-seral community. Bluebunch wheatgrass, Thurber's needlegrass and other perennial bunchgrasses dominate. Depending on fire severity patches of intact sagebrush may remain. Rabbitbrush and other sprouting shrubs may be sprouting. Perennial forbs may be a significant component for a number of years following fire.

Community Phase Pathway 1.2a, from Phase 1.2 to 1.1:
Time and lack of disturbance will allow sagebrush to increase.

Community Phase 1.3:
Sagebrush increases in the absence of disturbance. Mature and/or decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or from herbivory. Sandberg bluegrass may increase and become co-dominant with deep rooted bunchgrasses.

Gravelly Clay 10-12" (023XY093NV) Phase 1.3 T. K. Stringham, July 2015

Community Phase Pathway 1.3a, from Phase 1.3 to 1.1:
A low severity fire, herbivory or combinations will reduce the sagebrush overstory and create a sagebrush/grass mosaic.

Community Phase Pathway 1.3b, from Phase 1.3 to 1.2:
Fire will decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community.

T1A: Transition from the Reference State 1.0 to Current Potential State 2.0:

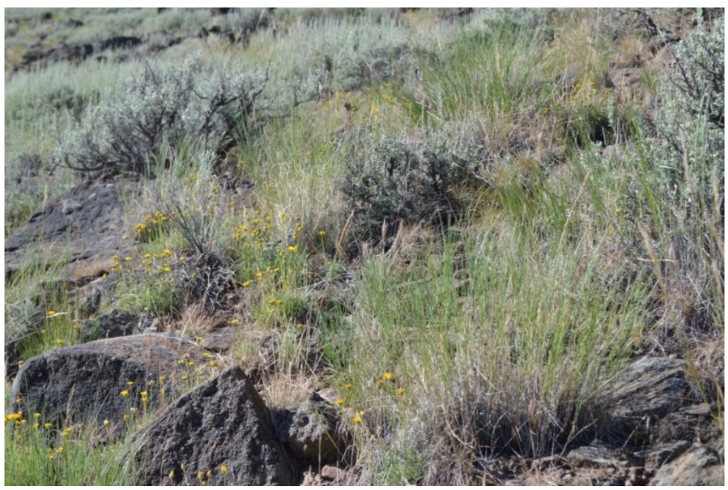
Trigger: This transition is caused by the introduction of non-native annual plants, such as cheatgrass, medusahead, mustards, and bur buttercup.
Slow variables: Over time, the annual non-native plants will increase within the community. The change in dominance from perennial grasses to annual grasses reduces organic matter inputs from root turn-over, resulting in reductions in soil water availability.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. This state has four general community phases. These non-native species can be highly flammable, and promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate, and adaptations for seed dispersal.

Community Phase 2.1:
This community phase is similar to the Reference State Community Phase 1.1, with the presence of non-native species in trace amounts. Lahontan/low sagebrush, bluebunch wheatgrass and Thurber's needlegrass dominate the site. Forbs and other shrubs and grasses make up smaller components of this site.

Gravelly Claypan 10-12" (023XY059NV) Phase 2.1 T. K. Stringham, August 2014



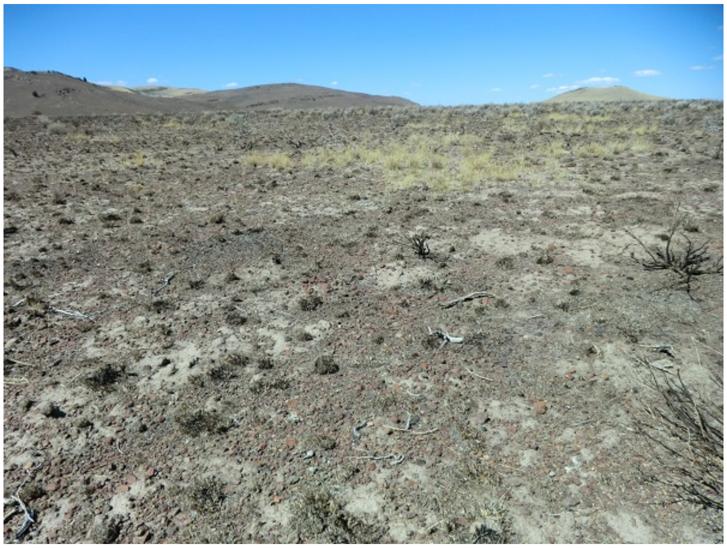
Clay Slope 8-12" (023XY037NV) Phase 2.1 T. K. Stringham, June 2015

Community Phase Pathway 2.1a, from Phase 2.1 to 2.2:
Fire reduces the shrub overstory and allows for perennial bunchgrasses to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels may be more severe and reduce sagebrush cover to trace amounts. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b, from Phase 2.1 to 2.3:
Time and lack of disturbance allows for sagebrush to increase and become decadent. Long-term drought reduces fine fuels and leads to a reduced fire frequency, allowing Lahontan/low sagebrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely Sandberg bluegrass may increase in the understory depending on grazing management.

Community Phase 2.2:
This community phase is characteristic of a post-disturbance, early to mid-seral community where annual non-native species are present. Sagebrush is present in trace amounts; perennial bunchgrasses dominate the site. Depending on fire severity patches of intact sagebrush may

remain. Rabbitbrush may be sprouting or dominant in the community. Perennial forbs may be a significant component for a number of years following fire. Annual non-native species are stable or increasing within the community.



Claypan 10-14" (023XY031NV) Phase 2.2 P. Novak-Echenique, August 2014

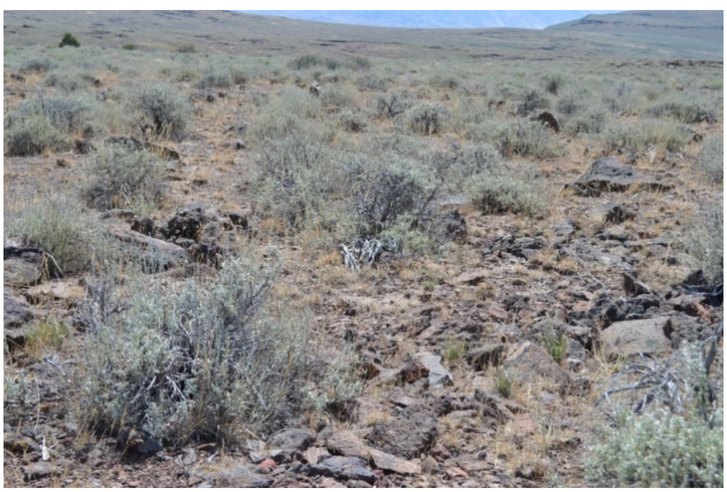
Claypan 10-14" (023XY031NV) Phase 2.2 T. K. Stringham, June 2015

Community Phase Pathway 2.2a, from Phase 2.2 to 2.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of sagebrush can take many years.

Community Phase Pathway 2.2b, from Phase 2.2 to 2.4:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Higher than normal spring precipitation creates high annual production of annual grasses (Bradley et al. 2016). Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

Community Phase 2.3 (At Risk):
This community is at risk of crossing a threshold to another state. Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing, or from both. Rabbitbrush may be a significant component. Sandberg bluegrass may increase and become co-dominant with deep rooted bunchgrasses. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Claypan 10-14" (023XY031NV) Phase 2.3 T. K. Stringham, August 2014



Scabland 10-14" (023XY021NV) Phase 2.3 T. K. Stringham, July 2015

Clay Slope 8-12” (023XY037NV) Phase 2.3 T.K. Stringham, May 2017

Community Phase Pathway 2.3a, from Phase 2.3 to 2.1:
A change in grazing management that reduces shrubs will allow the perennial bunchgrasses in the understory to increase. Heavy late-fall or winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. Brush treatments with minimal soil disturbance will also decrease sagebrush and release the perennial understory. A low severity fire would decrease the overstory of sagebrush or leave patches of shrubs, and would allow the understory perennial grasses to increase. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b, from Phase 2.3 to 2.2:
Fire eliminates/reduces the overstory of sagebrush and allows the understory perennial grasses to increase. Fires may be high severity in this community phase due to the dominance of sagebrush resulting in removal of overstory shrub community. Annual non-native species respond well to fire and may increase post burn.

Community Phase Pathway 2.3c, from Phase 2.3 to 2.4:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Higher than normal spring precipitation creates high annual production of annual grasses (Bradley et al. 2016). Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species increase in production and density throughout the site. Perennial bunchgrasses may also increase in production.

Community Phase 2.4 (at risk):
This community is at risk of crossing to an annual state. Native bunchgrasses and forbs still comprise 50% or more of the understory annual production, however non-native annual grasses are nearly codominant. If this site originated from phase 2.3 there may be significant shrub cover as well. Annual production and abundance of these annuals may increase drastically in years with heavy spring precipitation. This site is susceptible to further degradation from grazing, drought and fire.

Community Phase Pathway 2.4a, from Phase 2.4 to 2.3:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Depending on temperatures and precipitation in winter and spring, annual grass production may be reduced in favor of perennial bunchgrasses.

Community Phase Pathway 2.4b, from Phase 2.4 to 2.2:
Fall, winter, and spring precipitation and temperatures mediate the ability for annual grasses and perennial grasses to germinate and/or survive. Depending on temperatures and precipitation in winter and spring, annual grass production may be reduced in favor of perennial bunchgrasses.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: To Community Phase 3.1: Inappropriate grazing will decrease or eliminate deep-rooted perennial bunchgrasses, increase Sandberg bluegrass and favor shrub growth and establishment. To Community Phase 3.2: Severe fire in community phase 2.3 will remove sagebrush overstory, decrease perennial bunchgrasses and enhance Sandberg bluegrass. Annual non-native species will increase.
Slow variables: Long term decrease in deep-rooted perennial grass density.
Threshold: Loss of deep-rooted perennial bunchgrasses changes nutrient cycling, nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Tree State 4.0

Trigger: Time and lack of disturbance or management action allows for Utah juniper and/or western juniper to dominate. This may be coupled with grazing management that favors tree establishment by reducing understory herbaceous competition for site resources.
Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.
Slow variables: Over time the abundance and size of trees will increase.
Threshold: Trees dominate ecological processes and number of shrub skeletons exceed number of live shrubs. Minimal recruitment of new shrub cohorts.

T2C: Transition from Current Potential State 2.0 to Annual State 5.0

Trigger: Fire or soil disturbing treatment would transition to Community Phase 5.1.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs changes temporal and spatial nutrient capture and cycling within the community. Increased, continuous fine fuels modify the fire regime by increasing frequency, size and spatial variability of fires.

Shrub State 3.0:

This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass will increase with a reduction in deep rooted perennial bunchgrass competition and become the dominant grass. Sagebrush dominates the overstory and rabbitbrush may be a significant component. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory and bluegrass understory dominate site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1 (At Risk):
Decadent sagebrush dominates the overstory. Rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Sandberg bluegrass and annual non-native species increase. Bare ground is significant.

Gravelly Claypan 10-12” (023XY059NV) Phase 3.1 P. Novak-Echenique, May 2015

Very Cobbly Claypan (023XY044NV) Phase 3.1 T.K. Stringham, July 2015

Shallow Stony Loam 9-12" (023XF081CA) Phase 3.1 T.K. Stringham, October 2018

Community Phase Pathway 3.1a, from Phase 3.1 to 3.2:
Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, will greatly reduce the overstory shrubs to trace amounts and allow Sandberg bluegrass to dominate the site.

Community Phase 3.2:
Bluegrass dominates the site; annual non-native species may be present but are not dominant. Trace amounts of sagebrush or rabbitbrush may be present.

Community Phase Pathway 3.2a, from Phase 3.2 to 3.1:
Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of Lahontan/low sagebrush can take many years.

T3A: Transition from Shrub State 3.0 to Tree State 4.0:

Trigger: Absence of disturbance over time allows for Utah juniper or western juniper dominance.
Feedbacks and ecological processes: Trees increasingly dominate use of soil water, contributing to reductions in soil water availability to grasses and shrubs. Overtime, grasses and shrubs are outcompeted. Reduced herbaceous and shrub production slows soil organic matter inputs and increases soil erodibility through loss of cover and root structure.
Slow variables: Long-term increase in juniper and/or western juniper density.
Threshold: Trees overtop Lahontan/low sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs in number. There is minimal recruitment of new shrub cohorts.

T3B: Transition from Shrub State 3.0 to Annual State 5.0

Trigger: Fire and/or treatments that disturb the soil and existing grass community. Further inappropriate grazing management transitions the site to phase 5.2.

Slow variables: Increased seed production (following a wet spring) and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing frequency, intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the temporal and spatial aspects of nutrient cycling and distribution.

Tree State 4.0:

This state is characterized by a dominance of Utah and/or western juniper in the overstory. Lahontan sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients and soil organic matter distribution and cycling have been spatially and temporally altered.

Community Phase 4.1:
Utah juniper and/or western juniper dominates the overstory and site resources. Trees are actively growing with noticeable leader growth. Trace amounts of bunchgrass may be found under tree canopies with trace amounts of Sandberg bluegrass and forbs in the interspaces. Sagebrush is stressed and dying. Annual non-native species are present under tree canopies. Bare ground interspaces are large and connected.

Claypan 10-14" (023XY031NV) Phase 4.1 T. K. Stringham, August 2014

Community Phase Pathway 4.1a, from Phase 4.1 to 4.2:
Time and lack of disturbance or management action allows for tree cover and density to further increase and trees to out-compete the herbaceous understory species for sunlight and water.

Community Phase 4.2:
Utah juniper /western juniper dominate overstory. Lahontan sagebrush is decadent and dying with numerous skeletons present or sagebrush may be missing from the system. Bunchgrasses present in trace amounts and annual non-native species may dominate understory. Herbaceous species may be located primarily under the canopy or near the drip line of trees. Bare ground interspaces are large and connected. Soil movement may be apparent.

T4A: Transition from Tree State 4.0 to Annual State 5.0:

Trigger: Catastrophic crown fire would reduce or eliminate trees to transition the site to 5.1. Tree removal when annual non-natives such as cheatgrass are present would also transition the site to state 5.0.
Slow variable: Increased seed production and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact nutrient cycling and distribution.

R4A: Restoration from Tree State 4.0 to Current Potential State 2.0:

Tree removal with minimum soil disturbance such as hand felling or mastication within community phase 4.1. This treatment may be combined with seeding for increased success when there is little understory.

Annual State 5.0:

An abiotic threshold has been crossed and state dynamics are driven by fire and time. The herbaceous understory is dominated by annual non-native species such as cheatgrass, medusahead, and mustards. Resiliency has declined and further degradation from fire facilitates a cheatgrass and sprouting shrub plant community. The fire return interval is shortened due to the dominance of cheatgrass in the understory and frequent fire drives site dynamics.

Community Phase 5.1:
Annuals such as cheatgrass, medusahead, or tumblemustard dominate; Sandberg bluegrass and perennial forbs may still be present in trace amounts. Surface erosion may increase with summer convection storms and could be identified by increased pedestalling of plants, rill formation, or extensive water flow paths.

Clay Slope 8-12" (023XY037NV) Phase 5.1 T. K. Stringham, June 2014

Gravelly Claypan 10-12" (023XY059NV) Phase 5.1 T. K. Stringham, July 2015

Shallow Stony Loam 9-12" (023XF081CA) Phase 5.1 T.K. Stringham, October 2018

Community Phase Pathway 5.1a, from Phase 5.1 to 5.2:

Time and lack of disturbance allows sprouting shrubs and some sagebrush to recover after fire.

Community Phase 5.2:

Medusahead or cheatgrass dominate the understory. Lahontan or low sagebrush dominates the overstory and sprouting shrubs may be present.

Shallow Stony Clay Loam 9-12" (023XF083CA) Phase 5.2 T.K. Stringham, October 2018

Potential Resilience Differences with other Ecological Sites:

Clay Slope 8-12” (023XY037NV):

This site has a Lahontan sagebrush, bluebunch wheatgrass, and Thurber’s needlegrass community that is very similar to the modal site, however with less precipitation and less production. Elevations range from 4500 to 6000 feet and production varies from 400 lbs/ac to 700 lbs/ac. This site is similar to the modal site, with five stable states. Upon further inspection the Claypan 10-14” site, written in 1963, may be more similar to this site concept with Lahontan sagebrush.

Gravelly Claypan 10-12” (023XY059NV):

The dominant grasses on this site are Thurber’s and Webber’s needlegrass. Like the modal site, Low sagebrush is the dominant shrub and spiny hopsage (*Grayia spinosa*) is a subdominant shrub. It is less productive than the modal site with 450 lbs/ac in a normal year. This site is found on convex summits and backslopes of low hills and erosional fan remnants, from 5000 to 6000 feet. The soils on this site have formed in alluvium or residuum derived from volcanic rock sources. These soils are generally shallow or moderately deep. There is a moderate to strong-structured, clay subsoil ranging from 8 to 12 inches in the soil profile. The soils have high amounts of gravel and/or small cobbles (over 65 percent ground cover) on the surface which provide a stabilizing effect on surface erosion conditions. This site has a four state model; it is unlikely to get a tree state or an eroded state. This site has been seen in a shrub state with no non-native annuals, indicating that it can transition from Reference to the Shrub State, Transition T1B: Long-term inappropriate grazing management favors shrubs and the shallow-rooted Sandberg bluegrass.

Gravelly Clay 10-12” (023XY093NV):

The soils in this site are typically moderately deep with depth to a moderate to strong-structure, clayey, subsoil ranging from 10 to 12 inches. Permeability is moderate and the soils are well drained. Available water capacity is low. Infiltration is restricted once these soils are wetted and they are subject to water loss by runoff. The soils have high amounts of gravels and/or cobbles on the surface which provide a stabilizing effect on surface erosion conditions. The plant community is dominated by Lahontan sagebrush and Thurber's needlegrass. It is less productive than the modal with 500 lbs/ac in a normal year. This site has a four state model without a tree state.

Scabland 10-14” (023XY021NV):

This site is dominated by Sandberg bluegrass, and is much less productive than the modal site with 200 lbs/ac in a normal year. It may have scattered juniper trees. The soils of this site have a very shallow effective rooting depth and are well drained. The soils are typically modified with over 50 percent gravels and other coarse fragments throughout the profile. These soils also have high amounts of gravels, cobbles, or stones on the surface which occupy plant growing space yet provide a stabilizing effect on surface erosion conditions. The available water capacity of these soils is very low. A surface cover of rock fragments helps to reduce evaporation and conserve the limited soil moisture. The harsh environment for plant growth presented by these soil properties restricts site productivity. Characteristic herbaceous plants have shallow root systems and the ability to make rapid early growth before evaporation depletes the limited supply of soil moisture. This site has a four state model without a tree state.

Cobbly Claypan 8-12" (023XY060NV):

This site has many cobbles on the soil surface, and is less productive than the modal site with 375 lbs/ac. The soils on this site have formed in alluvium or residuum derived from volcanic rock sources. These soils have a shallow effective rooting zone with depth to bedrock ranging from 10 to 20 inches. Depth to a dense, strong-structured, clay subsoil is less than 10 inches. Available water holding capacity is low. The soils have high amounts of cobbles and/or small stones (over 65 percent ground cover) on the surface which provides a stabilizing effect on surface erosion conditions. Pedestalling of some grass plants is common during the winter due to frost heave. The plant community is dominated by low sagebrush, bluebunch wheatgrass, and Thurber's needlegrass. This site is similar to the modal site; the model has five stable states.

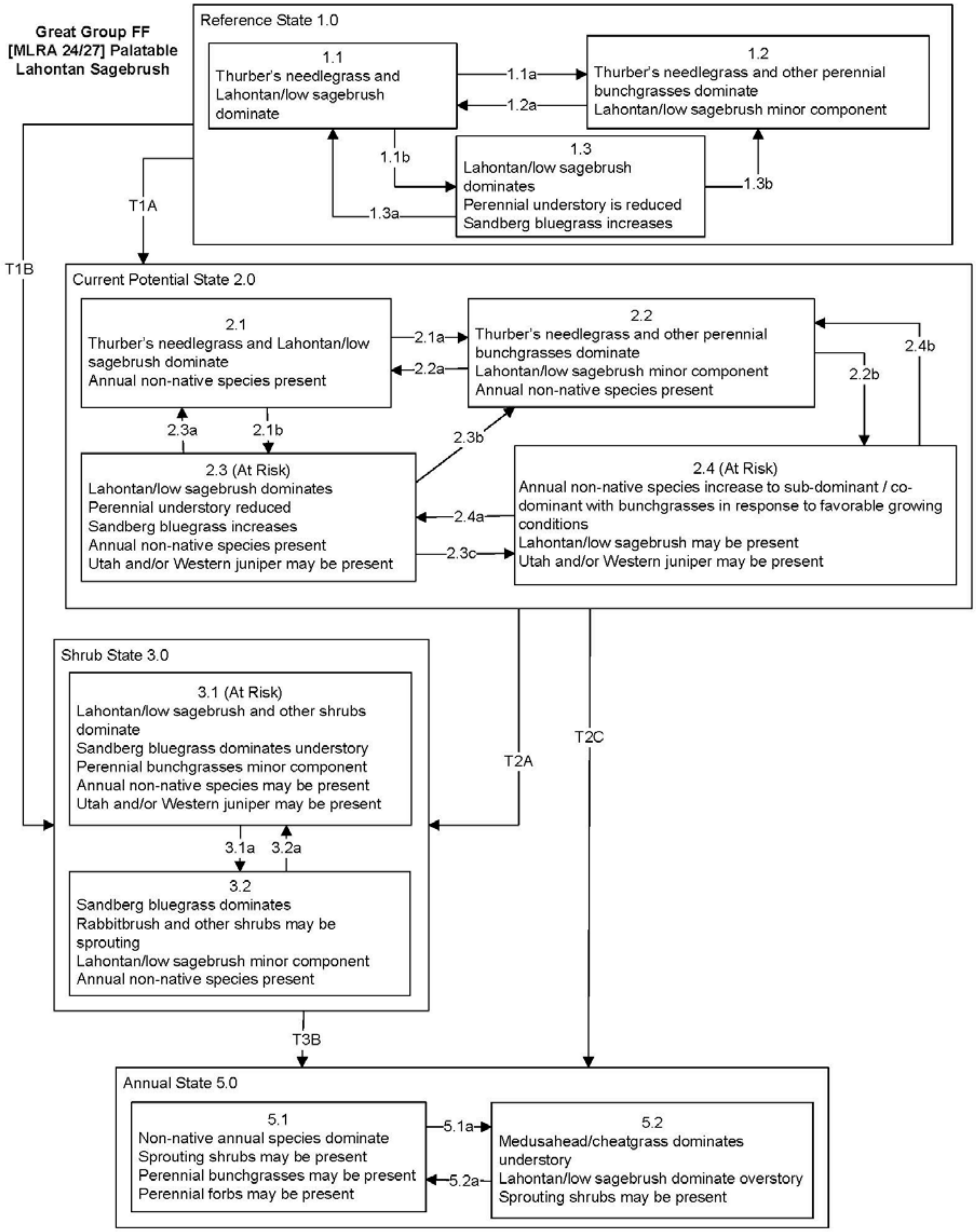
Shallow Stony Clay Loam 9-12" (023XF083CA):

This site has a similar plant community to the modal site, dominated by bluebunch wheatgrass, Lahontan sagebrush and Thurber's needlegrass. Spiny hopsage (*Grayia spinosa*) may also be present. The soils have a shallow effective rooting depth and low soil moisture capacity. Production is lower than the modal site at 600 lbs/ac in a normal year. The soils in this site and Shallow Stony Loam (023XF081CA) are very similar, but are believed to have a higher amount or distribution of clay. This site is similar to the modal site; the model has five stable states.

Shallow Stony Loam 9-12" (023XF081CA):

This site is characterized by shallow effective rooting depth and low soil moisture capacity. The plant community is similar to the modal site with a Western juniper component. Production is also similar to the modal site at 700 lbs/ac in a normal year, but in favorable years can produce as much as 1000 lbs/ac. This site is similar to the modal site; the model has five stable states.

Modal State and Transition Model for Great Group FF:



Great Group FF
[MLRA 24/27] Palatable Lahontan Sagebrush

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire. Excessive herbivory may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub reestablishment.
1.3a: Low severity fire, herbivory or combinations reduces sagebrush.
1.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs.

Transition T1A: Introduction of non-native annual species.
Transition T1B: Long-term inappropriate grazing management favors shrubs and Sandberg bluegrass.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush and leads to early/mid-seral community, dominated by grasses and forbs: non-native annual species present.
2.1b: Time and lack of disturbance such as fire. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for shrub reestablishment.
2.2b: Fall and spring growing conditions that favors the germination and production of non-native, annual grasses. Pathway typically occurs 3 to 5 years post-fire and 2.4 may be a transitory plant community.
2.3a: Low severity fire creates sagebrush/ grass mosaic, herbivory, or combination or brush management with minimal soil disturbance.
2.3b: High severity fire significantly reduces sagebrush and leads to early/mid-seral community or brush management with minimal soil disturbance reduces sagebrush.
2.3c: Fall and spring growing season conditions that favors the germination and production of non-native annual grasses. 2.4 may be a transitory plant community.
2.4a: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.
2.4b: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (to 3.1). Brush management of Community Phase 2.3 may result in Community Phase 3.2.
Transition T2C: Severe fire and/or multiple fires.

Shrub State 3.0 Community Phase Pathways
3.1a: High severity fire; brush management with minimal soil disturbance.
3.2a: Time and lack of disturbance (unlikely/may take many years).

Transition T3B: Invasive annual grasses increase under shrubs, or, high-severity fire or multiple fires and/or treatments that disturb the soil surface in the presence of non-native annual grasses. (to 5.1).

Annual State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance.
5.2a: Fire.

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Great Group G: Wyoming Big Sagebrush

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group G - Ecological sites:

MLRA 25 DRG 4 (Modal)	
Loamy 8-10" P.Z. (Modal)	025XY019NV
Loamy 10-12" P.Z.	025XY014NV
South Slope 12-14" P.Z.	025XY009NV
South Slope 8-12" P.Z.	025XY015NV
Chalky Knoll	025XY025NV
Shallow Loam 8-12" P.Z.	025XY021NV
Ashy Loam 10-12" P.Z.	025XY066NV
Stony Bottom	025XY050NV
Bouldery Loam	025XY058NV
Loamy Fan 8-10" P.Z.	025XY070NV
Juniper Savanna	025XY085NV
MLRA 23 DRG 9	
Loamy 8-10" P.Z. (Modal)	023XY006NV
Loamy Slope 10-14" P.Z.	023XY039NV
Loamy 10-12" P.Z.	023XY020NV
Loamy Fan 8-10" P.Z.	023XY097NV
Granitic Loam 10-12" P.Z.	023XY057NV
Granitic Loam 8-10" P.Z.	023XY068NV
Droughty Loam 8-10" P.Z.	023XY038NV
Granitic South Slope 8-12" P.Z.	023XY049NV
Loamy Fan 10-12" P.Z.	023XY082NV
Granitic Fan 8-10" P.Z.	023XY040NV
Sandy 8-12" P.Z.	023XY051NV
Channery Hill 8-10" P.Z.	023XY099NV
Stony Slope 8-10" P.Z.	023XY101NV
Gravelly Clay Slope 10-12" P.Z.	023XY102NV
Stony Loam 9-12" P.Z.	023XF082CA
Loamy Upland 9-12" P.Z.	023XF091CA
MLRA 23 DRG 10	
Gravelly Clay 8-10" P.Z. (Modal)	023XY047NV

Loamy Hill 10-14" P.Z.	023XY076NV
Chalky Knoll	023XY088NV
South Slope 8-12" P.Z.	023XY030NV
Shallow Granitic Hill 10-14" P.Z.	023XY063NV
Shallow Loam 10-14" P.Z.	023XY077NV
Shallow Hill 10-14" P.Z.	023XY075NV
MLRA 25 DRG 5	
Ashy Loam 8-10" P.Z.	025XY045NV
MLRA 26 DRG 7	
Loamy 8-10" P.Z. (Modal)	026XY016NV
Stony Slope 8-10" P.Z.	026XY022NV
Droughty Loam 8-10" P.Z.	026XY024NV
South Slope 8-10" P.Z.	026XY011NV
Churning Clay 10-12" P.Z.	026XY019NV
Gravelly Loam 8-10" P.Z.	026XY098NV
Coarse Loamy 8-10" P.Z.	026XY099NV
Gravelly Clay Loam 8-10" P.Z.	026XY102NV
MLRA 26 DRG 8	
Eroded Slope 10-12" P.Z. (Modal)	026XY029NV
Eroded Slope 8-10" P.Z.	026XY094NV
MLRA 26 DRG 9	
Loamy 10-12" P.Z. (Modal)	026XY010NV
Loamy Hill 10-12" P.Z.	026XY017NV
Granitic Fan 10-12" P.Z.	026XY008NV
Granitic South Slope 10-12" P.Z.	026XY018NV
Granitic Slope 10-12" P.Z.	026XY026NV
Shallow Loam 10-12" P.Z.	026XY015NV
Granitic Loam 10-12" P.Z.	026XY103NV
Gravelly Coarse Loamy	026XF004CA
Shallow South Slope 10-14" P.Z.	026XF070CA
Shallow Loam 10-14" P.Z.	026XF069CA
MLRA 28 DRG 3A	
Loamy 8-10" P.Z. (Modal)	028AY015NV
Coarse Gravelly Loam 10-12" P.Z.	028AY010NV
Shallow Loam 8-10" P.Z.	028AY017NV
Loamy Plain	028AY124NV
Gravelly Clay 8-10" P.Z.	028AY022NV
Loamy 10-12" P.Z.	028AY095NV
Droughty Loam 8-10" P.Z.	028AY028NV
Loamy Fan 8-10" P.Z.	028AY031NV
MLRA 28 DRG 3B	
Loamy 8-10" P.Z. (Modal)	028BY010NV
Shallow Loam 8-10" P.Z.	028BY080NV
Loamy Plain 8-10" P.Z.	028BY014NV
Loamy 10-12" P.Z.	028BY007NV
Gravelly Clay 10-12" P.Z.	028BY086NV
Loamy Fan 8-12" P.Z.	028BY045NV
Droughty Loam 8-10" P.Z.	028BY052NV

Description of Great Group G:

Great Group G consists of nine DRGs and 70 ecological sites. These sites range in precipitation from 8 to 14 inches. The elevation range of this group is 4,200 to 8,500 feet. Slopes range from 0 to 75 percent. Soils on these sites vary greatly depending on slope, aspect and elevation. These soils are typically shallow to moderately deep and well drained. These soils are modified with a high amount of gravels, cobbles and stones on the surface and throughout the profile which occupy plant growing space yet provide a stabilizing effect on surface erosion conditions. The available water holding capacity ranges from very low to moderate. Because some of these sites are found on southerly exposures more sunlight is received and the soils tend to warm and plant growth is initiated earlier than on adjacent sites. High evapotranspiration potentials result in depletion of the available soil moisture supply sooner than on surrounding areas at elevations where these sites occur. The soil temperature regime is either mesic or frigid and the soil moisture regime is aridic bordering on xeric. Sites within this disturbance response group are characterized by a dominance of Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*) and Thurber's needlegrass (*Achnatherum thurberianum*). Annual production for a normal year ranges from 350 to 900 lbs/acre. Indian ricegrass (*Achnatherum hymenoides*), basin wildrye (*Leymus cinereus*), and antelope bitterbrush (*Purshia tridentata*) are other important species on these sites.

Ecological Dynamics and Disturbance Response

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

The ecological sites in this DRG are dominated by deep-rooted cool season, perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m. (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 meters in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Dobrowolski et al. 1990).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al 2006).

Variability in plant community composition and production depends on soil surface texture and depth. Thurber's needlegrass will increase on gravelly soils, whereas Indian ricegrass will increase with sandy soil surfaces, and bottlebrush squirreltail will increase with silty soil surfaces. A weak argillic horizon will promote production of bluebunch wheatgrass. Production generally increases with soil depth. The amount of sagebrush in the plant community is dependent upon disturbances like fire, Aroga moth infestations, and grazing. Sandberg bluegrass more easily dominates sites where surface soils are gravelly loams or when there is an increase in ash in the upper soil profile.

Wyoming big sagebrush is the most drought tolerant of the big sagebrushes, is generally long-lived; therefore it is not necessary for new individuals to recruit every year for perpetuation of the stand. Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is dependent on adequate moisture conditions.

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (*Aroga websteri*). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and have been ongoing in Nevada since 2004 (Bentz, et al 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Perennial bunchgrasses generally have somewhat shallower root systems than shrubs in these systems, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m but taper off more rapidly than shrubs. General differences in root depth distributions between grasses and shrubs result in resource partitioning in these shrub/grass systems.

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation, both among years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The moisture resource supporting the greatest amount of plant growth is usually the water stored in the soil profile during the winter. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al. 2007).

The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual state. Conversely, as fire frequency decreases, sagebrush will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

At the upper range of this group's precipitation range, there is potential for infilling by Utah juniper (*Juniperus osteosperma*) and/or singleleaf pinyon (*Pinus monophylla*). Infilling may also occur if the site is adjacent to woodland sites or other ecological sites with juniper present. Without disturbance in these areas, Utah juniper will eventually dominate the site and out-compete sagebrush for water and sunlight severely reducing both the shrub and herbaceous understory (Miller and Tausch 2000, Lett and Knapp 2005). The potential for soil erosion increases as the woodland matures and the understory plant community cover declines (Pierson et al. 2010).

The ecological sites in this DRG have low resilience to disturbance and low resistance to invasion. Increased resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Six possible stable states have been identified for the Loamy 8-10" ecological site. Differences in resilience to disturbance for the remaining ecological sites contained within this DRG are described at the end of this document.

Fire Ecology:

Wyoming big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common at 10-70 year return intervals (Young et al. 1978, West and Hassan 1985, Bunting et al. 1987). Davies et al. (2006) suggest fire return intervals in Wyoming big sagebrush communities were around 50-100 years. Wyoming big sagebrush is killed by fire and only regenerates from seed. Recovery time for Wyoming big sagebrush may require 50-120 or more years (Baker 2006). However, the introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013) and restoration potential of Wyoming big sagebrush communities.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983).

Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976). Fire can cause high mortality, in addition to reducing basal area and yield of Thurber's needlegrass (Britton et al. 1990). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influenced the response and mortality of Thurber's needlegrass, smaller bunch sizes were less likely to be damaged by fire (Wright and Klemmedson 1965). Thurber's needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985, Britton et al. 1990). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Evans and Young 1978).

Fire will remove aboveground biomass from bluebunch wheatgrass but plant mortality is generally low (Robberecht and Defossé 1995) because the buds are underground (Conrad and Poulton 1966) or protected by foliage. Uresk et al. (1976) reported burning increased vegetative and reproductive vigor of bluebunch wheatgrass. Thus, bluebunch wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983). Plant response will vary depending on season, fire severity, fire intensity and post-fire soil moisture availability.

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below ground plant crowns. Indian ricegrass has been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus the presence of surviving, seed producing plants is necessary for reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Sandberg bluegrass, a minor component of this ecological site, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975). Sandberg bluegrass may retard reestablishment of deeper rooted bunchgrass. Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces, leading to increased fire frequency and potentially an annual plant community.

The range and density of Utah juniper and singleleaf pinyon has increased since the middle of the nineteenth century (Tausch 1999, Miller and Tausch 2000). Causes for expansion of trees into sagebrush ecosystems include wildfire suppression, historic livestock grazing, and climate change (Bunting 1994).

Depending on fire severity, rabbitbrush and horsebrush may increase after fire. Rubber rabbitbrush is top-killed by fire, but can resprout after fire and can also establish from seed (Young 1983). Yellow rabbitbrush is top-killed by fire, but sprouts vigorously after fire (Kuntz 1982, Akinsoji 1988). As cheatgrass increases, fire frequencies also increase to frequencies between 0.23 and 0.43 times a year; then even sprouting shrubs such as rabbitbrush will not survive (Whisenant 1990).

Livestock/Wildlife Grazing Interpretations:

This site is suitable for grazing. Grazing management considerations include timing, duration and intensity of grazing.

Overgrazing leads to an increase in sagebrush and a decline in understory plants like bluebunch wheatgrass and Thurber’s needlegrass. Squirreltail or Sandberg bluegrass will increase temporarily with further degradation. Invasion of annual weedy forbs and cheatgrass could occur with further grazing degradation, leading to a decline in squirreltail and bluegrasss and an increase in bare ground. A combination of overgrazing and prolonged drought leads to soil erosion, increased bare ground and a loss in plant production. Wildfire in sites with cheatgrass present could transition to cheatgrass dominated communities. Without management cheatgrass and annual forbs are likely to invade and dominate the site, especially after fire. Although trees are not part of the site concept, Utah juniper and/or singleleaf pinyon can invade and eventually dominate this site.

Thurber's needlegrass is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber’s needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

Bluebunch wheatgrass is moderately grazing tolerant and is very sensitive to defoliation during the active growth period (Blaisdell and Pechanec 1949, Laycock 1967, Anderson and Scherzinger 1975).

Herbage and flower stalk production was reduced with clipping at all times during the growing season; however, clipping was most harmful during the boot stage (Blaisdell and Pechanec 1949, Britton et al. 1990) Tiller production and growth of bluebunch was greatly reduced when clipping was coupled with drought (Busso and Richards 1995). Mueggler (1975) estimated that low vigor bluebunch wheatgrass may need up to 8 years rest to recover. Although an important forage species, it is not always the preferred species by livestock and wildlife.

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton (*Halogeton glomeratus*), bur buttercup (*Ceratocephala testiculata*) and annual mustards to occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas hold a little more moisture and may retain deep-rooted perennial grasses whereas convex areas are slightly less resilient and may have more Sandberg bluegrass present

State and Transition Model Narrative for Great Group G

This is a text description of the states, phases, transitions, and community pathways possible in the modal State and Transition model for Great Group G.

Reference State 1.0:

The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:

Wyoming big sagebrush, bluebunch wheatgrass and Thurber’s needlegrass dominate the site. Indian ricegrass, Sandberg bluegrass, basin wildrye, squirreltail and perennial forbs are also common on this site.

Community Phase Pathway 1.1a, from phase 1.1 to 1.2:

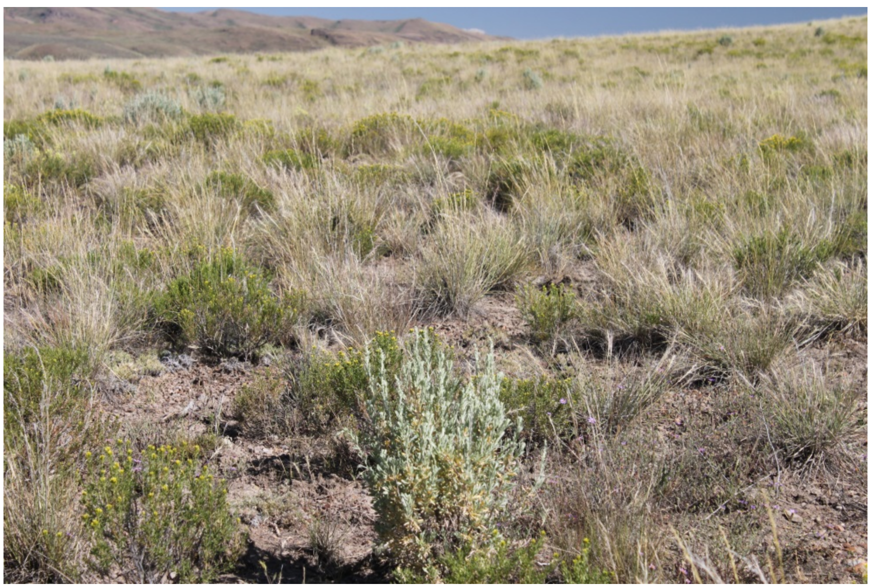
Fire would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

Community Phase Pathway 1.1b, from phase 1.1 to 1.3:

Long-term drought, time and/or herbivory favor an increase in Wyoming big sagebrush over deep-rooted perennial bunchgrasses. Combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. Sandberg bluegrass may increase in density depending on the grazing management.

Community Phase 1.2:

This community phase is characteristic of a post-disturbance, early to mid-seral community phase. Rabbitbrush, horsebrush, spiny hopsage and perennial grasses such as bluebunch wheatgrass, Indian ricegrass and squirreltail are common. Wyoming big sagebrush is killed by fire, therefore decreasing within the burned community. Sagebrush could still be present in unburned patches. Thurber's needlegrass can experience high mortality from fire and may be reduced in the community for several years.



Loamy 10-12" (025XY014NV) Phase 1.2 T. K. Stringham, July 2011

Community Phase Pathway 1.2a, from phase 1.2 to 1.1:

Time and lack of disturbance allows for sagebrush to reestablish.

Community Phase 1.3:

Wyoming big sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from herbivory. Sandberg bluegrass will likely increase in the understory and may be the dominant grass on the site.

Community Phase Pathway 1.3a, from phase 1.3 to 1.1:

Aroga moth infestation and or release from growing season herbivory may reduce sagebrush dominance and allow recovery of the perennial bunchgrass understory.

Community Phase Pathway 1.3b,from phase 1.3 to 1.2:

Fire would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual weeds, such as cheatgrass, mustard and halogeton.
Slow variables: Over time the annual non-native plants will increase within the community decreasing organic matter inputs from deep-rooted perennial bunchgrasses resulting in reductions in soil water availability for perennial bunchgrasses.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:

This state is similar to the Reference State 1.0. Ecological function has not changed, however the resiliency of the state has been reduced by the presence of invasive weeds. This state has the same three general community phases. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal. Additionally, the presence of highly flammable, non-native species reduces State resilience because these species can promote fire where historically fire has been infrequent leading to positive feedbacks that further the degradation of the system.

Community Phase 2.1:

Wyoming big sagebrush, bluebunch wheatgrass, and Thurber’s needlegrass dominate the site. Indian ricegrass, Sandberg bluegrass, basin wildrye, squirreltail and perennial forbs are also common on this site. Non-native annual species are present in minor amounts.

Chalky Knoll (025XY025NV) Phase 2.1 T. K. Stringham, June 2011

Community Phase Pathway 2.1a, from phase 2.1 to 2.2:

Fire would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Community Phase Pathway 2.1b, from phase 2.1 to 2.3:

Time, long-term drought, grazing management that favors shrubs or combinations of these would allow the sagebrush overstory to increase and dominate the site, causing a reduction in the perennial bunchgrasses. However, Sandberg bluegrass and/or squirreltail may increase in the understory depending on the grazing management. Heavy spring grazing will favor an increase in sagebrush. Annual non-native species may be stable or increasing within the understory.

Community Phase 2.2:

This community phase is characteristic of a post-disturbance, early seral community phase. Rabbitbrush, horsebrush, spiny hopsage and perennial bunchgrasses such as bluebunch wheatgrass, needleandthread and Indian ricegrass are common. Wyoming big sagebrush is killed by fire, therefore decreasing within the burned community. Sagebrush could still be present in unburned patches. Perennial forbs may increase or dominate after fire for several years. Thurber's needlegrass can experience high mortality from fire and may be reduced in the community for several years. Annual non-native species generally respond well after fire and may be stable or increasing within the community. Rabbitbrush may dominate the aspect for a number of years following wildfire.

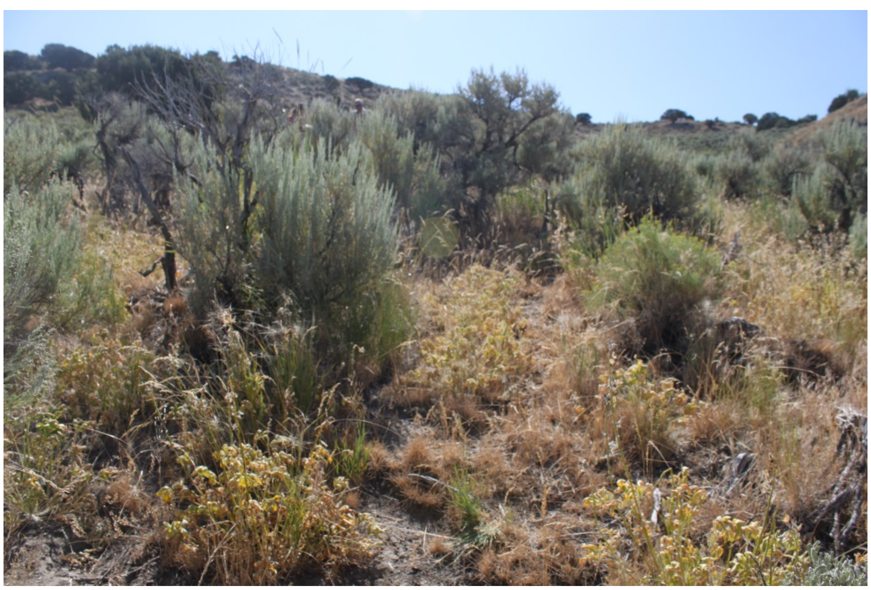
Loamy 8-10” (025XY019NV) Phase 2.2 T. K. Stringham, July 2011

Ashy Loam 10-12” (025XY066NV) Phase 2.2 T. K. Stringham, August 2011

Loamy 10-12" (025XY014NV) Phase 2.2 T. K. Stringham, August 2011

Community Phase Pathway 2.2a, from phase 2.2 to 2.1:
Absence of disturbance over time allows for the sagebrush to recover, or grazing management that favors shrubs.

Community Phase 2.3:
Wyoming big sagebrush increases and the perennial understory is reduced. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs or from inappropriate grazing management. Sandberg bluegrass will likely increase in the understory and may be the dominant grass on the site. Utah juniper may be present. Annual non-native species present.



Loamy 10-12" (025XY014NV) Phase 2.3 T. K. Stringham, July 2011

South Slope 12-14" (025XY009NV) Phase 2.3 T. K. Stringham, June 2011

Community Phase Pathway 2.3a, from phase 2.3 to 2.1:
Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Other disturbances/practices include brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.

Community Phase Pathway 2.3b, from phase 2.3 to 2.2:
Fire would decrease or eliminate the overstory of sagebrush and allow for the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during growing season would favor shrubs and initiate transition to Community Phase 3.1. Fire would cause a transition to Community Phase 3.2.
Slow variables: Long term decrease in deep-rooted perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.
Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0:

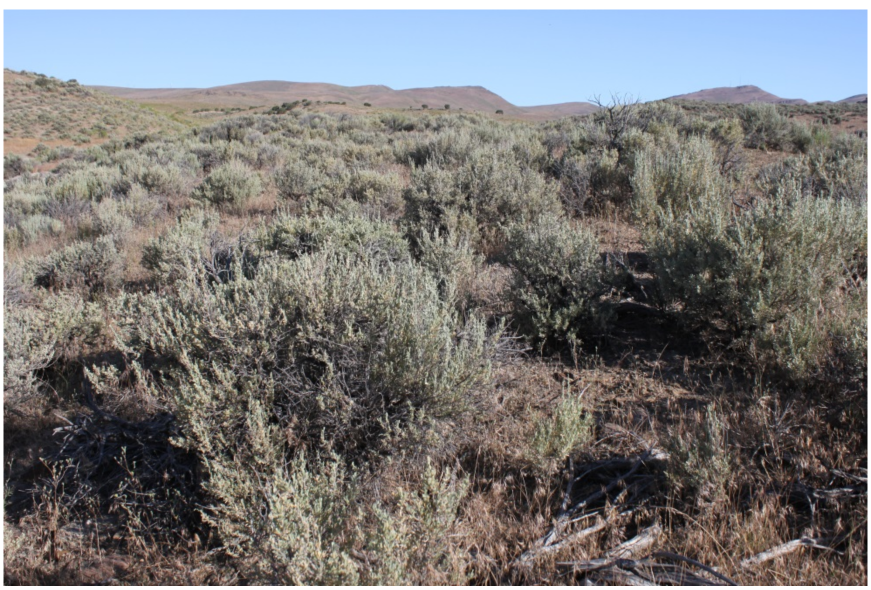
Trigger: Fire or a failed range seeding leads to plant community phase 4.1. Inappropriate grazing management that favors shrubs in the presence of non-native annual species leads to community phase 4.2.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Cheatgrass or other non-native annuals dominate understory.

Shrub State 3.0

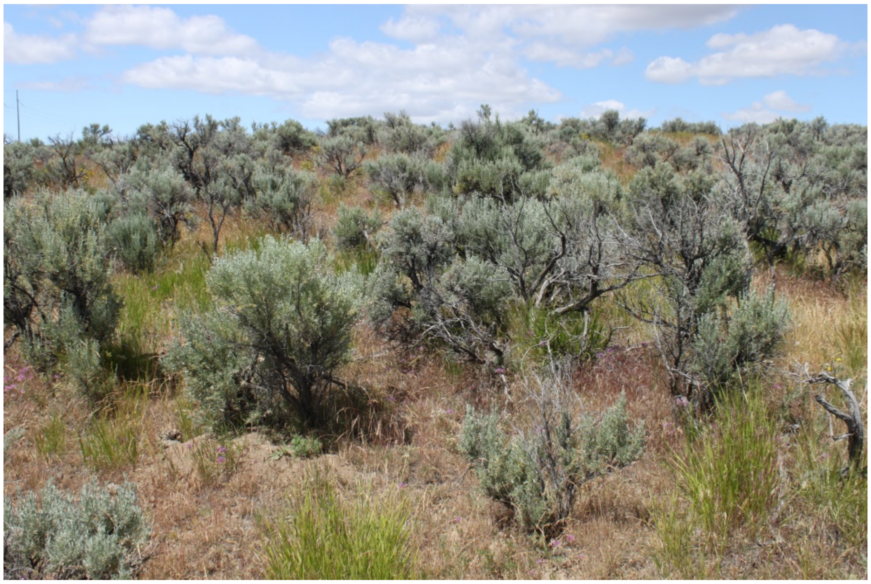
This state has two community phases: a Wyoming big sagebrush dominated phase and a rabbitbrush dominated phase. This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass will increase with a reduction in deep rooted perennial bunchgrass competition and become the dominant grass. Sagebrush dominates the overstory and rabbitbrush may be a significant component. Sagebrush canopy cover is high and sagebrush may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory and Sandberg bluegrass understory dominate site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed.

Community Phase 3.1:

Wyoming big sagebrush dominates overstory and rabbitbrush may be a significant component. Sandberg bluegrass dominates the understory and squirreltail may also be a significant component of the plant community. Utah juniper may be present or increasing. Annual non-native species are present to increasing. Understory may be sparse, with bare ground increasing. If coming from the seeded state, the shrub state may have trace amounts of seeded species such as crested wheatgrass. Grasses may be absent from plant interspaces but may be found surviving under the canopy of shrubs.



Loamy 10-12" (025XY014NV) Phase 3.1 T. K. Stringham, July 2011



Loamy 10-12" (025XY014NV) Phase 3.1 T. K. Stringham, July 2011

Loamy 8-10" (025XY019NV) Phase 3.1 T. K. Stringham, July 2011

Loamy 8-10" (025XY019NV) Phase 3.1 T. K. Stringham, July 2011

Shallow Loam 8-12" (025XY021NV) Phase 3.1 T. K. Stringham, August 2011

Community Phase Pathway 3.1a, from phase 3.1 to 3.2:

Fire would decrease or eliminate the overstory of sagebrush. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the Sandberg bluegrass, forbs and sprouting shrubs. Heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, would greatly reduce the overstory shrubs and allow for Sandberg bluegrass to dominate the site.

Community Phase 3.2

Sandberg bluegrass dominates the understory; annual non-natives are present but are not dominant. Trace amounts of sagebrush may be present. Rabbitbrush may dominate for a number of years following fire.

Loamy 10-12" (025XY014NV) Phase 3.2 T. K. Stringham, June 2011

Community Phase Pathway 3.2a, from phase 3.2 to 3.1:

Absence of disturbance over time would allow for sagebrush and other shrubs to recover.

T3A: Transition from Shrub State 3.0 to Annual State 4.0:

Trigger: Fire or inappropriate grazing management can eliminate the Sandberg bluegrass understory and transition to community phase 4.1 or 4.2.
Slow variable: Increased seed production and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Loamy 8-10" (025XY019NV) Shrub treatment T. K. Stringham, July 2011

T3B: Transition from Shrub State 3.0 to Tree State 6.0:

Trigger: Lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management that reduces fine fuels.

Slow variables: Increased establishment and cover of juniper trees, reduction in organic matter inputs.

Threshold: Trees overtop Wyoming big sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs with minimal recruitment of new cohorts.

R3A: Restoration from Shrub State 3.0 to Current Potential State 2.0:

Brush management, herbicide or sub-soiling of Sandberg bluegrass and seeding of desired perennial bunchgrass.

R3B: Restoration from Shrub State 3.0 to Seeded State 5.0:

Brush management, herbicide of Sandberg bluegrass and seeding of crested wheatgrass and/or other desired species.

Annual State 4.0

This state has two community phases; one dominated by annual non-native species and the other is a shrub dominated site. This state is characterized by the dominance of annual non-native species such as cheatgrass and tansy mustard in the understory. Sagebrush and/or rabbitbrush may dominate the overstory. Annual non-native species and squirreltail dominate the understory.

Community Phase 4.1:

Annual non-native plants such as cheatgrass or tansy mustard dominate the site. This phase may have seeded species present if resulting from a failed seeding attempt.

Loamy 8-10” (025XY019NV) Phase 4.1 T. K. Stringham, July 2011

Loamy 10-12" (025XY014NV) Phase 4.1 T. K. Stringham, July 2011

Community Phase Pathway 4.1a, from phase 4.1 to 4.2:
Time and lack of disturbance. Occurrence of this pathway is unlikely.

Community Phase 4.2:
Wyoming big sagebrush remains in the overstory with annual non-native species, likely cheatgrass, dominating the understory. Trace amounts of desirable bunchgrasses may be present.

Loamy 8-10" (025XY019NV) Phase 4.2 T. K. Stringham, July 2011

Community Phase Pathway 4.2a, from phase 4.2 to 4.1:
Fire allows for annual non-native species to dominate site.

R4A: Restoration from Annual State 4.0 to Seeded State 5.0:
Application of herbicide and seeding of desired species. Success for this restoration pathway is unlikely; probability of success is best immediately following fire.

Seeded State 5.0:
This state has three community phases; a grass-dominated phase, and grass-shrub dominated phase, and a shrub dominated phase. This state is characterized by the dominance of seeded introduced wheatgrass species in the understory. Forage kochia and other desired seeded species including Wyoming big sagebrush, native and non-native forbs may be present.

Community Phase 5.1:
Seeded wheatgrass and/or other seeded species dominate the community. Non-native annual species are present. Trace amounts of Wyoming big sagebrush may be present, especially if seeded.


Loamy 8-10" (025XY019NV) Phase 5.1 T. K. Stringham, July 2011

Loamy 10-12" (025XY014NV) Phase 5.1 T. K. Stringham, August 2011

Community Phase Pathway 5.1a, from phase 5.1 to 5.2:
Time and lack of disturbance may be coupled with inappropriate grazing management.

Community Phase 5.2:
Wyoming big sagebrush increases and may become the dominant overstory. Seeded wheatgrass species dominate understory. Annual non-native species may be present in trace amounts.

Loamy 8-10" (025XY019NV) Phase 5.2 T. K. Stringham, August 2011

Loamy Fan 8-10" (025XY070NV) Phase 5.2 T. K. Stringham, August 2011

Loamy 8-10" (025XY019NV) Phase 5.2 T. K. Stringham, August 2011

Community Phase Pathway 5.2a, from phase 5.2 to 5.1:

Fire, brush management and/or Aroga moth infestation reduces sagebrush overstory and allows for seeded wheatgrasses or other seeded grasses to increase.

Community Phase Pathway 5.2b, from phase 5.2 to 5.3:

Continued inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.

Community Phase 5.3 (at risk):

Sagebrush becomes the dominant plant. Perennial bunchgrasses in the understory are reduced due to increased competition. Annual non-native species may be increasing. Utah juniper may be present.

Community Phase Pathway 5.3a, from phase 5.3 to 5.1:

Fire or brush management with minimal soil disturbance would reduce sagebrush to trace amounts and allow for the perennial understory to increase.

T5A: Transition from Seeded State 5.0 (Community Phase 5.3) to Annual State 4.0:

Trigger: Fire
Slow variables: Increased production and cover of non-native annual species
Threshold: Cheatgrass or other non-native annuals dominate understory

T5B: Transition from Seeded State 5.0 (Community Phase 5.3) to Tree State 6.0:

Trigger: Lack of fire allows for trees to dominate site; may be coupled with inappropriate grazing management that reduces fine fuels.
Slow variables: Increased establishment and cover of juniper trees, reduced infiltration and increased runoff.
Threshold: Trees overtop Wyoming big sagebrush and out-compete shrubs for water and sunlight. Shrub skeletons exceed live shrubs with minimal recruitment of new cohorts.

T5C: Transition from Seeded State 2.0 to Shrub State 3.0:

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during growing season would favor shrubs and initiate transition to Community Phase 3.1. Fire would cause a transition to Community Phase 3.2.
Slow variables: Long term decrease in deep-rooted perennial grass density resulting in a decrease in organic matter inputs and subsequent soil water decline.
Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

Tree State 6.0:

This state has two community phases that are characterized by the dominance of Utah juniper and singleleaf pinyon in the overstory. Wyoming big sagebrush and perennial bunchgrasses may still be present, but they are no longer controlling site resources. Soil moisture, soil nutrients, soil organic matter distribution and nutrient cycling have been spatially and temporally altered.

Community Phase 6.1:

Juniper trees dominate overstory, sagebrush is decadent and dying, deep rooted perennial bunchgrasses are decreasing. Recruitment of sagebrush cohorts is minimal. Annual non-natives may be present or increasing.

Loamy 10-12” (025XY014NV) Phase 6.1 T. K. Stringham, July 2011

Loamy 10-12” (025XY014NV) Phase 6.1 T. K. Stringham, July 2011

Loamy 8-10” (025XY019NV) Phase 6.1 T. K. Stringham, August 2011

Community Phase Pathway 6.1a, from phase 6.1 to 6.2:

Absence of disturbance over time allows for tree cover and density to further increase and out-compete the herbaceous understory species for sunlight and water.

Community Phase 6.2:

Utah juniper dominates the site and tree leader growth is minimal; annual non-native species may be the dominant understory species and will typically be found under the tree canopies. Trace amounts of sagebrush may be present however dead skeletons will be more numerous than living sagebrush. Bunchgrasses may or may not be present. Sandberg bluegrass or mat forming forbs may be present in trace amounts. Bare ground interspaces are large and connected. Soil redistribution is evident.

T6A: Transition from Tree State 6.0 to Annual State 4.0:

Trigger: Catastrophic crown fire would reduce or eliminate trees to transition the site to 4.1. Tree removal when annual non-natives such as cheatgrass are present would also transition the site to state 4.0.
Slow variable: Increased seed production and cover of annual non-native species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture and impact the nutrient cycling and distribution.

Potential Resilience Differences within other Ecological Sites

Loamy 10-12” 025XY014NV:

This site can be dominated by any of the three big sagebrush species or a combination of the three. The Shrub, Tree, and Seeded States have been field verified. Site variation and prior disturbance may cause a significant reduction or absence of either dominant grass – bluebunch wheatgrass or Thurber's needlegrass. Basin wildrye will increase in places with run-on moisture.

South Slope 12-14" 025XY009NV:

This site is more resilient than the modal site. Soils will generally have a mollic epipedon. Cheatgrass can still invade the site, but this site is more likely to maintain a dominance of perennial bunchgrasses after fire. Shrubs allow for more intense fires, which may decrease the response of bunchgrasses and increase the presence of cheatgrass post-fire. However, an increase in cheatgrass within the perennial bunchgrass dominated community phase sets the site up to burn earlier in the year which is more damaging to bunchgrasses than a fire after the growing season is complete. This site has been seen in a phase 2.4, characterized by an increase in cheatgrass to codominance with perennial grasses.

Community Phase Pathway 2.2b, from phase 2.2 to 2.4:

Higher than normal spring precipitation favors annual non-native species such as cheatgrass. Non-native annual species will increase in production and density throughout the site. Pathway typically occurs 3 to 5 years post-fire.

Community Phase Pathway 2.3c, from phase 2.3 to 2.4:

Higher than normal spring precipitation favors annual non-native species such as cheatgrass and can increase overall production on the site. Pathway occurs when there is available interspace for increased annual grass production.

Community Phase 2.4 (At Risk):

This community is at risk of crossing into an annual state, but may be transitory in response to particular annual weather patterns. Native bunchgrasses dominate; however, annual non-native species such as cheatgrass may increase to codominance in the understory. Annual production and abundance of these annuals may increase drastically in years with heavy spring precipitation. Seeded species may be present. Sagebrush and/or bitterbrush are a minor component. Juniper may be present. This site is susceptible to further degradation from grazing, drought, and fire.

South Slope 12-14" (025XY009NV) Phase 2.4 T. K. Stringham, June 2011

Community Phase Pathway 2.4a, from phase 2.4 to 2.2:
Rainfall patterns unfavorable to cheatgrass production. Less than normal spring precipitation followed by higher than normal summer precipitation will favor perennial bunchgrass production.

Community Phase Pathway 2.4b, from phase 2.4 to 2.3:
Rainfall patterns unfavorable to cheatgrass production. Shrubs must be present in the 2.4 phase for this pathway to occur. Less than normal spring precipitation followed by higher than normal summer precipitation will favor perennial bunchgrass production.

South Slope 8-12" 025XY015NV:
Soils typically have an ochric epipedon. This site has Utah juniper present in trace amounts in the reference plant community. Post-fire response in sites with a large presence of cheatgrass can be patchy with areas dominated by bluebunch wheatgrass and other areas dominated by cheatgrass and mustards.

Chalky Knoll 025XY025NV:
Production is much less than the modal site. Site can express a wide range in variation with regards to the plant community and is generally a forb rich site. Black sagebrush may be present within this community. Inherent site characteristics make this site less resilient to disturbance than the modal site. This site is very susceptible to erosion and some rills and soil creep is normally expected. Cheatgrass easily invades this site and increases with fire or repeated fire. The Tree state can experience extreme soil loss/movement and the understory can be very sparse.

Shallow Loam 8-12 025XY021NV:
This site is very similar in composition to the modal site, but is less productive and therefore less resilient. Soils are modified by 35-75% gravels or coarse fragments throughout the profile, which

effectively reduces the available water capacity of the site. Bluebunch wheatgrass and Wyoming big sagebrush co-dominate the site.

Ashy Loam 10-12 025XY066NV:

This site has Utah juniper present in trace amounts in the reference plant community. Sandberg bluegrass does not have the potential to dominate the understory due to the coarse ashy soils of this site. Site can express a community dominated by rabbitbrush and western wheatgrass after fire.

Stony Bottom 025XY050NV:

This site is dominated by bluebunch wheatgrass and is generally an inclusion within a Wyoming big sagebrush community. The large rock fragments present within the soil profile favor a dominance of perennial bunchgrasses.

Bouldery Loam 025XY058NV:

Never visited this site. No mapped acres. This site is co-dominated by bluebunch wheatgrass and creambush oceanspray.

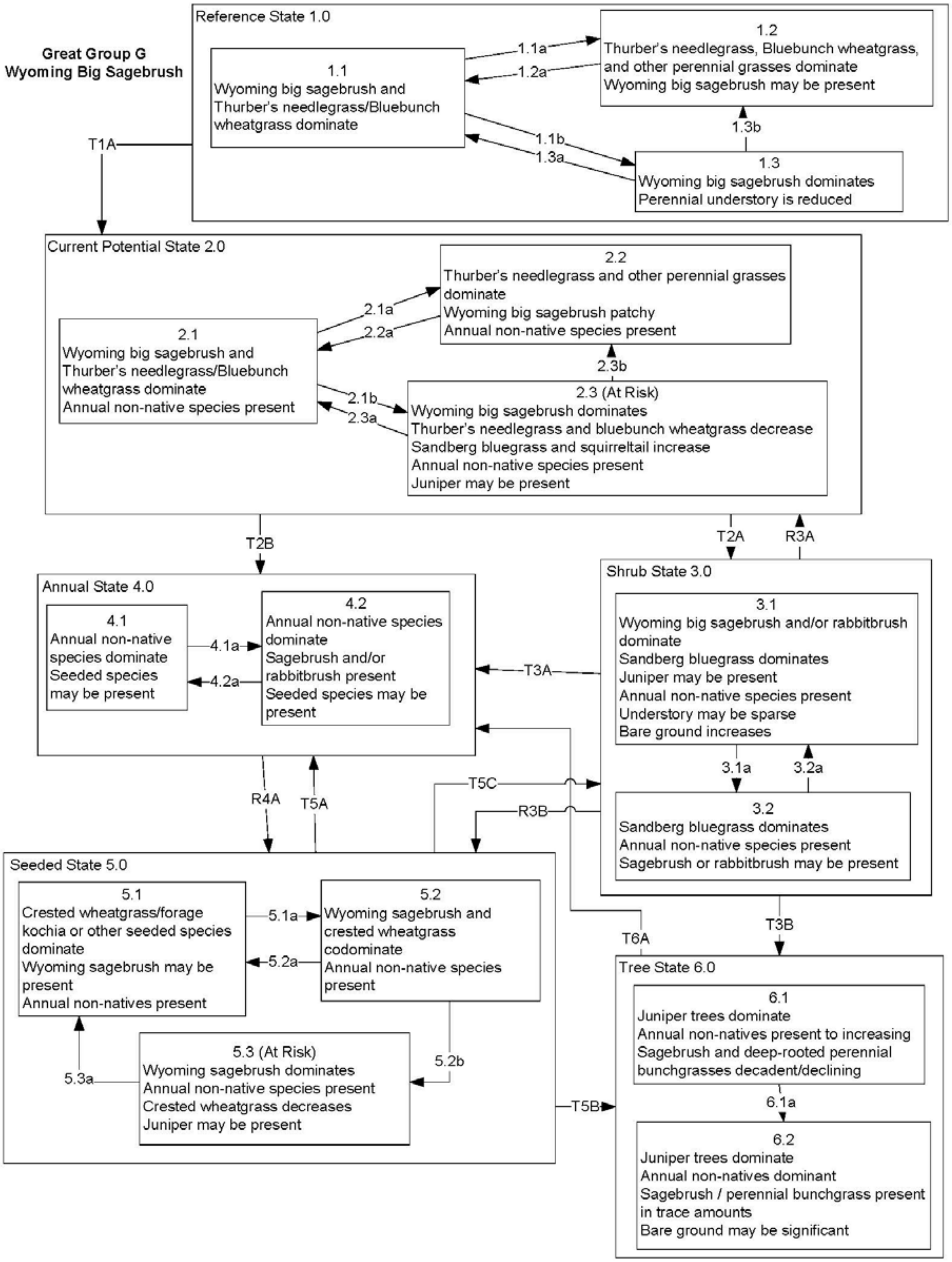
Loamy Fan 025XY070NV:

This site is similar in concept to a Loamy Bottom with about half the production. This site does have a Seeded state. These sites can be influenced by draining or lowered water tables associated with gullying of stream channels. Therefore a “Drained” or eroded state may be necessary to describe site dynamics. Rare flooding of this site may occur when in close proximity to stream channels. Tree (Utah juniper) encroachment has been observed.

Juniper Savanna 025XY085NV:

As of March 2015, this ecological site is in development. Soils correlated to this ecological site have an ochric epipedon. Soils are very shallow to shallow to a strongly cemented or indurated duripan. This site is generally found on middle fan piedmont remnants. It is characterized by the presence of Wyoming big sagebrush and a low canopy cover (<10-15%) of Utah juniper. Although this site is still under development, it is believed that it may be capable of developing an old growth tree state.

Modal State and Transition Model for Great Group G



Great Group G
Wyoming Big Sagebrush

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs
1.1b:Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to a early/mid-seral community.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments will lead to phase 3.2.
Transition T2B: Catastrophic fire (to 4.1); inappropriate cattle/horse grazing management that removes bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2)

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance.

Restoration R3A: Brush management and seeding of native deep rooted bunchgrasses (probability of success is low).
Restoration R3B: Brush management and seeding of crested wheatgrass and/or other non-native desirable species.

Transition T3A: Fire and/or soil disturbing treatments.
Transition T3B: Time and lack of disturbance such as fire favors an increase in tree dominance (from phase 3.1.)

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Big sagebrush is unlikely to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Application of herbicide and seeding of desired species (probability of success best immediately following fire).

Seeded State 5.0 Community Phase Pathways
5.1a: Time without disturbance.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Inappropriate grazing management decreases perennial bunchgrass understory.
5.3a: Fire, brush management, Aroga moth infestation.

Transition T5A: Catastrophic fire (coming from 5.3).
Transition T5B: Time and lack of disturbance allows trees to dominate site resources.
Transition T5C: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.

Tree State 6.0 Community Phase Pathways
6.1a: Time without disturbance.

Transition T6A: Catastrophic fire that kills trees. Inappropriate tree removal practices may also lead to dominance by non-native annuals.

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Great Group GG: [MLRA 24/27] Wyoming Big Sagebrush

Great Groups represent an upscaling of the Disturbance Response Group (DRG) concept (Stringham et al. 2016) and are utilized in this application to simplify management decisions in regards to livestock grazing and invasive annual grass management. Great Groups include multiple ecological sites, often from more than one Major Land Resource Area (MLRA), that have similar dominant vegetation, mean annual precipitation, soils and similar response to disturbance or management actions. The similarity in ecological response to disturbances and management actions facilitates the use of one modal state-and-transition model for the entire Great Group. Specific project applications may require use of the individual ecological site state-and-transition models located at **https://naes.unr.edu/rangeland_ecology/**.

Great Group GG – Ecological Sites:

MLRA 24 DRG 1 (Modal)	
Loamy 8-10" P.Z. (Modal)	024XY005NV
Droughty Loam 8-10" P.Z.	024XY020NV
South Slope 8-12" P.Z.	024XY028NV
Shallow Loam 10-14" P.Z.	024XY035NV
Sandy Loam 8-10' P.Z.	024XY058NV
Stony Slope 6-10" P.Z.	024XY026NV
Loamy 10-12" P.Z.	024XY013NV
Steep North Slope 10-12" P.Z.	024XY033NV
Shallow Loam 8-10" P.Z.	024XY047NV
MLRA 27 DRG 3	
Droughty Loam 8-10" P.Z. (Modal)	027XY008NV
Loamy Slope 8-10" P.Z.	027XY007NV
South Slope 8-10" P.Z.	027XY051NV
Granitic Loam 8-10" P.Z.	027XY067NV
Granitic Slope 10-12" P.Z.	027XY072NV
Granitic Fan 10-12" P.Z.	027XY092NV
Gravelly Fan 8-10" P.Z.	027XY029NV
Sandy 8-10" P.Z.	027XY045NV
MLRA 27 DRG 4	
Granitic Slope 8-10" P.Z.	027XY065NV
Granitic Loam 10-12" P.Z.	027XY088NV
Loamy Slope 10-12" P.Z.	027XY054NV
Loamy 10-12" P.Z.	027XY058NV

Description of Great Group GG:
Great Group GG consists of three DRGs and 21 ecological sites. These sites range in precipitation from 6 to 12 inches. Sites within this disturbance response group are characterized by a dominance of Wyoming big sagebrush (*Artemisia tridentata ssp. Wyomingensis)*. Elevation for all sites ranges from 4000 to 7000 feet. Slopes range from 2 to75 percent, but less than 30 percent are typical. Soils correlated to sites in this group have a wide range of physical and chemical properties and range in depth from shallow to very deep. Parent materials are typically mixed alluvium. Although precipitation is limited, soils in this

group do not accumulate significant concentrations of near surface salt and sodium. However, accumulations of secondary carbonates in subsoil and substratum layers are common. Annual production ranges from 100 to 1300 lbs/ac. Annual production for a normal year ranges from 300 to 1000 lbs/ac. The potential native plant community for these sites varies depending on precipitation, elevation and landform. In addition to dominance by Wyoming big sagebrush, Mountain big sagebrush (*Artemisia tridentata ssp. vaseyana)* and basin big sagebrush (*Artemisia tridentata ssp. tridentata)* are important species on these sites. Thurber's needlegrass (*Achnatherum thurberianum*), Indian ricegrass (*Achnatherum hymenoides)*, bluebunch wheatgrass (*Pseudoroegneria spicata)*, needleandthread grass (*Hesperostipa comate)*, squirreltail (*Elymus elymoides)* and Sandberg bluegrass (*Poa secunda)* are also common among the sites.

Ecological Dynamics and Disturbance Response:
An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al 2013).

The ecological sites in this DRG are dominated by deep-rooted cool season perennial bunchgrasses and long-lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m. (Comstock and Ehleringer 1992). Root length of mature sagebrush plants was measured to a depth of 2 meters in alluvial soils in Utah (Richards and Caldwell 1987). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al 2006).

Variability in plant community composition and production depends on soil surface texture and depth. Thurber's needlegrass will increase on gravelly soils, whereas Indian ricegrass will increase with sandy soil surfaces. A weak argillic horizon will promote production of bluebunch wheatgrass. Production increases with soil depth. The amount of sagebrush in the plant community is dependent upon disturbances such as fire, Aroga moth infestations and grazing. Sandberg bluegrass more easily dominates sites where surface soils are gravelly loams than those where surface soils are silt loams. The higher production sites would be much more resilient than other sites in this group.

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (Aroga websteri). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and have been ongoing in Nevada since 2004 (Bentz, et al 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

The perennial bunchgrasses generally have somewhat shallower root systems than the shrubs, but root densities are often as high as or higher than those of shrubs in the upper 0.5 m but taper off more rapidly than shrubs. General differences in root depth distributions between grasses and shrubs results in resource partitioning in these shrub/grass systems.

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons. Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The moisture resource supporting the greatest amount of plant growth is usually the water stored in the soil profile during the winter. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance. The invasion of sagebrush communities by cheatgrass has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Chambers et al 2007).

The introduction of annual weedy species, like cheatgrass, may cause an increase in fire frequency and eventually lead to an annual state. Conversely, as fire frequency decreases, sagebrush will increase and with inappropriate grazing management the perennial bunchgrasses and forbs may be reduced.

The ecological sites in this DRG have low resilience to disturbance and low resistance to invasion. Resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible alternative stable states have been identified for this DRG.

Fire Ecology:
Fire is the principal means of renewal of decadent stands of Wyoming big sagebrush. Wyoming big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common at 10 to 70 year return intervals (West and Hassan 1985, Bunting et al. 1987). Davies et al. (2007) suggest fire return intervals in Wyoming big sagebrush communities were around 50 to 100 years. More recently, Baker (2011) estimates fire rotation to be 200-350 years in Wyoming big sagebrush communities. Wyoming big sagebrush is killed by fire and only regenerates from seed. Recovery time for Wyoming big sagebrush may require 50 to 120 or more years (Baker 2006). Post-fire hydrologic recovery and resilience is primarily influenced by pre-fire site conditions, fire severity, and post-fire weather and land use that relate to vegetation recovery. Sites with low abundances of native perennial grasses and forbs typically have reduced resiliency following disturbance and are less resistant to invasion or increases in cheatgrass (Miller et al 2013). However, the introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013) and restoration potential of Wyoming big sagebrush communities.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more related to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Young 1983, Wright 1971).

Burning has been found to decrease the vegetative and reproductive vigor of Thurber's needlegrass (Uresk et al. 1976). Fire can cause high mortality, in addition to reducing basal area and yield of Thurber's needlegrass (Britton et al. 1990a). The fine leaves and densely tufted growth form make this grass susceptible to subsurface charring of the crowns (Wright and Klemmedson 1965). Although timing of fire highly influenced the response and mortality of Thurber's needlegrass, smaller bunch sizes were less likely to be damaged by fire (Wright and Klemmedson 1965). Thurber's needlegrass often survives fire and will continue growth or regenerate from tillers when conditions are favorable (Koniak 1985, Britton et al. 1990a). Reestablishment on burned sites has been found to be relatively slow due to low germination and competitive ability (Koniak 1985). Cheatgrass has been found to be a highly successful competitor with seedlings of this needlegrass and may preclude reestablishment (Evans and Young 1978).

Indian ricegrass is fairly fire tolerant (Wright 1985), which is likely due to its low culm density and below-ground root crowns. Vallentine (1989) cites several studies in the sagebrush zone that classified Indian ricegrass as being slightly damaged from late summer burning. Indian ricegrass has also been found to reestablish on burned sites through seed dispersed from adjacent unburned areas (Young 1983, West 1994). Thus the presence of surviving, seed producing plants facilitates the reestablishment of Indian ricegrass. Grazing management following fire to promote seed production and establishment of seedlings is important.

Squirreltail is considered more fire tolerant than Indian ricegrass due to its small size, coarse stems, broad leaves and generally sparse leafy material (Wright 1971, Britton et al. 1990). Postfire regeneration occurs from surviving root crowns and from on-and off-site seed sources. Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. Early spring growth and ability to grow at low temperatures contribute to the persistence of bottle brush squirreltail among cheatgrass dominated ranges (Hironaka and Tisdale 1972).

Sandberg bluegrass, a minor component of this ecological site, has been found to increase following fire likely due to its low stature and productivity (Daubenmire 1975). Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species to occupy interspaces, leading to increased fire frequency and potentially an annual plant community. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management. Repeated frequent fire in this community will eliminate big sagebrush and severely decrease or eliminate the deep rooted perennial bunchgrasses from the site and facilitate the establishment of an annual weed community with varying amounts of Sandberg bluegrass and rabbitbrush.

Fire will remove aboveground biomass from bluebunch wheatgrass but plant mortality is generally low (Robberecht and Defossé 1995) because the buds are underground (Conrad and Poulton 1966) or protected by foliage. Uresk et al. (1976) reported burning increased vegetative and reproductive vigor of bluebunch wheatgrass. Thus, bluebunch wheatgrass is considered to experience slight damage to fire but is more susceptible in drought years (Young 1983). Plant response will vary depending on season, fire severity, fire intensity and post-fire soil moisture availability.

Wildfire in sites with cheatgrass present could transition to cheatgrass dominated communities. Without management cheatgrass and annual forbs are likely to invade and dominate the site, especially after fire.

Livestock/Wildlife Grazing Interpretations:
This site is suitable for grazing. Grazing management considerations include timing, duration and intensity of grazing.

Many wildlife species are dependent on the sagebrush ecosystem including the greater sage grouse, sage sparrow, pygmy rabbit and the sagebrush vole. Dobkin and Sauder (2004) identified 61 animal species, including 24 mammals and 37 birds, associated with the shrub-steppe habitats of the Intermountain West.

Overgrazing leads to an increase in big sagebrush and a decline in understory plants like Thurber’s needlegrass, Indian ricegrass and needle and thread grass. Squirreltail and Sandberg bluegrass will increase temporarily with further degradation. Invasion of annual weedy forbs and cheatgrass could occur with further grazing degradation, leading to a decline in squirreltail and an increase in bare ground. A combination of overgrazing and prolonged drought may lead to soil redistribution, increased bare ground and a loss in plant production.

Thurber's needlegrass is an important forage source for livestock and wildlife in the arid regions of the West (Ganskopp 1988). Although the seeds are apparently not injurious, grazing animals avoid them when they begin to mature. Sheep, however, have been observed to graze the leaves closely, leaving stems untouched (Eckert and Spencer 1987). Heavy grazing during the growing season has been shown to reduce the basal area of Thurber’s needlegrass (Eckert and Spencer 1987), suggesting that both seasonality and utilization are important factors in management of this plant. A single defoliation, particularly during the boot stage, was found to reduce herbage production and root mass thus potentially lowering the competitive ability of this needlegrass (Ganskopp 1988).

Wyoming big sagebrush communities are important winter ranges for big game (Allen et al 1984, Tweit and Houston 1980). The literature is unclear as to the palatability of Wyoming big sagebrush. Generally, Wyoming sagebrush is the least palatable of the big sagebrush taxa (Bray et al 1991, Sheehy and Winward 1981) however it may receive light or moderate use depending upon the amount of understory herbaceous cover (Tweit and Houston 1980). Personius et al (1987) found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable).

Indian ricegrass is a deep-rooted, cool season perennial bunchgrass that is adapted primarily to well-drained soils. Indian ricegrass is a preferred forage species for livestock and wildlife (Cook 1962, Booth et al. 2006). This species is often heavily utilized in winter because it cures well (Booth et al. 2006). It is also readily utilized in early spring, being a source of green feed before most other perennial grasses have produced new growth (Quinones 1981). Booth et al (2006) also notes that the plant does well when utilized in winter and spring. Cook and Child (1971), however, found that repeated heavy grazing reduced crown cover, which may reduce seed production, density, and basal area of these plants. The seed crop may be reduced where grazing is heavy (Bich et al. 1995). Additionally, heavy early spring grazing was found to reduce plant vigor and stand density (Stubbendieck et al. 1985). In eastern Idaho, productivity of Indian ricegrass was at least 10 times greater in undisturbed plots than in heavily grazed ones (Pearson 1965). Yet, Cook and Child (1971) found significant reduction in plant cover after 7 years of rest from heavy (90%) and moderate (60%) spring use. Tolerance to grazing increases after May, thus spring deferment may be necessary for stand enhancement (Pearson 1964, Cook and Child 1971); however, utilization of less than 60% is recommended.

Bottlebrush squirreltail, a minor component of this ecological site is a short lived perennial bunchgrass that is generally an early seral species (Jones 1998). It is thought to be grazing tolerant but will decrease in basal area with heavy grazing (Eckert and Spencer 1987). Its grazing tolerance is likely due to its morphology and early dormancy during the summer months (Wright 1967). Squirreltail is considered to be fair forage for livestock and wildlife until the heads develop (Dayton 1937). Squirreltail also exhibits traits that allow it to be a good competitor with cheatgrass (Bromus tectorum) and make it a viable option when rehabilitating invaded rangelands (Rowe and Leger 2010).

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass expansion and/or cheatgrass and other invasive species such as halogeton (Halogeton glomeratus), bur buttercup (Ceratocephala testiculata) and annual mustards to occupy interspaces. Sandberg bluegrass increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass or cheatgrass may become the dominant understory with inappropriate grazing management.

Long-term disturbance response may be influenced by small differences in landscape topography. Concave areas hold a little more moisture and may retain deep-rooted perennial grasses whereas convex areas are slightly less resilient and may have more Sandberg bluegrass present.

State and Transition Model Narrative – Great Group GG

Reference State 1.0: The Reference State 1.0 is a representative of the natural range of variability under pristine conditions. The reference state has three general community phases; a shrub-grass dominant phase, a perennial grass dominant phase and a shrub dominant phase. State dynamics are maintained by interactions between climatic patterns and disturbance regimes. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These include the presence of all structural and functional groups, low fine fuel loads, and retention of organic matter and nutrients. Plant community phase changes are primarily driven by fire, periodic drought and/or insect or disease attack.

Community Phase 1.1:

Wyoming big sagebrush and Thurber's needlegrass dominate the site. Indian ricegrass, Sandberg bluegrass and squirreltail are also common. Forbs are present but not abundant.

Community Phase Pathway 1.1a: Fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

Community Phase Pathway 1.1b: Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Long-term drought, herbivory, or combinations of these would cause a decline in perennial bunchgrasses and fine fuels and lead to a reduced fire frequency allowing big sagebrush to dominate the site.

Community Phase 1.2: This community phase is characteristic of a post-disturbance, early seral community phase. Thurber's needlegrass and other perennial grasses dominate. Depending on fire severity or intensity of Aroga moth infestation, patches of intact sagebrush may remain.

Community Phase Pathway 1.2a: Absence of disturbance over time would allow sagebrush to increase.

Community Phase 1.3:
Wyoming big sagebrush increases in the absence of disturbance. Decadent sagebrush dominates the overstory and the deep-rooted perennial bunchgrasses in the understory are reduced either from competition with shrubs and/or from herbivory.

Community Phase 1.3a: A low severity fire, Aroga moth or combination would reduce the sagebrush overstory and create a sagebrush/grass mosaic with sagebrush and perennial bunchgrasses co-dominant.

Community Phase Pathway 1.3b: Fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires would typically be low severity resulting in a mosaic pattern due to low fine fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels, may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T1A: Transition from Reference State 1.0 to Current Potential State 2.0

Trigger: This transition is caused by the introduction of non-native annual weeds, such as cheatgrass, mustards, bur buttercup and halogeton.
Slow variables: Over time the annual non-native plants will increase within the community.
Threshold: Any amount of introduced non-native species causes an immediate decrease in the resilience of the site. Annual non-native species cannot be easily removed from the system and have the potential to significantly alter disturbance regimes from their historic range of variation.

Current Potential State 2.0:
This state is similar to the Reference State 1.0. This state has the same three general community phases. Ecological function has not changed, however the resiliency of the state has been reduced by the

presence of invasive weeds. Non-natives may increase in abundance but will not become dominant within this State. These non-natives can be highly flammable and can promote fire where historically fire had been infrequent. Negative feedbacks enhance ecosystem resilience and contribute to the stability of the state. These feedbacks include the presence of all structural and functional groups, low fine fuel loads and retention of organic matter and nutrients. Positive feedbacks decrease ecosystem resilience and stability of the state. These include the non-natives' high seed output, persistent seed bank, rapid growth rate, ability to cross pollinate and adaptations for seed dispersal.

Community Phase 2.1: Wyoming big sagebrush and Thurber's needlegrass dominate the site. Indian ricegrass and squirreltail may be significant components while Sandberg bluegrass and forbs make up smaller percentages by weight of the understory. Non-native annual species are present.

Community Phase Pathway 2.1a: Fire reduces the shrub overstory and allows for perennial bunchgrasses to dominate the site. Fires are typically low severity resulting in a mosaic pattern due to low fuel loads. A fire following an unusually wet spring or a change in management favoring an increase in fine fuels, may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs. Annual non-native species are likely to increase after fire.

Community Phase Pathway 2.1b: Time and lack of disturbance such as fire allows for sagebrush to increase and become decadent. Chronic drought reduces fine fuels and leads to a reduced fire frequency allowing Wyoming big sagebrush to dominate the site. Inappropriate grazing management reduces the perennial bunchgrass understory; conversely Sandberg bluegrass may increase in the understory depending on grazing management. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle and/or horses are the dominant grazers, cheatgrass often increases.

Community Phase 2.2: This community phase is characteristic of a post-disturbance, early seral community phase. Thurber's needlegrass and other perennial grasses dominate. Wyoming big sagebrush is present in trace amounts. Depending on fire severity or intensity of Aroga moth infestations, patches of intact sagebrush may remain. Rabbitbrush may be sprouting. Forbs may increase post-fire but will likely return to pre-burn levels within a few years. Annual non-native species generally respond well after fire and may be stable or increasing within the community.

Loamy 8-10 (024XY005NV) Phase 2.2 T.K. Stringham, April 2010

Community Phase Pathway 2.2a: Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The establishment of Wyoming big sagebrush can take many years.

Community Phase 2.3 (at risk): This community is at risk of crossing a threshold to another state. Sagebrush dominates the overstory and perennial bunchgrasses in the understory are reduced, either from competition with shrubs or from inappropriate grazing management, or from both. Rabbitbrush may be a significant component. Sandberg bluegrass may increase and become co-dominate with deep rooted bunchgrasses. Annual non-natives species may be stable or increasing due to lack of competition with perennial bunchgrasses. This site is susceptible to further degradation from grazing, drought, and fire.

Loamy 8-10 (024XY005NV) Phase 2.3 T.K. Stringham, April 2010

Droughty Loam 8-10" (024XY020NV) Phase 2.3 T.K. Stringham, June 2010

Community Phase Pathway 2.3a: A change in grazing management that decreases shrubs would allow the perennial bunchgrasses in the understory to increase. Heavy late-fall/winter grazing may cause mechanical damage and subsequent death to sagebrush, facilitating an increase in the herbaceous understory. An infestation of Aroga moth or a low severity fire would reduce some sagebrush overstory and allow perennial grasses to increase in the community. Brush treatments with minimal soil disturbance would also decrease sagebrush and release the perennial understory. Annual non-native species are present and may increase in the community.

Community Phase Pathway 2.3b: Fire would decrease or eliminate the overstory of sagebrush and allow the perennial bunchgrasses to dominate the site. Fires would typically be small and patchy due to low fuel loads. A fire following an unusually wet spring or a change in management may be more severe and reduce sagebrush cover to trace amounts. A severe infestation of Aroga moth could also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs.

T2A: Transition from Current Potential State 2.0 to Shrub State 3.0

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during the growing season would favor sagebrush.
Slow variables: Long-term decrease in deep-rooted perennial grass density.
Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

T2B: Transition from Current Potential State 2.0 to Annual State 4.0

Trigger: To Community Phase 4.1: Severe fire and/or soil disturbing treatments. To Community Phase 4.2: Inappropriate grazing management that favors shrubs in the presence of non-native species.
Slow variables: Increased production and cover of non-native annual species.

Threshold: Loss of deep-rooted perennial bunchgrasses and shrubs truncates, spatially and temporally, nutrient capture and cycling within the community. Increased, continuous fine fuels from annual non-native plants modify the fire regime by changing intensity, size and spatial variability of fires.

Shrub State 3.0:
This state is a product of many years of heavy grazing during time periods harmful to perennial bunchgrasses. Sandberg bluegrass may increase with a reduction in deep rooted perennial bunchgrass competition and may become the dominate grass or the herbaceous understory may be completely eliminated. Sagebrush dominates the overstory and spiny hopsage and/or rabbitbrush may be a significant component. Sagebrush cover exceeds site concept and may be decadent, reflecting stand maturity and lack of seedling establishment due to competition with mature plants. The shrub overstory dominates site resources such that soil water, nutrient capture, nutrient cycling and soil organic matter are temporally and spatially redistributed. Bare ground may be significant with soil redistribution occurring between interspace and canopy locations.

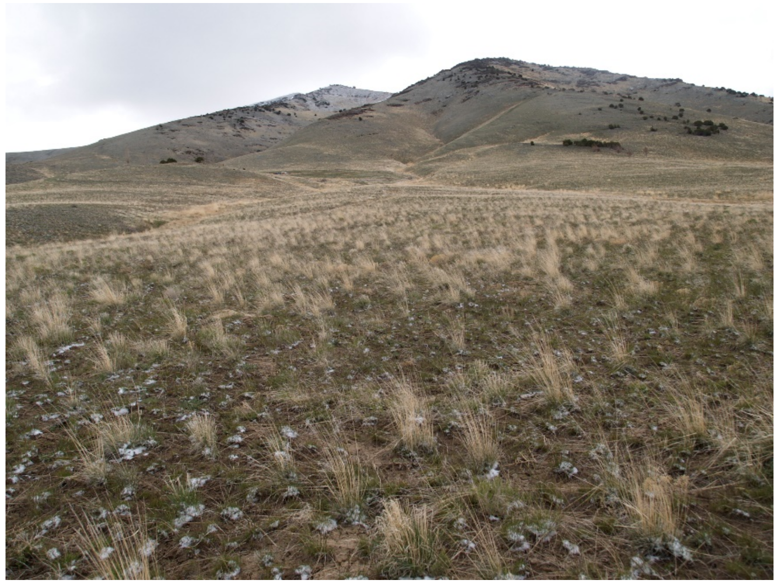
Community Phase 3.1:
Wyoming big sagebrush dominates overstory and spiny hopsage and/or rabbitbrush may be a significant component. Deep-rooted perennial bunchgrasses may be present in trace amounts or absent from the community. Sandberg bluegrass may dominate the understory. Annual non-native species are present and may be co-dominant. Bare ground is significant. Utah juniper may be present. If coming from the seeded state, the shrub state may have trace amounts of seeded species such as crested wheatgrass. Grasses may be absent from plant interspaces but may be found surviving under the canopy of shrubs.

South Slope 8-12 (024XY028NV) Phase 3.1 T.K. Stringham, June 2010

Community Phase Pathway 3.1a: Fire, heavy fall grazing causing mechanical damage to shrubs, and/or brush treatments with minimal soil disturbance, will greatly reduce the overstory shrubs to trace amounts and allow Sandberg bluegrass to dominate the site.

Community Phase 3.2

Bluegrass dominates the site; annual non-native species may be present but are not dominant. Trace amounts of sagebrush may be present. Sprouting shrubs such as spiny hopsage or rabbitbrush may be dominant.



Droughty Loam 8-10 (024XY020NV) Phase 3.2 T.K. Stringham, April 2010

Community Phase Pathway 3.2a: Time and lack of disturbance and/or grazing management that favors the establishment and growth of sagebrush allows the shrub component to recover. The re-establishment of Wyoming big sagebrush can take many years. With the dominance of bluegrass, this pathway is unlikely to occur.

T3A: Transition from Shrub State 3.0 to Annual State 4.0

Trigger: To Community Phase 4.1: Severe fire and/or soil disturbing treatments. To Community Phase 4.2: Inappropriate grazing management in the presence of annual non-native species.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Increased, continuous fine fuels modify the fire regime by changing intensity, size and spatial variability of fires. Changes in plant community composition and spatial variability of vegetation due to the loss of perennial bunchgrasses and sagebrush truncate energy capture spatially and temporally thus impacting nutrient cycling and distribution.

R3A: Restoration from Shrub State 3.0 to Current Potential State 2.0

Brush management with minimal soil disturbance, coupled with seeding of deep rooted perennial native bunchgrasses. Probability of success very low.

R3B: Restoration from Shrub State 3.0 to Seeded State 5.0

Brush management with minimal soil disturbance, coupled with seeding of desired species, usually wheatgrasses (5.1 or 5.2). Restoration attempts causing soil disturbance will likely initiate a transition to an annual state. Probability of success very low.

Annual State 4.0:

This community is characterized by the dominance of annual non-native species such as cheatgrass and tansy mustard in the understory. Sprouting shrubs such as rabbitbrush, shadscale, broom snakeweed and spiny hopsage may dominate the overstory.

Community Phase 4.1
Annual non-native plants such as cheatgrass or tansy mustard dominate the site. Rabbitbrush may or may not be present.

Shallow Loam 10-14" (024XY035NV) Phase 4.1 T.K. Stringham, June 2010

Droughty Loam 8-10" (024XY020NV) Phase 4.1 T.K. Stringham, June 2010

Community Phase Pathway 4.1a: Time and lack of fire allows for the sagebrush to establish. Probability of sagebrush establishment is extremely low.

Community Phase 4.2: Sprouting shrubs such as spiny hopsage and Rabbitbrush along with broom snakeweed dominate overstory. Wyoming big sagebrush may be a minor component. Annual non-native species dominate understory. Trace amounts of desirable bunchgrasses may be present. Bare ground is significant.

Community Phase Pathway 4.2a: Fire removes sagebrush and allows for annual non-native species to dominate the site.

R4A: Restoration from Annual State 4.0 to Seeded State 5.0: Seeding of deep-rooted introduced bunchgrasses and other desired species; may be coupled with brush management and/or herbicide. Probability of success is extremely low.

Seeded State 5.0: This state is characterized by the dominance of seeded introduced wheatgrass species. Forage kochia and other desired seeded species including Wyoming big sagebrush and native and non-native forbs may be present. Soil nutrients and soil organic matter distribution and cycling are primarily driven by deep rooted bunchgrasses.

Community Phase 5.1: Introduced wheatgrass species and other non-native species such as forage kochia dominate the community. Native and non-native seeded forbs may be present. Trace amounts of big sagebrush may be present, especially if seeded. Annual non-native species present.

Loamy 8-10” (024XY005NV) Phase 5.1 T.K. Stringham, June 2010

Community Phase Pathway 5.1a: Inappropriate grazing management particularly during the growing season reduces perennial bunchgrass vigor and density and facilitates shrub establishment**.** Absence of shrub removal disturbances over time coupled with inappropriate grazing management facilitates shrub dominance.

Community Phase 5.2: Wyoming big sagebrush and seeded wheatgrass species co-dominate. Annual non-native species stable to increasing.

Community Phase Pathway 5.2a: Low severity fire, brush management, and/or Aroga moth infestation would reduce the sagebrush overstory and allow seeded wheatgrass species to become dominant.

Community Phase Pathway 5.2b: Absence of shrub removal disturbances over time coupled with inappropriate grazing management that promotes a reduction in perennial bunchgrasses and facilitates shrub dominance.

Community Phase 5.3 (at risk): This community phase is at-risk of crossing a threshold to another state. Wyoming big sagebrush dominates. Rabbitbrush may be a significant component. Wheatgrass vigor and density reduced. Annual non-native species stable to increasing.

Community Phase Pathway 5.3a: Fire eliminates/decreases the overstory of sagebrush and allows for the understory perennial grasses to increase. Fires would typically be low severity resulting in a mosaic pattern due to low fine fuel loads. A fire following an unusually wet spring or change in management favoring an increase in fine fuels, may be more severe and reduce the shrub component to trace amounts. A severe infestation of Aroga moth would also cause a large decrease in sagebrush within the community, giving a competitive advantage to the perennial grasses and forbs. Brush treatments with minimal soil disturbance would also decrease sagebrush and release the perennial understory. Annual non-native species respond well to fire and may increase post-burn.

T5A: Transition from Seeded State 5.0 (Community Phase 5.3) to Annual State 4.0:

Trigger: Fire.
Slow variables: Increased production and cover of non-native annual species.
Threshold: Cheatgrass or other non-native annuals dominate understory.

T5B: Transition from Seeded State 5.0 to Shrub State 3.0

Trigger: Inappropriate, long-term grazing of perennial bunchgrasses during the growing season would favor sagebrush.
Slow variables: Long-term decrease in deep-rooted perennial grass density.
Threshold: Loss of deep-rooted perennial bunchgrasses changes spatial and temporal nutrient cycling and nutrient redistribution, and reduces soil organic matter.

Potential Resilience Differences with other Ecological Sites

Droughty Loam 8-10" 024XY020NV: The soils of this site generally have an effective rooting depth of less than 20 inches. Bedrock, or a strongly cemented duripan restricts deeper root penetration in most soils. Shallow depth and/or high volumes of coarse fragments in the soil profile, work to significantly reduce the amount of moisture these soils can supply to plants. Roots of plants supported by these soils are mostly within a zone of 5 to 20 inches of the surface. The potential plant community is dominated by Wyoming big sagebrush, spiny hopsage, Thurber's needlegrass and Indian ricegrass. Sandberg bluegrass and bottlebrush squirreltail are important grasses on this site. This site goes to shadscale after fire without the presence of cheatgrass, if the soils support this.

South Slope 8-12" 024XY028NV: The soils of this site are shallow to moderately deep and well-drained. Subsoils are moderately fine to fine textured and most of the soils are modified with 35 to 50 percent rock fragments through the soil profile. On the southerly exposures of this site, more sunlight is received and the soils tend to warm and promote plant growth earlier in the spring than on adjacent sites. High evapotranspiration potentials on this site result in depletion of the available soil moisture supply early in the growing season. The plant community is dominated by bluebunch wheatgrass and big sagebrush. Utah juniper may exist on this site, but is not likely to become dominant. Sites that are in the 8" precipitation zone will not likely exhibit an increase in Sandberg bluegrass. This site was only seen in a shrub state with reduced perennial bunchgrasses present on the field visits. However it likely has a similar state-and-transition model with 5 stable states.

Shallow Loam 10-14" 024XY035NV: The soils of this site are shallow to bedrock or a restrictive layer and well drained. Depth to a moderately fine or fine textured subsoil underlying a surface layer 12-20" thick. The soils are modified with 35-75 percent gravels and other coarse fragments throughout the profile. This site is dominated by bluebunch wheatgrass and Thurber's needlegrass. Both mountain big sage and Wyoming big sagebrush dominate the shrub component. This site was not seen on the field visits. However it likely has a similar state-and-transition model with 5 stable states.

Sandy Loam 8-10" 024XY058NV: The soils of this site have a deep to very deep effective rooting zone with depth to bedrock greater than 40 inches. These soils have a high volume of gravel in the subsoil allowing for increased water availability. The plant community is dominated by big sagebrush, needleandthread, and Indian ricegrass with lesser amounts of Thurber's needlegrass. This site was only seen once on the field visits. However it likely has a similar state-and-transition model with 5 stable states.

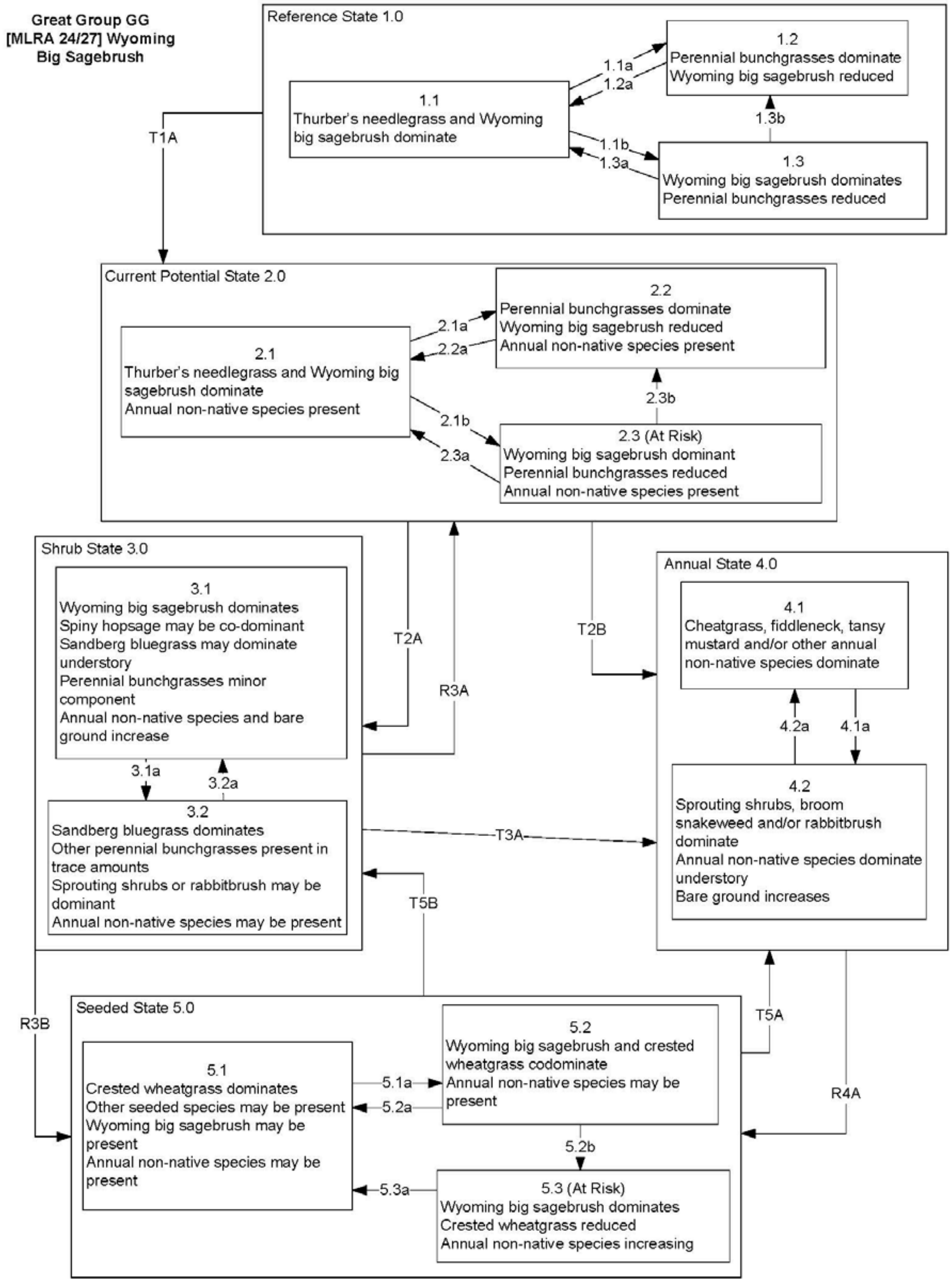
Stony Slope 6-10" 024XY026NV: This site is dominated by shrubs; Wyoming big sagebrush and shadscale. Shadscale can increase with grazing due to decreased competition from more palatable species. Shadscale does not readily recover from fire, reestablishment is primarily through seed. Bottlebrush squirreltail is the predominant perennial bunchgrass on this site. The soils of this site have a shallow effective rooting depth and are modified by a high volume of rock fragments throughout the profile. This lends to the low productivity of the site and the dominance of shrubs. This site is less resilient to disturbances such as fire. Due to the large amount of rock fragments and the terrain these sites are not likely to have a seeded state but may have seeded species present from aerial seedings or nearby seed sources.

Loamy 10-12" 024XY013NV: This site is very similar to the modal site but is dominated by bluebunch wheatgrass.

Steep North Slope 024XY033NV: This site occurs on very steep, smooth to slightly convex, mountain backslopes of northerly exposure. Annual precipitation is 10 to 12 inches. The aspect of these sites allows for slow snow melt and an increase in water holding capacity which has allowed for a higher concentration of perennial bunchgrasses and created deep to very deep soils. This site is dominated by Idaho fescue (*Festuca Idahoensis)* and Cusick's bluegrass (*Poa cusickii*). Idaho fescue is a valuable forage for livestock and tends to decrease under grazing pressure. Idaho fescue is a dense, fine-leaved bunchgrass, which allows fires to burn and smolder in the accumulated leaves at the base of the plant making it more susceptible to fire kill. Cusick's bluegrass increases under grazing pressure due to a decrease in competition from more palatable species. Due to the terrain these sites are not likely to have a seeded state.

Shallow Loam 8-10" 024XY047NV: This site is less productive than the modal site. It is associated with shallow soils and low to very low available water capacity. These factors affect the resilience of the site, making it less resistant to disturbance when compared to the modal site. However it likely has a similar state-and-transition model with 5 stable states.

Modal State and Transition Model for Great Group GG



Great Group GG
[MLRA 24/27] Wyoming Big Sagebrush

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs. A severe infestation of Aroga moth could also reduce sagebrush cover.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also reduce perennial understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.
1.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T1A: Introduction of non-native species.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present. A severe infestation of Aroga moth could also reduce sagebrush cover.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.3a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush management treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire or Aroga moth significantly reduces sagebrush cover leading to early/mid-seral community.

Transition T2A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.
Transition T2B: Catastrophic fire and/or soil disturbing treatments (to 4.1); inappropriate cattle/horse grazing management that removes bunchgrasses, favors shrubs and promotes the presence of non-native annual species (to 4.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush treatment with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
3.2a: Time and lack of disturbance may allow for sagebrush to re-establish.

Restoration R3A: Brush management and seeding of native deep rooted bunchgrasses (probability of success is low).
Restoration R3B: Brush management and seeding of crested wheatgrass and/or other non-native desirable species.

Transition T3A: Fire and/or soil disturbing treatments.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of disturbance. Wyoming big sagebrush is unlikely to reestablish and may take many years.
4.2a: High-severity fire.

Restoration R4A: Application of herbicide and seeding of desired species (probability of success best immediately following fire).

Seeded State 5.0 Community Phase Pathways
5.1a: Inappropriate grazing management facilitates shrub reestablishment. Time and lack of disturbance/management would also allow for shrubs to establish and increase.
5.2a: Fire, brush management, or Aroga moth infestation reduces shrub component.
5.2b: Inappropriate grazing management decreases perennial bunchgrass understory and facilitates sagebrush overstory.
5.3a: High severity fire, Aroga moth or brush management reduces sagebrush cover leading to a early/mid seral community.

Transition T5A: Catastrophic fire (coming from 5.3).
Transition T5B: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.

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